ABSTRACT

GLASSCOCK, NAOMI FRANCES. Exploring the relationships between psychosocial factors, biomechanical workstyle, muscle tension, and musculoskeletal discomfort reporting. (Under the direction of Dr. Gary A. Mirka and Dr. Katherine W. Klein.)

Psychosocial factors are becoming increasingly more prominent in studies of musculoskeletal injury. This research initiative explored various aspects associated with inclusion of trait and state psychosocial factors in laboratory-based biomechanical investigations. The project was comprised of three separate phases. The first phase involved administration of a variety of self-report surveys in written form to 83 subjects. The purpose of this effort was to explore the relationships and overlaps between various psychosocial constructs and musculoskeletal discomfort. The results were used to design the research approach and specific methods for the second and third phase laboratory experiments.

Prior to the conduct of the laboratory studies, 102 participants were pre-tested on a selected subset of written surveys. Scores on one specific survey, the Jenkins Activity Survey, were used to categorize participants as personality Type A or B. An equal number of Type A (n=12) and B (n=12) individuals completed the second experiment in which they performed an assembly task while their performance and wrist motion parameters were recorded. The task was performed under two conditions of psychosocially-imposed time stress (no-stress and stress), both imposed via verbal script. From the pre-tested pool of subjects, a separate group of Type A (N=12) and Type B (N=13) participants performed the third experiment. During this experiment, participants performed a pipetting task and a computer entry task while performance and muscle activity were measured. The pipetting task was performed under two conditions of psychosocially-imposed time stress. The computer entry task was performed under two conditions of psychosocially-imposed frustration stress. The conditions were counterbalanced across subjects in both experiments. Discomfort and anxiety reporting behaviors were evaluated in both experiments.

Personality type impacted performance during assembly but not during pipetting or computer entry. Type A assembly performance times were 12 – 14% faster than Type B's. However, personality type did not impact wrist motion kinematics. The effects of personality type on muscle tension, discomfort, and anxiety were often moderated by gender.

Psychosocially-imposed time stress impacted performance. During assembly, performance times were 11 – 18% faster during the stress condition. During pipetting, performance time was 23% faster during the time stress condition but only when this condition followed the no-stress condition. Time stress produced 8 – 26% increases in wrist motion velocities and accelerations during assembly. Time stress during pipetting increased muscle tension by 9 – 23% in six of the muscles sampled. However, the dominant flexor and extensor activities only increased (by 25 to 29%) for females. In general, time stress did not impact discomfort reports, but it did increase anxiety by 8% for the assembly task.

Psychosocially-imposed frustration stress impacted computer task performance but only when the stress condition preceded the no-stress condition. For this case, performance time was 13% slower during the stress condition. Frustration stress did not impact muscle tension or discomfort reports, although it did increase reported anxiety by 6%.

The results of this study demonstrate that the biomechanical response of individuals is a complex phenomenon, encompassing interactions of individual characteristics, task characteristics, and psychosocial stress (e.g., time stress, frustration stress). Specific findings and potential implications of these findings were presented in this study. It is hoped that this effort will provide additional insight into (1) the potential biobehavioral pathways between psychosocial factors and musculoskeletal illness and (2) the methodological strategies for exploring these relationships.

EXPLORING THE RELATIONSHIPS BETWEEN PSYCHOSOCIAL FACTORS, BIOMECHANICAL WORKSTYLE, MUSCLE TENSION, AND MUSCULOSKELETAL DISCOMFORT REPORTING

by

NAOMI FRANCES GLASSCOCK

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

INDUSTRIAL ENGINEERING

Raleigh, North Carolina

June 2003

APPROVED BY:

____________________________ ____________________________

____________________________ ____________________________

Co-chair of Advisory Committee   Co-chair of Advisory Committee

DEDICATION

I would like to dedicate this dissertation first and foremost to my mother, Frances. She has always believed in me, encouraged me, and loved me. *There's a light shining in her eyes, and like a beacon in the night I can keep in might sight … and no matter how rough the storm, I can find my way home.* A special dedication also goes to her mother, aunt, and grandmother – Grace Jordan, Evelyn Clayton, and Cornelia Long ("Big Mama") – who have passed on but continue to reach across time and touch the souls of us all. I have been blessed to have these women as my heritage. They are the epitome of strength, kindness, and grace. Whoever first said that "there's nothing greater than a mother's love" must have known these four women.

I would like to dedicate this dissertation to my father, Tommie. As a small child, I was always following him around, trying to learn everything that he knew, and constantly underfoot. He taught me how to build and fix things, how to drive a lawnmower, and how to throw a baseball. He picked me up many times from my softball/basketball games and practices. He would park his '63 Chevy pickup (that belonged to his father before him) in front of the school and wait for me to come out and climb in. That truck now calls my driveway home.

I want to especially thank my parents for teaching me about integrity, strong work ethic, how to make do with a little, and how to overcome your circumstances. They have stretched every dollar, and sometimes given me their last one, to provide for me and give me opportunities that they never had.

I would like to dedicate this dissertation to my sisters, Paula, Denise, and Reitha. I am so proud to call them my sisters. They have always supported me and encouraged me. Whether it was a phone call, a card in the mail, or a drive across the miles, they have been there when I needed them. They have let me know that they love me and are proud of me. They have widened our family with their own families. They have broadened my life experience by being not just "my people," but really "good people."

I am blessed to have been born with this family. However, my family is much bigger. I dedicate this dissertation to those friends who I also call family. They have believed in me, loved me, brought me dinner, fixed my car, called me from abroad, talked me through "it," … and even sometimes resorted to bribery when I needed to "work 100 hours this week." In so many ways, they have contributed to my growth as a person. They don't need to be mentioned to know who they are, but I will mention them anyway – Lisa Giannini, Liz LaMuraglia (alias Liz#2), Jennifer Page, Dawn Hege, Risa Foster, Lisa Childress, Janet Garrison, Patty Hanneman, Pam Wood, Laurie Moffitt, Annette Potak, Elizabeth Broyles, Melissa & Robby Taylor, Catriona Chaplin, Elke Leyman, Susan Guadagno, Ken & Kris Workman, Shelley Rohm, Tonya Smith-Jackson, and my many friends from SWOOP. Sometimes you meet people in life who share a connection with your soul and give of themselves to care for that connection. It is then that you are truly blessed.

I would like to make an additional dedication to my canine companions, Eric, Gucci (who is no longer here), and Maggie (the newest arrival). They have always greeted me at the door with wagging tails, given me a good reason to take a break, tolerated the absence of attention when I didn't take any breaks, laid at my feet through countless hours of working on this project, filled their roles on many a car trip as my back-seat drivers, and given me a constant source of conversation. Those of you who know Shetland Sheepdogs like Eric know they can be talkers. Those of you who have known an exceptional pound puppy like Gucci, know that they can be the most incredible creatures in the world. They can defy all odds, teaching you along the way that you can, too. These dogs will always have a special place to call home – my heart.

Though I have definitely sweated many hours completing this project, this dissertation is a product of these individuals. I would like to end this dedication with a special tribute to all of them. To them, and to all of the others who have supported my music, I leave you with the lyrics to a song you have inspired:

Sometimes you pushed me a little harder than before.
Sometimes you buried me underneath a whole lot more.
Sometimes you drug me kicking screaming through that door.
But even when the door closed again, you always believed.
You always believed I'd finally make it here.
You never had my doubts. You never had my fears.
And through all the truths I've chased through all these years.
And even when the truth disappeared,

YOU always believed.

BIOGRAPHY

Naomi Glasscock was born in Roxboro, NC in 1964 (but who's counting). She was raised for most of her life in a place most people have never heard of – Skipwith, VA. There in Skipwith, the population of cows outnumbered *the* population. She spent most of her childhood and young adult years riding bicycles/motorcycles in the woods (if there was a path we found it or made it) and working on the surrounding farms. It was during those years, that she learned how to "pull" tobacco, "hand" leaves, "string" tobacco, "tote" irrigation pipes, "sack" tobacco, "fill" a barn, and drive a tractor. She left that small country area to move to Raleigh, NC in 1982 as an undergraduate at North Carolina State University. With her mother and her motorcycle in the back of her Aunt Jean's van, she headed down Hillsborough Street to campus and took up residence in Lee Hall. There, a new era began. After five years of education in engineering and life experience, and jobs that included painting, bartending, and building parts of I-40 as a road construction worker, she graduated with a B.S. in Aerospace Engineering in 1987. From there, she headed "down east" to the Naval Aviation Depot in Cherry Point, NC. As an engineer there, Naomi worked on the V-22 Osprey tiltrotor program which was in development and managed to steal quite a few rides in the H-46 Sea Knight helicopter. While working full-time and traveling almost all of the time some years, she completed her Masters of Engineering degree. She also realized her growing interest in human factors and, after seven years it was time to move on and pursue that dream of getting a Ph.D. So back to Raleigh she went. There, she worked as a research assistant in the Ergonomics Laboratory, served as a teaching assistant for the undergraduate ergonomics course, and took countless hours of coursework. For three years during her time as a graduate student, she also worked full-time at Ericsson, designing user interfaces for mobile communication devices. During that time, she got the incredible opportunity to live and work in Sweden for six months. It was also during that time that she decided to give up that job and focus on finishing her dissertation. As a result of that decision and all of the experiences that came before it, she finally made it here.

ACKNOWLEDGMENTS

I would like to acknowledge and thank Dr. Gary Mirka, Dr. Katherine Klein, Dr. Carolyn Sommerich, and Dr. Samuel Moon for their immense efforts in helping me to reach my academic goal. This has been a project of challenges and rewards for us all. I want to especially thank Dr. Mirka and Dr. Klein for allowing me, and helping me, to cross the boundaries of academic disciplines and create my own path. I express my sincerest thanks to Dr. Sommerich for always being there. Whether my problem was small or large, professional or personal, her door was always open and I managed to find my way in. With her help, I usually found my way out. I want to also thank both Dr. Mirka and Dr. Sommerich for not getting too mad when we (I won't mention names) ruined a batch of electrodes, burned up a motherboard (accidentally and for the sake of science), and broke that Kin/Com again. Dr. Mirka used to say "If you never break anything, then you're probably not doing anything."

I wish to also thank my fellow graduate students who have traveled this path with me, and who have paused their own paths at times to help me when I needed it or just to share their energies and thoughts on the pursuit of science. In particular, I am especially honored to have shared my academic journey with Sharon Joines, Dan Kelaher, Brad Lawrence, Melanie Wright, Jennie Psihogios, Ann Baker McGrew, and Elke Leyman. I also want to acknowledge some of the previous colleagues in my professional career who have played significant roles in my professional development, including Kenneth Workman, Joe Gresham, Richard Fahey, Patrik Heuman, Barry Beith, and Tonya Smith-Jackson. A special note of thanks also goes to the many excellent teachers I had early on that influenced me in so many ways, especially Diane Byrd, Betty Crowder, Betty Roberts, Mrs. Webb, Mrs. Broyles, and Mrs. Van Hoy.

Finally, I would like to acknowledge the many scientists and pioneers who have put aside the artificial boundaries of bureaucracy, and focused on the pursuit of knowledge for the good of human kind. They have often ignored the maps drawn on a page somewhere, maps that often separate the human race into "us" and "them." With this, I express a special note of appreciation for the astronauts of the space shuttles Challenger and Columbia, who in their pursuit of a better tomorrow

… flew.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CTD – cumulative trauma disorder

CTS – carpal tunnel syndrome

EMG – electromyography

F/E – flexion/extension

JAS – Jenkins Activity Survey

LBD – low back disorder

LBP – low back pain

MDS – Musculoskeletal Discomfort Survey

MVC – maximum voluntary contraction

NIEMG – normalized integrated electromyography

R/U – radial/ulnar

RMS – repetitive motion syndrome

ROM – range of motion

RSI – repetitive strain injury

UECTD – upper extremity cumulative trauma disorder

VAS – Visual Analogue Scale

WRMSD – work-related musculoskeletal disorder

WRUED – work-related upper extremity disorder

NOMENCLATURE FOR VARIABLES

3cN – survey administration following “no-stress” condition during computer task

3cS – survey administration following “stress” condition during computer task

3N – survey administration following “no-stress” condition during assembly task

3pN – survey administration following “no-stress” condition during pipetting task

3pS – survey administration following “stress” condition during pipetting task

3S – survey administration following “stress” condition during assembly task

aLFEacc – mean absolute value of left flexion/extension acceleration (degrees/second^2)

aLFEvel – mean absolute value of left flexion/extension velocity (degrees/second)

aLRUacc – mean absolute value of left radial/ulnar acceleration (degrees/second^2)

aLRUvel – mean absolute value of left radial/ulnar velocity (degrees/second)

ANXtot – state anxiety score

aRFEacc – mean absolute value of right flexion/extension acceleration (degrees/second^2)

aRFEvel – mean absolute value of right flexion/extension velocity (degrees/second)

aRRUacc – mean absolute value of right radial/ulnar acceleration (degrees/second^2)

aRRUvel – mean absolute value of right radial/ulnar velocity (degrees/second)

avgASSYtpu – average assembly time per unit (seconds)

avgCOMtpp – average time per part number entered (seconds)

avgDIStpu – average disassembly time per unit (seconds)

avgPIPtpc – average time per pipetting cell filled (seconds)

COPE – independent variable indicating coping style

dEXT – dominant side extensor digitorum/carpi group

dFLEX – dominant side forearm flexor digitorum/carpi group

dPARA– dominant side paraspinalis muscles at the level of T10

dRHOM – dominant side rhomboid-trapezius-erector spinae regions

dTRAP – dominant side upper descending portions of the trapezius

MDSaeL and MDSaeR – left and right arm/elbow discomfort score

MDSavg – average overall discomfort score

MDSavgF – average frequency of discomfort across body regions (Phase I study)

MDSavgI – average discomfort intensity across body regions (Phase I study)
MDSavgW – average weighted discomfort across body regions (Phase I study)
MDSbak – average back discomfort score
MDSh – head discomfort score
MDShbL and MDShbR – left and right hips/buttocks discomfort score
MDShwL and MDShwR – left and right hand/wrist discomfort score
MDSlbL and MDSlbR – left and right lower back discomfort score
MDSlfL and MDSlfR – left and right feet/legs discomfort score
MDSnsL and MDSnsR – left and right neck/shoulder discomfort score
MDSubL and MDSubR – left and right upper/middle back discomfort score
MDSupx – average upper extremity discomfort score
nEXT – non-dominant side extensor digitorum/carpi group
nFLEX – non-dominant side forearm flexor digitorum/carpi group
nLFEpos – mean non-absolute value of left flexion/extension position (degrees)
nLRUpos – mean non-absolute value of left radial/ulnar position (degrees)
nPARA – non-dominant side paraspinalis muscles at the level of T10
nRFEpos – mean non-absolute value of right flexion/extension position (degrees)
nRHOM – non-dominant side rhomboid-trapezius-erector spinae regions
nromLFE – left flexion/extension normalized range of motion (fraction of maximum)
nromLRU – left radial/ulnar normalized range of motion (fraction of maximum)
nromRFE – right flexion/extension normalized range of motion (fraction of maximum)
nromRRU – right radial/ulnar normalized range of motion (fraction of maximum)
nRRUpos – mean non-absolute value of right radial/ulnar position (degrees)
nTRAP – non-dominant side upper (descending) portions of the trapezius
romLFE – left flexion/extension range of motion (degrees)
romLRU – left radial/ulnar range of motion (degrees)
romRFE – right flexion/extension range of motion (degrees)
romRRU – right radial/ulnar range of motion (degrees)
STRESS – independent variable indicating the psychosocially imposed stress condition
SURVEY – independent variable representing survey administration
TYPE – independent variable indicating personality type

1. SPECIFIC AIMS

The specific aims of this research were to (1) develop an appropriate strategy and methodology for inclusion of psychosocial factors in laboratory-based biomechanical investigations and (2) to employ this strategy to determine the effects of individual differences in specific psychosocial traits under varying conditions of psychosocial stress on biomechanical indicators of task performance. These indicators included measures of performance times, wrist motion postures and kinematics, muscle activity, and discomfort/anxiety reporting behaviors during performance of various laboratory-simulated occupational tasks.

Many of the previous studies that have explored the role of psychosocial factors on occupational illness/injury have been limited to field evaluations of (1) state measures of psychosocial factors describing the environment (e.g., job control, peer support) or individual reactions to the environment (e.g., job satisfaction, job stress) or (2) measures (e.g., MMPI) intended for diagnosing psychopathology (e.g., hypochondriasis) of the individual. Laboratory-conducted biomechanical studies have typically not included individual differences in psychosocial characteristics. However, injury outcome measures continue to vary between individuals performing the "same" tasks. More research is required to understand the individual's role in this process. Though psychosocial factors are becoming increasingly more prevalent in ergonomic studies, few have evaluated the direct impact of these factors on biomechanical indicators often used to categorize job risk.

This research was based on the belief that certain individual trait characteristics, such as personality and coping style, affect both externally observable and internally measured biomechanical responses to given tasks. Previous studies have shown that muscle tension is present in individuals even when the task does not seem to dictate the need for such activity levels and/or subsequent changes in muscle activity levels cannot be attributed to changes in task characteristics (e.g., force, posture, etc.). However, these patterns of muscle activity have varied substantially across individuals. Studies have also shown that body segment postures and motions differ across individuals performing similar tasks. Other studies have evaluated acceptable task performance rates/weights but have not considered that individuals with different psychosocial traits might naturally prefer to perform these tasks differently and thus perform them differently if possible. Individuals may have natural workstyles that affect the way they approach and perform work. Additionally, these workstyles may be affected by the psychosocial stress associated with the task.

Specifically, this research measured task performance, hand/wrist kinematics, and electromyographic responses of individuals while they performed a series of simulated occupational tasks including gross assembly/disassembly, fine motor manipulation, and computer data entry. During pre-testing, subjects completed self-report measures of psychosocial trait attributes including Type A personality, anxiety, social desirability, and body awareness. Scores on the Jenkins Activity Survey measure of Type A personality were used to categorize and select subjects for the laboratory experiments. During the laboratory sessions, subjects completed multiple administrations of self-report state measures of anxiety and musculoskeletal discomfort. They also completed additional surveys related to basic dimensions of personality and life events stress. It was hypothesized that (1) subjects of different personality types would perform tasks differently and that these differences would be reflected in measured parameters of task performance, kinematics, and electromyographic activity; (2) these responses would differ under varying psychosocial stress conditions associated with the task; (3) subjects of different personality types would differ in discomfort and anxiety reporting behaviors; and (4) individuals of different traits might be affected differently by the psychosocial stress nature of the task.

The importance of the results of this research include (1) expansion of empirical evidence related to the role of psychosocial factors in the occupational task – injury process, (2) increased awareness of the significance of and methodological implications associated with incorporating psychosocial trait and state variables into ergonomics and biomechanical evaluations, and (3) increased theoretical understanding of the roles of psychosocial factors in occupational injury/illness.

2. BACKGROUND AND SIGNIFICANCE

2.1 OCCUPATIONAL ILLNESS/INJURY

Occupationally induced musculoskeletal injuries are common, causing the average employed person to lose nearly two workdays each year. These injuries cause more working age people to be disabled than any other category of disorder (Putz-Anderson, 1988). These problems may be caused by a single acute trauma or by repeated microtrauma in the tissues. Two areas of great significance to ergonomics research and intervention deal with disorders of the low back and the upper extremity.

2.1.1 Low Back Pain Epidemiology

Low back pain (LBP), or low back disorder (LBD), represents the most common musculoskeletal problem for the adult working population. Lifetime prevalence rates have been estimated to be as high as 70 to 85 percent (Bigos, Spengler, Martin, Zeh, Fisher, & Nachemson, 1986; Carabelli, 1986; Marras, 2000; Medical Multimedia Group, 1998; Pope & Novotny, 1993) with episodes usually occurring "during the ages of 30 to 50, the most productive period of most people's lives" (Medical Multimedia Group, 1998). In the United States, LBP is the "number one leading impairment in occupational injuries" and "the second most common cause of missed work days" (Medical Multimedia Group, 1998). Studies have found that back injuries comprise approximately one-third or more of the costs of compensable work injuries (Ciriello, Snook, & Hughes, 1993; Snook & Jensen, 1984; Webster & Snook, 1990; Webster & Snook, 1994) with each case costing an average of $6807 (Webster & Snook, 1990). Total compensation costs for low back pain cases in the United States rose from an estimated $4.6 billion (Snook & Jensen, 1984) in 1980 to $11.1 billion in 1986 (Webster & Snook, 1990). The yearly cost to the United States economy has been estimated to be $80 billion (Andersson, 1981; Medical Multimedia Group, 1998; Pope & Novotny, 1993). LBP impacts nations worldwide. Back pain, including neck and shoulder pain, represents the "single largest cause of worker absenteeism in the United States, Sweden, Great Britain and Canada" and "produces qualitative changes in people's lives" (Sarno, 1984).

The etiology for low back disorders is often questionable or unknown. According to Pope and Novotny (1993), the precise diagnosis is unknown in 80 to 90 percent of low back pain (LBP) patients. These are referred to as "non-specific" low back disorders. The etiology in non-specific low back pain is now considered to be multifactorial. Of the many factors that may play a role in the injury process, both the physical and psychosocial nature of the work, workplace, and worker are believed to be important.

Of the physical factors, occupational manual materials handling has been most associated with increased risk of LBP (Bigos et al., 1986; Ciriello, Snook, Blick, & Wilkinson, 1990; Gagnon & Smyth, 1991; Herrin, Jaraiedi, & Anderson, 1986; Marras & Mirka, 1992). Marras and Mirka (1992) report that the National Institute for Occupational Safety and Health (NIOSH) associates over 60% of low back disorder (LBD) claims with overexertion during occupational lifting. Marras, Lavender, Leurgans, et al. (1993) found that lateral velocity, twisting velocity, and sagittal angle were three of the five most significant factors separating high and low risk jobs. A great deal of research has focused on understanding and evaluating the role of lifting and its corresponding biomechanical indicators to the experience of back injury. Other factors have included whole-body vibration (e.g., in seated driving of high-vibration producing equipment) and prolonged sitting (where compressive forces on the lumbar vertebral disks are high).

2.1.2 Upper Extremity Disorder Epidemiology

Upper extremity musculoskeletal injuries also pose a significant concern to today's workforce, both in terms of cost and human suffering. Conditions may result that cause an individual to experience pain or limited functional ability in part(s) of the upper extremity. Although definitions vary, such conditions have been labeled as cumulative trauma disorder (CTD), repetitive strain injury (RSI), repetitive motion syndrome (RMS), work-related upper extremity disorder (WRUED), and work-related musculoskeletal disorder (WRMSD). According to CTDNews (Center for Workplace Health, 1998), 281,100 "repeated trauma injuries" were reported by the U.S. Bureau of Labor Statistics in 1996. Though this number was lower than those reported in the previous two years (308,200 in 1995 and 332,000 in 1994), it still represents a significant concern. Warren et al. (2000) state that Webster and Snook (1994) "estimated total compensable costs for upper-extremity cumulative trauma disorders in the Unites States at over $500 million."

The etiology of these cumulative trauma disorders is complex and multifaceted and may include various aspects of the occupational work, workplace, and worker as well as non-occupational factors. Occupational tasks that require high force, high repetition, and/or extremely deviated postures increase the risk of these injuries, especially if accompanied by insufficient rest (Armstrong & Chaffin, 1979; Armstrong & Silverstein, 1987; Moore, Wells, & Ranney, 1991; Putz-Anderson, 1988; Simmons & Wyman, 1992). Kinematic indicators of repetitive wrist motion have been shown to differentiate high and low-risk groups for wrist CTD's (Marras & Schoenmarklin, 1993). In addition to task-related factors, risk of developing CTD's has also been shown to increase due to certain personal factors. Such factors include genetics, gender, physical strength, joint laxity, joint range of motion, muscle fiber composition, general health/fitness, obesity, leisure activities, prior injuries, gynecological conditions, and systemic diseases including rheumatoid arthritis, hypertension, thyroid disorders, kidney disorders, gout, and alcoholism (Armstrong & Chaffin, 1979; Cannon, Bernacki, & Walter, 1981; Putz-Anderson, 1988). Other studies have noted increased risk of developing symptoms of CTD's due to diabetes mellitus (Chammas, Bousquet, Renard, Poirier, Jaffiol, & Allieu, 1995), pregnancy (Massey, 1978), use of oral contraceptives (Sabour & Fadel, 1970), age (Roto & Kivi, 1984), and psychological factors (Nadelson, 1992).

2.2 THE EPIDEMIOLOGIC CHALLENGE

Epidemiological studies of CTD's and LBD's are complicated by many factors, including the cumulative nature of the disorders and the diversity of the potential risk factors. Symptoms often develop only after many years of exposure or reoccur after periods of latency (Gaffey, 1973), therefore lengthy study periods are required. Specific causal factors for all individuals cannot be determined and thus eliminated. Instead, efforts are made to develop exposure-response relationships that quantify risk of developing a specific musculoskeletal disorder based on exposure to certain risk factors. Exposure variables must be appropriately defined along with techniques for determining the exposure-response relationship (Hagberg, 1992). These relationships must account for, and quantify, the dose received for a given exposure level and somehow assess the ability or capacity of each individual to handle the exposure dose. Many advanced tools (e.g., motion monitors, electromyography, etc.) and techniques (e.g., biomechanical models) are now available to quantify those physical risk factors (e.g., force, repetition, posture, kinematics) that are well understood. However, even precise quantification of the physical demands of work still leaves unexplained variance in models of the exposure-response relationship.

Psychosocial factors may alter this relationship in one or more ways. Studies on psychosocial factors have included a wide range of constructs related to the individual (e.g., stable traits, individual perceptions of transient states) and the work environment (e.g., job stress, work organization). Many questions remain regarding the role of psychosocial factors in the dose-response relationships that exist for musculoskeletal illness. For example, which psychosocial factors are important? How do these factors contribute to the process? How do we measure these factors? How do we quantify the "dose" produced by these factors? Though these factors have become increasingly more recognized as significant contributors to the illness outcomes resulting from this dose-response relationship, the actual contributions, mechanisms, and biobehavioral pathways are still unclear and deserve further research attention.

2.3 SPECIFIC BIOMECHANICAL INDICATORS

2.3.1 Observable Workstyle

2.3.1.1 Definition

One possible mechanism for individual differences to play a significant role in this process is through an individual's workstyle. In its most general sense, workstyle can refer to the global patterns of work preferred or selected by an individual. This construct might be described as "macro-workstyle" and could include such things as job preference/selection, task scheduling, and vacation usage. In a more detailed sense, workstyle can refer to the specific methods an individual employs, if allowed, to perform a task. This might be described as "micro-workstyle" and could include such aspects of task performance as specific rates of work and kinematic profiles employed by the worker to accomplish the work task.

Feuerstein (1996) proposes a definition for the construct of workstyle that presents it as "one psychosocial variable" representing "how the individual worker approaches [performs] work" (p. 177). The following operational definition of workstyle is proposed by Feuerstein: (p. 179):

1. Workstyle is an individual pattern of cognitions, behaviors, and physiological reactivity that co-occur while performing job tasks.
2. Workstyle may be associated with alterations in physiological state, that following repeated elicitation, can contribute to the development, exacerbation,

and/or maintenance of recurrent or chronic musculoskeletal symptoms related to work.

3. Adverse workstyle (i.e., associated with increased occurrence of work-related upper–extremity symptoms) may be evoked by a high work demand (perceived or directly communicated by supervisor), self-generated by a high need for achievement and acceptance, increased fear of job loss or avoidance of a job-related negative consequence of inadequate or improper training, lack of awareness that a particular workstyle might be potentially high risk, and/or self-generated by time pressure.

Essentially, what this definition suggests is that a characteristic style or pattern of behaviors and cognitions exists in a given individual worker which is evoked in response to a set of work demands. This response to work demands can be characterized by heightened behavioral, cognitive, and physiological reactivity.

If this definition is accepted for discussion, it seems apparent that both stable traits of individuals and transient states of their environments are critical. It also seems plausible that certain individuals might be predisposed to increased risk of injury due to their natural or preferred workstyle. This topic deserves further research and was a primary focus of this study. For the purposes of this study, the construct of workstyle only included the "behavioral" aspect of the proposed definition. This includes externally observable or measurable indicators of the individual's approach to work such as task performance metrics (e.g., work rates, rest frequencies and times, cycle times) and aspects of posture and movement. Physiological manifestations (e.g., heart rate, blood pressure, muscle tension) and cognitive tendencies were not considered as part of the construct, but as separate constructs whose relationships to the more focused construct of workstyle might be interesting.

2.3.1.2 Empirical Evidence

Elements of the construct of workstyle are supported by findings of other researchers. For discussion purposes, these can be described as falling into three general categories of support for the construct of workstyle: (1) general approach to work, (2) specific biomechanical indicators of upper extremity work, and (3) specific biomechanical indicators associated with lifting.

2.3.1.2.1 General approach to work

Differences in general approach to work might be captured by such metrics as vacation time used per month of work, percent of time on scheduled or unscheduled general breaks from work (i.e., not rest cycles of specific anatomical regions), use of instructions, and use of job aids (including ergonomic "assist" devices). For example, deZwart, Doombos, vanderWeide, Frings-Dresen, Caspers, and vanderWoude (2000) explored "work technique" between experienced and inexperienced drivers and included "use of ergonomic devices, trunk position during work, and breaks during work" as their measures of work technique (p.3-169). They found that experienced parcel delivery drivers spent significantly more time (6.7% of total loading time) during truck loading on small unofficial breaks than inexperienced drivers (2.5% of total loading time). They also found a non-significant trend toward higher use of a hand truck to aid in loading. They did not, however, find any difference in total time to load the truck. Though their measures also included trunk postures, these would not be included in the current study under the construct of general workstyle, but would be included in the category of specific biomechanical indicators associated with lifting.

2.3.1.2.2 Biomechanical indicators of upper extremity work

Differences in workstyle might also be reflected in biomechanical indicators, for example in the upper extremity. Several studies can be described to illustrate this. Kilbom and Persson (1987) state that "the gross characteristics of the work tasks do not show a large variation, [and] powerful individual factors must exert their influence, either protecting the individual or increasing vulnerability" (p. 273). Motivated by this observation and a high prevalence of cervicobrachial disorders in the manufacturing industry, they used a video protocol to study 96 (at study onset) female workers in the electronics manufacturing industry. Their aim was to investigate, among other things, the possible relationship between individual variation in working technique and neck-shoulder-arm-region disorders. They found that "the most powerful risk factors were … associated with 'poor' working movements and postures" (p. 277). For example, some of the working technique variables that presented as strong outcome predictors included percentage of work time in certain neck flexion or arm adduction postures, number of shoulder elevations per hour, and average time with upper arm at rest. Two smaller subgroups of female workers were observed to evaluate individual variation in working technique. Sixteen (16) individuals in one group performed an identical circuit board assembly and soldering task while twelve (12) workers in the second group performed a different assembling task. Even though tasks within the groups were "identical" and "familiar" to the workers, a wide variation in work technique was observed as evidenced by several indicator variables. For example, work cycle time varied between 4.6 and 9.1 minutes in the first group and between 4.4 and 6.5 minutes in the second group. Other variables that resulted in large ranges across workers performing the "same" task included total number of changes in posture and percentage of work cycle time in various postures. The authors concluded that some workers "worked in a more relaxed way, seeking support for their arms as much as possible, whereas others strained their shoulder and neck muscles during long-lasting static postures with flexed neck and raised arms" (p. 273).

Wolf, Keane, Brandt, and Hillberry (1993) investigated the performance technique of 8 male injury-free pianists. Biomechanical indicators of performance included keystrike force and angular position of the finger. These parameters were used in addition to finger anthropometric measures to estimate finger joint and tendon forces using a biomechanical model. Although the within-subject variation was high, there was a 178% difference between the mean keystrike force of the subjects with the lowest and highest mean keystrike force values. There appeared to be a strong ($r=0.79$) inverse trend between years of experience and average keystrike force. The joint and tendon forces also varied significantly between subjects. The estimated intrinsic tendon force (INT – representing the sum of three intrinsic tendons) was as much as 13 times different between two subjects for a given note within the musical passage.

Feuerstein and Fitzgerald (1992) investigated workstyle-related biomechanical factors in sign language interpreters. They classified subjects into two groups, one group (N=16) working with pain and one group (N=13) working without pain, and exposed them to a "standard interpreting task" (p. 257). They found that the group working with pain "demonstrated a distinct pattern of biomechanical risk factors previously associated with UECTDs [upper extremity cumulative trauma disorders] in other occupations" (p. 257). Compared to controls, the group with pain worked with significantly fewer rest breaks per minute (0.8 compared to 1.7, $p<0.05$), more frequent hand/wrist deviations per minute (10.2 compared to 7.5, $p<0.05$), more frequent excursions from an optimal work envelope per minute (2.7 compared to 1.0, $p<0.05$), and more rapid finger/hand movements while interpreting based on observer ratings on a visual analog scale (6.1 compared to 3.8, $p<0.01$). These findings could not be attributed to any significant differences in age, gender, wrist and forearm endurance and flexibility, or experience as measured by years signing or years interpreting. They concluded that biomechanical stress on the upper extremities is increased by an interaction between work demands and workstyle.

2.3.1.2.3 Biomechanical indicators of lifting

Davis, Marras, and Young (2000) investigated differences in estimated spinal loads between males (N=20) and females (N=25) performing sagittally symmetric and asymmetric free-dynamic lifting tasks. Though only minor differences were found in three-dimensional spinal loads, they found that females and males demonstrated different lifting styles as reflected by kinematic parameters. Females used about 12 degrees more pelvic/hip motion than males. Males used about 5 degrees more lumbar trunk motion than females. Females had faster hip motions (about 13 deg/sec) and slower lumbar trunk motion (about 13 deg/sec) than males. During asymmetric lifting, females demonstrated more (about 5 degrees more) and faster (about 10 deg/sec faster) rotational pelvic/hip motion than males. Females also generated higher muscle coactivation levels than males. Though no direct injury outcome was measured, the authors speculated that the estimated spinal loads would increase risk of injury for females due to lower spinal tolerances.

2.3.2 General "Internal" Muscle Tension/Activity

Muscle tension/activity is considered to be a significant factor in understanding the exposure-response relationship between work and musculoskeletal injury/illness. Many studies have employed electromyographic techniques to (1) describe the characteristics of muscle activity associated with particular types of work (e.g., lifting, sustained static work, light repetitive work); (2) investigate the potential link between muscle activity and discomfort, pain, or injury; and (3) model the loads imposed on the body's joints using EMG-driven biomechanical models. Many factors (e.g., stress, movement, attention/arousal) may cause changes in muscle tension/activity and "little is known regarding the level and temporal pattern of muscle tension due to such influences" (Westgaard & Bjorklund, 1987, p. 911). The exact relationship(s) that exist between muscle tension and injury remains ambiguous, but it is generally believed that muscle tension is a significant component of musculoskeletal illness.

Several approaches have been used to quantify muscle tension or muscle activity including the following quantifications: (1) mean amplitude of the integrated signal, (2) percent of time that the electromyographic activity is less than a certain low level (e.g., gap time), (3) number of times that the activity drops below a certain level (e.g., gaps), (4) static activity representing the level below which the activity is found 10% of the time, (5) median activity representing the level below which the activity is found 50% of the time, and so forth. Results of studies have suggested the following general conclusions:

1. Muscle tension appears to be a significant factor in pain of musculoskeletal origin.
2. The nature of the physical loads imposed by work influences measures of muscle tension.
3. Muscle tension is influenced by factors (e.g., attention-demanding requirements of the task, task difficulty, motivation, anxiety) separate from that required to maintain or change posture.
4. There is a large interindividual variation in measures of muscle tension.
5. Patterns of muscle activity seem to exist within individuals.

There is an enormous body of literature related to these suggested aspects of muscle tension and musculoskeletal illness. Support can be found in much earlier work. For example, Sainsbury and Gibson (1954) provide support for anxiety producing muscle tension even when "relaxing," a general muscle tension construct, greater muscle activity where pain symptoms are, and muscle activity increases in healthy subjects with common anxiety-producing procedures (e.g., taking blood pressure). A few more recent studies are mentioned here to support the general conclusions offered above.

The relationship between muscle tension/activity measures and musculoskeletal illness has been demonstrated in many studies (e.g., Bansevicius, Westgaard, & Jensen, 1997; Hägg, 1994; Hägg & Åström, 1997; Harms-Ringdahl & Ekholm, 1986; Jensen, Finsen, Hansen, & Christensen, 1999; Lundberg, Melin, Ekström, Dohns, Sandsjö, Palmerud, Kadefors, & Parr, 1999; Veiersted, Westgaard, & Andersen, 1990; Veiersted, Westgaard, & Andersen, 1993). Most of these studies rely on self-reports of discomfort/injury or clinical examinations of signs indicating such. Many studies have reported a positive association between increased muscle load and musculoskeletal discomfort. Lundberg et al. (1999) found that 50 cashiers suffering from neck-shoulder pain had higher EMG during the first hour, second hour, and total two hours at work than pain-free controls. The pain group also reported more tension after work. Others have demonstrated a relationship between higher static activity and/or fewer EMG gaps and pain (Jensen et al., 1999; Veiersted et al., 1990). However, some studies have not found an association between muscle activity and symptoms. For example, Takala and Viikari-Juntura (1991) did not find an association between increased muscle activity and symptoms in the upper trapezius and rhomboideus/erector spinae muscles in neck-shoulder pain cases compared to matched controls. Westgaard, Vasseljen, and Holte (2001) did not find differences in EMG measures between workers with and without shoulder/neck pain.

It is commonly accepted that physical load affects muscle tension and EMG levels. This is one basic tenet behind the use of EMG measurements and EMG-assisted biomechanical models in the evaluation of work tasks. However, relationships between muscle tension and other factors have also been suggested. Such factors have included "psychogenic" or attention-demanding muscle activity (Waersted & Westgaard, 1996), motivation via reward incentive (Waersted, Bjorklund, & Westgaard, 1994), stress (Ekberg, Eklund, Tuvesson, Örtengren, Odenrick, & Ericson, 1995; Sporrong, Palmerud, Kadefors, & Herberts, 1998), and anxiety (Sainsbury & Gibson, 1954).

One remarkable finding that has emerged from studies related to muscle tension is the large variation in muscle activity between individuals (i.e., interindividual variability). This is supported by numerous studies (Ekberg et al., 1995; Palmerud, Sporrong, Herberts, & Kadefors, 1998; Sporrong et al., 1998; Veiersted et al., 1990; Waersted, Bjorklund, & Westgaard, 1991; Waersted & Westgaard, 1996; Westgaard et al., 2001). This may be indicative of a "general muscle tension" characteristic of individuals. Ekberg et al. (1995) measured EMG in left and right upper trapezius under stressful and non-stressful conditions during a data entry task. They showed large interindividual variation in muscular reactions. "The results indicate that some individuals may be more prone to general muscle tension, making them more likely to develop symptoms and musculoskeletal pain" (p. 475). Sporrong et al. (1998) evaluated activity of the trapezius, anterior deltoid, medial deltoid, levator scapulae, rhomboid, supraspinatus, and infraspinatus muscles with a combination of surface and needle electrodes during light precision work. They also observed variability across subjects that they remark "is not surprising" and they subsequently imply that effects of individual factors (e.g., gender, training, general muscle tension, stress, etc.) may be contributing to their findings (p. 181-182).

Patterns of muscle activity seem to exist within individuals. Palmerud et al. (1998, p. 191) reported that shoulder muscle "patterns of action show a high degree of individual reproducibility and an intraindividual similarity" (from Laursen, 1996). Intraindividual *variation* also exists. Cram (1989) reports correlations between activity of several muscles (cervical paraspinalis; trapezius; T1, T6, T10, and L3 paraspinalis) with a total summed muscle activity during sitting and standing in a primarily back pain population. Correlations with the summed total ranged from 0.49 to 0.72 for sitting and 0.40 to 0.73 for standing. The T10 paraspinalis demonstrated the highest correlation with the total activity. Left-side activity levels were found to be higher than right-side activities and possibly explained by a biomechanical model (e.g., resulting from right-handedness of the population majority) or an emotional model (e.g., with pain-related emotions represented in the right hemisphere of the brain and the left side of the body). The second of these explanations might contribute to the tendency of an individual to exhibit "general muscle tension."

If a "general muscle tension" tendency indeed exists, then certain individuals may exhibit more harmful patterns of muscle tension than other individuals. This may or may not be related to self-report measures of perceived tension. However "perceived general tension" has been shown to differentiate workers with and without shoulder/neck pain, may be an independent risk factor for muscle pain, and may be related to personality factors (Vasseljen, Holte, & Westgaard, 2001). This was a significant motivating factor behind the current study.

In summary, it seems evident that muscle tension is a significant factor in musculoskeletal injury and that variation between individuals "may help to explain differences in the development of musculoskeletal injuries among workers exposed to similar postural loads as defined by biomechanical methods, or why persons in work situations not demanding maintained postural load nevertheless develop such injuries" (Westgaard & Bjorklund, 1987, p. 911). Psychosocial factors may play a significant role in this phenomenon.

2.4 THE ROLE OF PSYCHOSOCIAL FACTORS

2.4.1 Definition and Review

Psychosocial factors are becoming increasingly more recognized as significant contributors to the understanding of musculoskeletal illness. They have been the recent focus of entire manuscripts (Moon & Sauter, 1996), symposiums (e.g., Georgetown Symposium on Biobehavioral Mechanisms of Work-Related Upper Extremity Disorders), and journal issues (American Journal of Industrial Medicine, Volume 41, Issue 5). The status of the research in this area continues to be the focus of comprehensive reviews (Ariens, van Mechelen, Bongers, Bouter, & van der Wal, 2001; Bongers, deWinter, Kompier, & Hildebrandt, 1993; Bongers, Kremer, & ter Laak, 2002; Davis & Heaney, 2000; Hoogendoorn, van Poppel, Bongers, Koes, & Bouter, 2000; Linton, 2000). With this increased focus, the associated definitions and methodologies may become more defined over time. For now, the definition of "psychosocial" factors is broad by nature and quite varied within the literature. Studies have included a wide range of constructs that have been referred to as, or could legitimately fall into the category of, psychosocial factors. Some of these include such factors as individual psychological attributes, social environment characteristics as perceived by the individual or other person in the environment, organizational attributes, work organization aspects, work demand factors, worker role characteristics, and so forth. Moon and Sauter (1996) suggest that these factors can be "loosely viewed in three categories, which clearly overlap and interrelate" (p. 111). These categories are (1) "objective work environment" characteristics (e.g., job demands, time pressure), (2) "responses to inquiry" reflecting worker perceptions of workplace characteristics, and (3) "measures of pre-existing and presumably personal characteristics" (e.g., traits such as personality and coping style).

The lack of consistent definition and scope of the term "psychosocial" imposes great difficulty on any attempt to perform a comprehensive review of the relevant literature. Additionally, specific psychosocial constructs have often been measured with different instruments across studies. A recent review emphasized the "need for more consistent use of measures that assess specific psychosocial constructs … [and] have demonstrated measurement properties that justify their use" (Bongers et al., 2002, p. 329). However, the existing characteristics of the psychosocial literature produce problems when trying to (1) make comparisons between studies, (2) perform quantitative meta-analyses on published empirical studies, and (3) draw specific conclusions regarding the role of psychosocial constructs in injury and illness. Regardless of the difficulties in defining the term "psychosocial," a general conclusion can be drawn that psychosocial factors are becoming increasingly more important in ergonomics research.

Most of the ergonomics literature on psychosocial factors and injury outcome measures addresses either psychosocial characteristics of the environment (e.g., work demands, job control, etc.), state measures of the individual (e.g., job satisfaction, stress, perceptions of peer/supervisory support, etc.), and/or measures of psychopathology (e.g., depression, various Minnesota Multiphasic Personality Inventory diagnoses). This was recognized in a recent review that "identified very few studies dealing with non-work-related psychosocial factors such as psychological distress, pain coping, and behavioral and personality characteristics in relation to development or prognosis of" upper extremity problems (Bongers et al., 2002, p. 327).

A recent review of the relationships between psychosocial work characteristics and low back pain intentionally excluded studies that investigated "personality traits and indicators of employee mental health" which they admit "many investigators have included ... under the umbrella of 'psychosocial factors'" (Davis & Heaney, 2000, p. 391). The psychosocial work characteristics that they summarize across studies appear to include both psychosocial aspects of the environment (e.g., high work demands, lack of variety and skill) and of the individual (e.g., low job satisfaction, high feeling of stress). It is difficult to tell whether these measures all evolved from self-report. If so, they may all reflect some stable tendency of the individual to report in a predictable fashion, but none would be considered measures of stable individual "traits." A recent review by Linton (2000) presented a table summary of 37 prospective studies resulting from a systematic search and review of the literature on psychological factors in neck and back pain. Most of these studies contained "predictor" measures of variable state aspects of the environment or the individual. Some included measures of psychopathology. A few studies included "predictors" that might be considered individual trait measures (e.g., self-efficacy, fear-avoidance, coping, personality) that are not necessarily indicators of psychopathology.

A few studies that have addressed the role of stable traits (e.g., personality) on outcome measures deserve further discussion. Wickström, Pentti, Hyytiänen, and Uutela (1989) looked at Type A personality and back pain in sedentary and manual workers. They found that manual workers with the competitive personality aspect of Type A behavior experienced back pain radiating to a leg more often than non-competitive workers. They offered a possible explanation that this "could be due to a more common occurrence of over-exertion and trauma affecting the back tissues in competitive type A workers, who are more prone to use all their strength than the less competitive type B workers" (p. 203). Salminen, Pentti, and Wickström (1991) looked at Type A personality and tenderness/pain in the neck and shoulders in metal industry workers. They found that those reporting tenderness "more often had type A behavior than those without tenderness (p=0.10)" and postulated that Type A personality might be "associated with increased muscle activity in the neck and shoulders leading to muscular fatigue and tenderness" (p. 344). Flodmark and Aase (1992) found relationships between Type A behavior in blue collar workers and self-reported musculoskeletal symptoms.

Bongers et al. (1993) report findings from an additional study that found a positive relationship between Type A behavior and back trouble (Hägg, Suurküla, & Kilbom, 1990). This author and colleagues looked at Type A personality and muscle activity in a controlled laboratory study (Glasscock, Turville, Joines, & Mirka, 1999). Results of this study showed that Type A subjects exhibited significantly higher levels of antagonist muscle activity during controlled elbow flexion tasks.

Some studies have also explored both "trait" and "state" measures. Vogelsang, Williams, and Lawler (1994) explored a variety of measures in predicting membership in a Carpal Tunnel Syndrome (CTS) group versus a non-CTS group of matched pairs of workers in occupations with a documented history of high CTS incidence rates. They found that the best model "appeared to be a combination of measures reflecting generic musculoskeletal problems and lifestyle organization" (p. 141). Marras, Davis, Heaney, Maronitis, and Allread (2000) explored the role of psychosocial stress and personality on lumbar spinal loading during sagittally symmetric lifts in the laboratory. They found that psychosocial stress increased the estimated spine loading in subjects with certain personality types (as defined by the Myers-Briggs Type Indicator (MBTI)) due to increased muscle coactivation levels. Davis, Marras, Heaney, Waters, and Gupta (2002) explored the effects of mental processing, MBTI personality type, and task pacing on spinal loads during lifting. Results from this study showed that spinal loads were impacted by all three factors. Though no direct relationship to injury or reporting of injury can be drawn from these last three studies, they did explore a direct link between one psychosocial characteristic (some construct of personality type) of the individual and biomechanical measures (increased muscle activity and/or estimated spinal load) believed to be important factors in the injury process.

There has been a great deal of work done in an attempt to define a specific pain-prone personality in clinical applications. This has produced varying levels of success, but has not resulted in the definition of one specific subset of personality characteristics that predisposes a person to, or results from, the experience of pain. It is becoming increasingly more obvious and accepted within the occupational medicine and rehabilitation literature that pain is a complex and multidimensional phenomenon. It is also quite clear in the ergonomics and biomechanics literature that the individual plays a significant role in the illness/injury outcome beyond the design of the task and the workplace. Otherwise, one cannot likely explain why only one individual becomes injured while another does not, even though both are performing "identical" tasks. Gaining insight into this paradox seems especially critical in the absence of physical requirements that are not believed to present a high risk of injury. Several individual difference mechanisms may contribute to this phenomenon.

The individual might play a significant role in this process via (1) differences in workstyle (e.g., observable differences in the way he/she does the job); (2) differences in internal physiological responses to the task or environment (e.g., muscle tension, hormonal level, and immune system changes); (3) differences in individual capacity to handle the imposed stressors; (4) differences in pain-threshold levels (e.g., afferent nerve signal processing); (5) differences in attributions about the symptoms (e.g., what an individual feels/believes are the causes/implications of the symptoms); (6) differences in reporting behaviors or tendencies (e.g., tends to report every physical symptom or never reports any, or desires secondary gains from reporting such as monetary compensation); and/or (7) differences in subsequent disability status/progression.

This research focused on (1), (2), and (6) above. It was hypothesized that certain individual psychosocial traits and environment psychosocially-imposed stress states would affect the relationship between the task assignment and (1) the individual's observable workstyle, as indicated by measures of task performance, posture, and kinematics; (2) the individual's internal physiological response to the task, primarily the electromyographic activity recorded from various muscles; and (3) the individual's discomfort reporting behaviors. This research also focused on evaluating the interaction of specific psychosocial traits and environment states on these measures.

2.4.2 Significant Explanatory/Discussion Models

Numerous and varied models have been proposed regarding the role of psychosocial factors in the injury process. Some of these models have influenced the governing model proposed for this study (described in the following section) and will be discussed here.

Davis and Heaney (2000) present a simple conceptual model depicting the potential relationships between psychosocial work characteristics, biomechanical work demands, and low back pain. This model depicts the following four possible relationships:

1. <u>Psychosocial work characteristics</u> (e.g., job satisfaction, lack of influence over work, high work demands, etc.) contribute directly to <u>low back pain</u> (e.g., discomfort, disorder, disability, etc.)

2. Biomechanical demands (e.g., heavy work, sitting, standing, awkward postures, repetitive trunk motions, vibration, etc.) contribute directly to low back pain.
3. Psychosocial work characteristics moderate relationship 2 above.
4. Psychosocial work characteristics and biomechanical demands may covary (e.g., poor psychosocial conditions may tend to exist in jobs and occupations with high biomechanical demands).

Though this model is rather simple and only includes low back pain, it does provide an overall framework for discussing the possible relationships between work-related state-dependent psychosocial factors and musculoskeletal injury. Other more complex models separate out some of the factors that are contained within the three factors outlined in this model and/or propose additional mechanisms.

Bongers et al. (1993) propose a much more complex hypothetical model that "serves mainly an illustrative purpose and provides a structure for the discussion of possible associations between psychosocial factors and musculoskeletal disease presented in the literature" (p. 298). They developed this model based on a merging of concepts from three areas of research including (1) stress and health, (2) chronic pain and associated personality/psychological disorders, and (3) epidemiology of musculoskeletal disease. This model suggests the following hypothetical relationships:

1. Psychosocial factors at work (e.g., job demands, job control, social support, time pressure, high work load, monotonous work, etc.) directly influence the mechanical load exposed on the individual.
2. Psychosocial factors at work directly influence stress symptoms.
3. Stress symptoms (worry, tension, anxiety, low job satisfaction, physiological parameters, etc.) directly influence physical and behavioral health indicators (e.g., poor physical health, stomach trouble, cardiovascular disease, use of medication, etc.).
4. Stress symptoms directly influence muscle tone or other physiological mechanism (e.g., hormonal response) in the individual.
5. Physical and behavioral health indicators directly influence musculoskeletal symptoms.
6. Increased muscle tone or other physiological mechanism directly influences musculoskeletal symptoms.

7. Musculoskeletal symptoms influence chronicity of symptoms, sick leave/disability status, and medical compensation.
8. Individual characteristics (Type A behavior, extravert personality, coping styles, depression, low social class, etc.) moderate relationships 2, 4, and 7 above.

Bongers et al. (1993) reviewed the epidemiologic literature on musculoskeletal disease and selected variables and concluded that though the epidemiological literature does not provide conclusive evidence, it does provide support for (1) a relationship between some psychosocial factors at work and musculoskeletal symptoms and (2) a possible contribution of stress and stress symptoms to the development of musculoskeletal disease.

Feuerstein (1996) proposes a model surrounding the construct of workstyle. This model encompasses the assumption that "workstyle may pre-exist as a characteristic approach to work demands and/or be triggered or exacerbated by the presence of workplace psychosocial stressors and/or increased work demands" (p. 191). This workstyle, in addition to ergonomic stressors (e.g., related to task or workstation), then directly influences the experience of upper extremity symptoms, disorders, and disability and these experiences influence workplace psychosocial stressors and work demands. This model also proposes that (1) work demands influence ergonomic stressors, (2) workplace psychosocial stressors and work demands influence each other, and (3) workstyle and ergonomic stressors directly influence each other. Elements of this model were discussed in greater detail in earlier sections of this manuscript.

Sauter and Swanson (1996) propose a causal model that attempts to integrate concepts from the generic psychosocial stress process and traditional biomechanical models of musculoskeletal disorders. Some of the suggested relationships are listed below:

1. The nature of the work technology (e.g., Video Display Terminal work) influences musculoskeletal outcomes via a complex model containing biomechanical, psychosocial, and cognitive components.
2. Work organization (e.g., increased specialization) directly influences physical demands (e.g., increased repetition) exposed on the individual.
3. Physical demands directly influence biomechanical strain.
4. Work organization directly influences psychological strain.

5. Psychological strain (e.g., stress) directly influences biomechanical strain by increasing muscle tension or through some other autonomic effect.
6. The effect of biomechanical strain (i.e., internal physiological events) on musculoskeletal outcomes is mediated by a "complex of cognitive processes … which involves the detection and labeling/attribution of somatic information (symptoms).
7. Individual factors moderate relationships 3, 4, and 6 above.
8. Work organization moderates relationship 6 above.
9. Psychological strain moderates relationship 6 above.
10. Musculoskeletal outcomes directly influence work organization and psychological strain.

Sauter and Swanson (1996) provide evidence to support varying aspects of this model and summarize by stating that "its linkages do not diminish the importance of physical environmental/ergonomic factors in the etiology of musculoskeletal disorders" but instead depict psychosocial effects as "complimentary to and interactive with effects of physical workplace demands" (p. 16).

Several of these models (Bongers et al., 1993; Feuerstein, 1996; Sauter & Swanson, 1996) were described and evaluated in a recent comprehensive review of three generic occupational stress and health models and six multivariate models of work-related musculoskeletal symptoms/disorders (Feuerstein, 2002). Aspects of these models have contributed to the development of the conceptual model proposed in this study. This is described in the following section.

2.4.3 Proposed Conceptual Model

The proposed conceptual research model for this study is contained in Figure 2-1. This model is based on various aspects contained in the previously reviewed models. Like those models, it attempts to present a simplified view of a phenomenon which, in reality, is known to be much more complex.

One major difference between the simplified model and the real phenomenon is the use of uni-directional causal indications for modeling and evaluating some relationships. Establishing causation between variables requires that (1) a relationship be shown to exist between the variables, (2) a temporal requirement be met that one variable precedes the other variable in time, and (3) other causes for one or both variables be ruled out as explanations. Some or all of the relationships shown in the model may not meet these requirements of causal relationships. For example, the proposed model implies that “individual” psychosocial factors have a direct “causal” impact on workstyle, when there may only be a relationship that exists without meeting requirements (2) and (3). It is also apparent that directions of influence (i.e., presumed causal effects) could be bi-directional. Modeling the phenomena this way allows for quantitative evaluation of the relationships as if uni-directional causal effects exist, but interpretation is limited to non-causal inferences.

Additional simplifications also exist within the model. For example, individual factors within general elements of this model correlate with and/or may causally influence other factors within that general element. These individual factors may also correlate with and/or influence individual factors contained in other general elements of the model. The magnitude and direction of these relationships may be different between a specific factor and other factors. For example, one “individual” psychosocial factor may impact one “environment” psychosocial factor while another “individual” psychosocial factor does not impact the “environment” psychosocial factor at all. However, the simplicity of the model provides a means for (1) defining the relationships to be evaluated, (2) evaluating these relationships with sound statistical tools, (3) interpreting the results of the analyses, and (4) conveying the findings.

2.5 POTENTIAL ROLE OF SPECIFIC PSYCHOSOCIAL TRAITS IN THE ETIOLOGY OF WORK-RELATED MUSCULOSKELETAL INJURY/ILLNESS

2.5.1 General Model

The roles that psychosocial factors contribute to occupational injury/illness outcomes are unclear. An individual’s approach to performing an occupational task may be fundamentally affected by cognitive, affective, and behavioral tendencies that can be associated with specific psychosocial traits. These individual traits (e.g., personality) are assumed to be rather stable over time, even though it is possible that the injury experience itself may impact one or more of these traits. Psychosocial states (e.g., job satisfaction, stress) are assumed to be transient. A possible model for the impact of various psychosocial variables including both “internal” psychosocial characteristics of the individual and "external" psychosocial characteristics of the environment was proposed in the previous section and is illustrated in Figure 2-1.

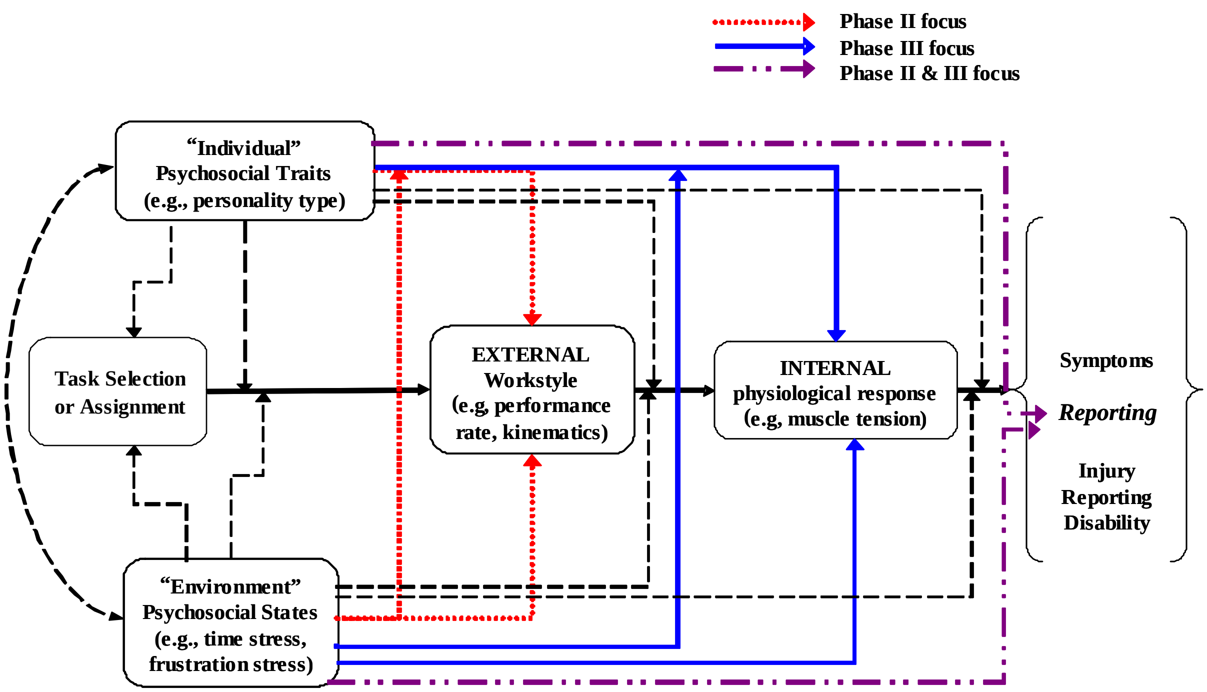


Figure 2-1. Proposed theoretical model of the possible effects of psychosocial factors on biomechanical indicators, discomfort reporting, and outcomes.

The specific implications of this model, many of which were investigated in this study, include the following:

1. Task assignment (e.g., assembly, computer data entry) directly influences external workstyle (e.g., performance, kinematics).
2. "Individual" psychosocial factors (e.g., traits and states) directly influence external workstyle.
3. "Individual" psychosocial factors directly influence internal physiological response.
4. "Environment" psychosocial factors (e.g., time pressure) directly influence external workstyle.
5. "Environment" psychosocial factors directly influence internal physiological response.

6. External Workstyle directly influences internal physiological response.
7. "Individual" psychosocial factors moderate relationships 1 and 6 above.
8. "Environment" psychosocial factors moderate relationships 1, 2, and 3 above.
9. Some "individual" and "environment" psychosocial factors moderate other relationships between other elements of the model.
10. Some "individual" and "environment" psychosocial factors directly influence task selection or assignment.
11. Some "individual" psychosocial factors and "environment" psychosocial factors correlate with each other.

Two individual difference traits that may affect both the way the task is "observably" performed and the subsequent physiological response are personality type (A or B) and repressive coping style. Type A personality was the major focus of this study and its design. Repressive coping style was explored as a secondary focus. These constructs are discussed in detail in the following sections. Some other psychosocial factors, including traits and states, were also considered in this research and are discussed briefly. These include (1) the five basic personality dimensions of neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness; (2) constructs associated with self-reported body awareness; and (3) life events stress.

2.5.2 Type A Personality

2.5.2.1 Definition

In the late 1950's, Friedman and Rosenman (1974) developed the concept of a coronary-prone behavior pattern and labeled it the "Type A" behavior pattern. They defined the Type A behavior pattern as "an action-emotion complex that can be observed in any person who is aggressively involved in a chronic, incessant struggle to achieve more and more in less and less time, and if required to do so, against the opposing efforts of other things or other persons." Type A behavior is characterized by extremes of competitiveness, ambition, high performance standards, aggressiveness, hard-driving effort, time urgency, polyphasing, impatience, irritability, free-floating hostility, and hurried motor and speech patterns (Dembroski, Macdougall, & Lushene, 1979; Dembroski, Macdougall, & Shields, 1977; Gastorf, 1981; Hart & Jamieson, 1983; Jamal, 1985;

Jenkins, Rosenman, & Friedman, 1967; Jenkins, Zyzanski, & Rosenman, 1971; Lambert, MacEvoy, Klackenberg-Larsson, Karlberg, & Karlberg, 1987; Price, 1982; Rowland & Sokol, 1977; Sparacino, 1979). Specifically, researchers have noted that Type A individuals experience "more frequent tense, hyperactive movements" (Sparacino, 1979), "vigorous voice and psychomotor mannerisms" (Dembroski et al., 1979), "restlessness, alertness, ... and hurried motor movement" (Jenkins et al., 1971), a "general appearance of tension" (Jamal, 1985), "restless motor mannerisms and staccato style of verbal response" (Jenkins et al., 1967), "explosiveness of speech, [and] tenseness of facial musculature" (Rowland & Sokol, 1977).

Though the construct of Type A personality behavior is over forty years old, it continues to be explored today. Recent studies have evaluated the role of Type A behavior, or aspects of the behavior, on performance, mental/physical health outcomes, and physiological indicators (Begley, Lee, & Czajka, 2000; Chen & Coorough, 1996; Day & Jreige, 2002; Edwards & Baglioni, 1991; Gill, Henderson, & Pargman, 1995; Glasscock et al., 1999; Gregg, Banderet, Reynolds, Creedon, & Rice, 2002; Kirkcaldy, Cooper, & Furnham, 1999; Kirkcaldy, Shephard, & Furnham, 2002; Lee, 1992; Lee, Jamieson, & Earley, 1996; Malchaire, Roquelaure, Cock, Piette, Vergracht, & Chiron, 2001; Perry & Baldwin, 2000; Vasseljen et al., 2001). A brief review by Hart (1997) concluded that the time urgency/irritability subcomponent of the Jenkins Activity Survey measure (see following section) of Type A behavior appears to be particularly related to negative health risk.

2.5.2.2 Operationalizing the Construct

The Type A personality construct has been "measured" by structured interview and self-report survey instruments. Numerous studies have employed the self-report Jenkins Activity Survey as a "valid measure of Type A behavior" (Jenkins, Zyzanski, & Rosenman, 1979) in order to assess the effects of personality type on individual health and performance. Other vastly different self-report measures of Type A behavior have also been used. Some of these include the following: (1) the 28-item Type A Self-Rating Inventory (TASRI) containing descriptive adjectives rated on a 7-point Likert scale (Blumenthal, Herman, O'Toole, Haney, Williams, & Barefoot, 1985), (2) a 9-item measure containing descriptive statements rated on a 7-point Likert scale (Caplan, Cobb, French Jr., Van Harrison, & Pinneau Jr., 1975), (3) a 16-item measure developed in Finland containing opposite pairs of behavior-related statements rated on a 5-point scale (Salminen et al., 1991; Wickström et al., 1989), (4) the 10-item Framingham Type A Scale (FTAS) that assesses dimensions like need for achievement and time urgency (Haynes, Feinleib, & Kannel, 1980), (5) the 14-item Bortner Scale (Bortner & Rosenman, 1967), and (6) the 12-item Revised Jenkins Activity Survey (RJAS) that generates Achievement Striving (AS) and Impatience-Irritability (II) scores (Spence, Helmreich, & Pred, 1987).

2.5.2.3 Relation to Illness and Injury

Various characteristics of the Type A personality behavior pattern have been investigated as to their contributory roles in diseases, illnesses, and injuries. A great deal of literature during the past 35 years discusses the association between Type A personality and coronary heart disease (Brannon & Feist, 1992; Dembroski et al., 1977; Dembroski, Weiss, Shields, Haynes, & Manning, 1978; Friedman, 1990; Friedman & Rosenman, 1974; Friedman & Ulmer, 1984; Gastorf, 1981; Jenkins et al., 1967; Jenkins et al., 1971; Price, 1982; Rowland & Sokol, 1977; Sarafino, 1990; Sparacino, 1979). This is evident in the label, coronary-prone behavior, originally given to this behavior pattern. Studies have indicated that Type A's are more likely to have more severe heart attacks and over twice as likely to die prematurely from coronary heart disease, though the behavior does not seem to be predictive of other diseases such as ulcers, colitis, and arthritis (Burke, 1984). However, Stout and Bloom (1982) found that Type A's had significantly more upper respiratory infections than Type B's, so it appears reasonable that links to the immune system response may exist.

Type A personality has also been investigated with athletes and injury experience. Fields, Delaney, and Hinkle (1990) investigated forty runners to determine whether personality factors predispose them to injury and found that subjects scoring higher on the Type A Self-Rating Inventory (TASRI; Blumenthal et al., 1985) experienced significantly more injuries, especially multiple injuries. Gill et al. (1995) assessed Type A personality using the TASRI, psychological stress, training habits, and injury experience. Though they found no differences between Type A and B runners in self-reported intensity and frequency of training sessions or number of injuries in the past year, the Type A runners did report an average of one week less training missed than the Type B runners. The authors suggest "Type A runners may ignore symptoms of stress or injury that interfere with running performance and that they may be at risk of chronic injury."

A few studies have investigated Type A behavior and its relation to occupational illness/injury. Sutherland and Cooper (1991) studied 360 personnel working in offshore oil and gas industry drilling rigs and production platforms. Using the Framingham Type A Scale to assess Type A behavior (though they also administered the Bortner scale), they found that Type A behavior was related to increased accident involvement, higher job dissatisfaction, poorer mental health, and more reported stress. Stolworthy (1996) found that stress-only claims were significantly higher in Type A behaviors (measured by Jenkins Form C) than physical injury only claims or physical injury in conjunction with stress claims, though no difference between the latter two claim groups. Lee, Niemcryk, Jenkins, and Rose (1989) studied 416 male air traffic controllers and found that Type A's who were not liked by their coworkers had the highest injury rates of liked and not-liked Type A's and B's. Results of multiple regression analyses showed that "distress from life events and being a not-liked Type A remained significantly correlated with later injury." As previously mentioned, Wickström et al. (1989) and Salminen et al. (1991) reported relationships between Type A behavior and experience of back pain and neck/shoulder discomfort, respectively. Flodmark and Aase (1992) found that self-reported musculoskeletal symptoms "during the past seven days" were significantly higher for Type A blue collar workers than for Type B workers for neck, shoulders, and low back. When symptoms "during the past 12 months" were evaluated, Type A's were only significantly higher for shoulder symptoms (p. 684). Bongers et al. (1993) report findings from an additional study that found a positive relationship between Type A behavior and back trouble (Hägg et al., 1990). A recent study of 133 women who performed "very repetitive work" showed a significant relationship between the urgency of time aspect of Type A behavior and neck complaints (Malchaire et al., 2001). However, one recent study found no relationship between the Achievement Striving and Irritability/Impactience indexes of Type A behavior (as measured by the Revised Jenkins Activity Survey) and shoulder/neck pain for female service workers (Vasseljen et al., 2001).

Though most of these studies reported a positive relationship between Type A personality and pain/injury, they do not necessarily indicate that Type A's will report higher discomfort levels, especially prior to injury status and/or in a laboratory. According to Matthews (1982), Type A's "tend to underreport severity of physical symptoms … and might delay seeking medical attention until symptoms become quite severe" (p. 313). In fact, Type A's were described in one of the previously described studies that reported a relationship to injury/illness as "significantly more likely to ignore fatigue and other symptoms" and "more likely to work when suffering from disabilities"

(Flodmark & Aase, 1992, p. 686). They are "thought to ignore symptoms in order to minimise their potential effect on work capacity and they tend to ignore anything that might interfere with their performance" (p. 686). This might indicate that discomfort reporting and injury are less related constructs for Type A's than possibly for others.

2.5.2.4 Potential Relationships to Psychosocial States

Much of the focus on psychosocial factors and injury in the occupational ergonomics literature has been on examining the potential role of psychosocial states on the injury outcomes. Numerous studies have found relationships between injury outcome measures and psychosocial state measures such as work overload, job satisfaction, role conflict, and social support. It seems possible that some of these "state" measures might be related to a more stable attribute of the individual, such as Type A personality. Some of these potential relationships are discussed here.

First, many studies have looked at various measures of workload. Burke (1984) states that "Type A individuals invest more of themselves in work activities than do Type B's … [and] work more hours per week and travel more days per year than do their Type B counterparts" (p. 175). It is possible that they are the individuals who report, experience, and/or report higher workload. It is also possible that workload has different physiological effects on Type A's than on Type B's. Caplan and Jones (1975) found that the relationship between workload and anxiety was significantly greater for Type A's (as measured by Vickers, 1973 short measure) than for Type B's. They also found a similar, though non-significant, relationship between anxiety and heart rate for Type A's compared to Type B's. The correlations for both of these relationships in Type A's were approximately twice (0.54 and 0.45) that of Type B's (0.27 and 0.22), respectively.

Second, many studies have measured job satisfaction and illness/injury outcomes. There is some evidence that supports the possibility that Type A's would experience and report lower levels of job satisfaction than Type B's. Burke (1984) states that "the evidence indicates that although Type A individuals invest more of themselves in their jobs, they are not necessarily more satisfied with their jobs" (p. 175). Type A behavior was also associated with job dissatisfaction in the previously described study of offshore drilling personnel (Sutherland & Cooper, 1991).

Third, studies have shown relationships between illness/injury and various "state" measures that represent aspects of social support. For example, associations have been found between lack of social support and incidence and outcome of cumulative trauma disorder (Moon & Sauter, 1996, p. 129). It is well believed that social support plays a significant role in the overall experience of illness/injury, possibly due to its emotional buffering effect or through direct aid activities. It is possible that Type A individuals may adversely impact their social support either (1) by alienating others with their competitive and/or hostile actions or (2) by not spending time on building or maintaining relationships. The first aspect of this is supported by recent work by this author (see section in this manuscript describing Phase I of this study). Type A personality measured by the Jenkins Activity Survey showed a negative correlation (-0.250, $p<0.05$, N=83) with the Agreeableness factor from the NEO Five Factor Inventory. The second aspect of this statement is supported by findings from the literature. Burke (1984) states that "the evidence indicates that although Type A individuals invest more of themselves in their jobs, they are not necessarily more satisfied with their jobs and may even be incurring the risk of personal and social alienation and disappointment." Burke also suggests that "Type A men may have less satisfying marriages and home lives" and "have few intimate friendships" (p. 175). Burke further states that "Type A men do not appear to be able to enjoy the beauties of nature, the spontaneous emotions of warm and loving human relationships, nor the tranquility associated with leisure and relaxation" and concludes that "Type A individuals appear to have less pleasure and joy in their daily experiences than do Type B's" (p. 175). In addition to impacting social support in the form of relationships, such state constructs as role conflict, peer support, and management support may be impacted by the stable trait characteristics of the Type A person who is reporting his/her experience of these transient states.

Finally, Type A's have been described as needing to be in control of their environments (Jamal, 1985). It seems possible that this "control" might be severely challenged by psychosocial factors like role ambiguity, role conflict, job uncertainty, job overload, and stress. This may mean that these measures would be differentially impacted by personality type and/or that their presence might have different consequences for Type A's.

2.5.2.5 Potential Relation to Workstyle

An individual's approach to performing an occupational task may be fundamentally affected by personality type (A or B). This might result in different externally observable indicators of task performance – or workstyle. The definition of Type A personality includes such adjectives as competitive, hard-driving, impatient, and so forth that indicate that Type A's are likely to demonstrate different behaviors, postures, movements, etc. in their approach to work in general, and more specifically to their workstyle. Researchers have noted aspects of Type A behavior that support this theory. In their approach to work in general, Type A's "invest more of themselves in work activities than do Type B's" by working more hours per week and traveling more days per year (Jamal, 1985). In relation to task-specific workstyle, Jamal (1985) reports from Burnam, Pennebaker, and Glass (1975) that evidence from "laboratory studies indicates that Type A's outperform Type B's on simple tasks" (p. 61). Jamal also states from Snow (1978) that Type A's "set higher initial goals for their task performance" (p. 61). Jamal relies on a control thesis by Glass (1977) to suggest that Type A's "prefer to be in control of their environment" and that "in the work environment, which brings out Type A behavioral characteristics that make people stress-prone, e.g., time urgency, hostility towards slowness, doing two or more things together, Type A's actively sought to gain control over stressful aspects of their environments" (p. 61). Though this element of need for control may enhance task performance, Type A's do not necessarily perform better across all different types of tasks and situations than Type B's. Jamal (p. 61) reports that "Type A's outperform Type B's in performance situations calling for persistence or endurance" (Glass, 1977 and Matthews, 1979) while "Type B's outperform Type A's on tasks that require slow, careful responses and broad focus of attention" (Glass, 1974; Gastorf et al., 1980; and Fazio et al., 1981). The competitive nature of Type A personality may also contribute to the natural or "preferred" workstyle of Type A individuals. Wickström et al. (1989) hypothesized that their findings of back pain in Type A workers might be related to tissue trauma resulting from Type A workers being "more prone to use all their strength than the less competitive type B workers" (p. 203). These findings indicate that workstyle might be fundamentally affected by personality type.

2.5.2.6 Potential Relation to Muscle Tension

From the definition of the Type A behavior pattern, it seems evident that muscle tension might play a significant role in the manifestations of the behavior. Specifically, the defining of the personality type by such characteristics as "general appearance of tension" and hurried motor movements" naturally seems to lead to hypothetical statements that Type A's might exhibit higher levels of muscle activity than Type B's. This has been investigated in a controlled laboratory study by this author and colleagues (Glasscock et al., 1999). Subjects performed a series of controlled static and dynamic elbow flexion tasks while electromyographic activity was recorded for the major elbow flexors (agonist muscles) and extensors (antagonist muscles). Type A's showed significantly higher levels of antagonist activity averaged across all conditions than Type B's. Though no definite link to occupational injury can be stated, increased muscle activity may lead to higher joint loading and an increased risk of injury.

While the previously discussed study explored a direct link between personality type and muscle activity with no direct link to injury outcome, others have explored the link between personality type and musculoskeletal injury/illness outcome and proposed a causal pathway involving muscle tension. Gastorf (1981) suggests that "Type A's and Type B's differ in their physiologic response to situational task demands" and "Type A's have more sympathetic arousal to tasks which provoke competition, time-urgency, and loss of control in the participants" (p. 16). This would suggest that situations that challenge the control aspect of Type A's might affect their physiological response of muscle tension. Salminen et al. (1991) explored the link between Type A behavior and tenderness and pain in the neck and shoulder region of metal industry employees. They found that Type A's experienced tenderness in the neck and shoulder more often that Type B's and hypothesized that their findings might be related to increased muscle activity of Type A workers. Type A behavior and back (including neck and shoulder) pain is discussed in the book titled *Mind Over Back Pain* (Sarno, 1984). Sarno refers frequently to patients exhibiting characteristics of Type A personality and hypothesizes that a potential pathway to their pain involves increased muscle tension. He coins a term tension myositis syndrome (TMS) that he believes is the basis for most back, neck, and shoulder pain cases where structural abnormalities are not the cause. According to Sarno's hypothesis, the basic mechanism of this TMS condition is that tension brings on pain by constricting the blood vessels that feed the muscles and subsequently deprives the muscles of oxygen causing muscle spasm and pain. He states that we generate "more and more tension" as "our lives become more complex" and that this "is the basis for most back pain" (p. 50). He also states that the "key word in tension production is personality" and that there is a "distinct TMS personality" which is "similar in some respects to that of so-called type A individuals" (p. 50). Although, these are only hypothetical explanations for what might be causing musculoskeletal pain or injury, they do reflect opinions that personality type may be related in some way to a general tendency of increased muscle tension.

2.5.2.7 Research Implications

An individual's approach to performing an occupational task may be fundamentally affected by personality type (A or B). This might result in different "externally observable" indicators of task performance such as trunk or wrist kinematics or in "internally manifested" physiologic indicators such as muscular recruitment patterns and coactivation levels. If Type A individuals experience more frequent or deviated postures, more extreme kinematics, and/or higher muscle antagonism levels, then higher biomechanical loads may be imposed on the joints and connective tissues. As joint loads increase, risk of injury and/or cumulative tissue trauma may also increase. Because of the documented observations (both externally and internally) of muscular and motor behavior in Type A individuals, the previously established associations with other illnesses and injuries, and the hard-driving, competitive, and time-urgent (i.e., impatient) characteristics of Type A behavior, the role of personality type on workstyle and muscle activation levels should be explored further.

2.5.3 Repression

2.5.3.1 Definition

Myers and Vetere (1997) state that the "notion of a repressive personality style has a long history in health and personality research" (p. 245). Repression can be defined as one aspect of the general construct of inhibition as it relates to cognition, emotion, and/or behavior. King, Emmons, and Woodley (1992) provide the following definition of inhibition:

> Inhibition can be broadly defined as the exercise of control over spontaneous activity within some realm of experience. This vernal process underlies a diverse number of constructs which have been introduced in research in personality and the relation between personality and physical and psychological well-being. Examples of such constructs are constraint (Tellegen, 1985), emotional inexpressiveness (Buck, 1984), emotional control (Rogers & Nesshoever, 1987), and repressiveness-defensiveness (Weinberger, 1990). Although inhibitory constructs differ in various ways, they share not only an emphasis on the exercise of control but also theoretical and empirical links to psychological variables, autonomic activity, and, in some cases, health outcomes. (p. 85-85)

Inhibition can consist of efforts, either intentional or automatic, that suppress cognitive awareness, emotional affect (i.e., general mood disposition), or outward behavior. In order to better understand the construct of repression, it is helpful to first define the construct of suppression.

Emotional suppression can be defined as the "conscious inhibition of one's own emotional expressive behavior while emotionally aroused" (Gross & Levenson, 1993). While suppression requires active inhibition of emotion, repression, by definition does not. Repressors are "individuals who consider maintaining low levels of negative affect central to their self-concepts [and] are likely to employ a variety of strategies [e.g., inhibition of cognitive awareness] to avoid conscious knowledge of their 'genuine reactions'" (Weinberger, 1990, p. 338). They are said to exhibit what is referred to as a repressive coping style, in which they appear to be unaware that they are inhibiting any emotional expression. Research indicates "that repressors, as a group, seem actively engaged in keeping themselves (rather than just other people) convinced that they are *not* prone to negative affect. Weinberger (1990) clarifies the "crucial transformation from suppression to repression comes when 'I prefer not to think about it' becomes 'There is nothing to think about'" (p. 373). However, their strongly held beliefs are contradicted by objective assessments of behavior and physiology that indicate that repressors have levels of anxiety equal to or greater than those of individuals reporting chronic distress" (Weinberger, 1990, p. 338).

2.5.3.2 Operationalizing the Construct

One commonly publicized method of operationalizing repression consists of administering self-report measures of trait anxiety and defensiveness (Weinberger, Schwartz, & Davidson, 1979). The Bendig short form Manifest Anxiety Scale (BMAS) and the Marlowe-Crowne Social Desirability Scale (MCSDS) are often used. The Marlowe-Crowne was originally developed to assess response bias (Weinberger, 1990), but studies have indicated that it is a "valid and already standardized measure of defensiveness" (Weinberger et al., 1979, p. 372). Subjects are categorized as scoring "low" or "high" on each of these measures. Those subjects who score low on the trait anxiety measure and high (at least in the upper third) on the social desirability measure are classified as repressors (Weinberger, 1990; Weinberger et al., 1979). Repressors are typically compared with the other subject groups classified with this method. These include truly low anxious, high anxious, and defensive high-anxious. The Byrne Repression-Sensitization (R-S) scale (Byrne, Barry, and Nelson, 1963) has also been used to measure repression. However, this scale correlates very highly with some measures of anxiety and neuroticism and may not be able to differentiate between repressors and truly low-anxious individuals (Weinberger et al., 1979).

2.5.3.3 Relation to Illness and Injury

There appears to be a great deal of support, both theoretical and empirical, that the repressive coping style might play a significant role in illness and disease. First, theoretical support is provided by (1) the direct physiological effects of repression and (2) the indirect effects of the repressor's "dissociations between self-report and physiological measures of arousal" which might indicate that "somatic signs would be less likely to trigger health behaviours to relieve distress" (Myers & Vetere, 1997 p. 246). Second, empirical support seems to substantially support the relationship between repression and various disease indicators. Weinberger (1990, p. 373) notes findings from several studies that indicate that the strategy used by repressors to "avoid experiencing subjective distress … does take its toll" which can be seen in the "growing evidence that repressive individuals are at greater risk than either distressed or nondefensive ones for a variety of specific illnesses" including hypertension, asthma, and cancer. He also reports findings that indicate that this "association between a repressive style and proneness to physical illness is not limited to adult populations." Myers and Vetere (1997) also report published links between the repressive coping style and disease indicators, including impaired immune function, carcinogenic disease, cardiovascular disease, and impaired pain perception.

The work of Pennebaker (1993; 1995a; 1997; 1995b) offers support for the potential relationship between repression and adverse physical health by noting and demonstrating the health benefits that can be achieved through expression, or disclosure, of emotions. Pennebaker (1995a) states that "virtually all therapies—irrespective of their theoretical orientation—bring about improvements in both psychological and physical health" and that the "disclosure process itself … may be as important as any feedback the client receives from the therapist" (p. 3). He also states that the "repression or inhibition of emotion is central to an understanding of disclosure" (p. 6).

2.5.3.4 Potential Relationships to Psychosocial States

It is not apparent what relationship might exist between repressive coping style and various psychosocial states that have been linked to musculoskeletal outcomes. However, one possibility is social support. Contrary to Type A individuals, repressors are not emotionally expressive. This could have two potentially contradictory effects. This might lead to less conflict and less alienation of others, thus increasing social support. On the other hand, repressors inability to express (or even become aware of) negative affect may result in poor problem solving and eventually to broken relationships. These two mechanisms operating simultaneously could negate significance in correlations between social support and outcome measures for repressors. Similar hypotheses could be formed for a variety of constructs obtained from repressors by self-report measures.

2.5.3.5 Potential Relation to Workstyle

Though it is not apparent what impact the repressive coping style may have on an individual's workstyle, some hypothetical expectations might arise from the repressor's need to maintain a specific self-image. Even though repressors may be unaware of their need to appear a certain way, this need to "control" and preserve self-image may cause the repressor to perform a task in a way that might be deemed "controlled" or "non-anxious." Weinberger et al. (1979) found that repressors responded most slowly to phrases in a phrase association reaction time task, compared to high anxious and low anxious subjects. This result differed for different types of phrases (e.g., neutral, aggressive, and sexual phrases), but most of the comparisons yielded higher reaction times for the repressors. Repressors also tended to react more slowly across order of trials (i.e., had higher reaction times for trials 11-15 than for trials 6-10 than for trials 1-5). The "data indicate that the repressors responded more slowly and evasively to minimize their sense of threat" (p. 378). These findings might suggest that the repressive coping style could impact the way an individual performs a task as measured by performance indicators as well as kinematic indicators.

2.5.3.6 Potential Relation to Muscle Tension

Based on the definition of repressive coping (e.g., physiological indications of anxiety are present when self-reports deny anxiety), it seems immediately plausible that a relationship may exist between this psychosocial trait and muscle tension, and subsequent experience/reporting of pain. Traue (1995) describes his early clinical experience with pain patients and his surprise that they exhibited non-remarkable and "normal" family lives, job situations, and intimate lives and that "a kind of supernormality seemed to be their salient personality feature" (p. 155). He describes Schlote's (1989) work with headache patients where, contrary to expectations, "the headache group reported significantly lower stress levels than the control group, but showed nearly twice as much muscle tension as controls" (p. 156). As an explanation for these findings, Traue considered the role of inhibition of emotion in the etiology and maintenance of pain of muscular origin and believed that "Wilhelm Reich's idea from the 1940s about 'muscular armoring' in connection with inhibited expressiveness had to be reconsidered" (p. 156). The potential role of repression in muscle tension can be seen in the statement Traue quotes from Reich (1969, p. 260) that 'Tension and cramps of muscle are the bodily realization of suppression and both are the basis for the maintenance of disorders' (p. 156). Support for this can also be found when Sarno (1984) describes a patient in whom, once she "learned about her repressed feelings and determined to make changes in her life, the pain seemed to melt away. ... Only after a long discussion did she reveal that her strategy for coping with life's problems was to put them out of her mind. She said she simply would not allow anything to bother her." Sarno states that the "correlation between psychological conflict and physical pain is clearly evident in this case history. Unresolved conflict produces tension, and tension can find an outlet in pain ... Putting things out of one's mind does not get rid of them; it simply relegates them to the unconscious, where they are free to create anxiety quite undisturbed. This tension then manifests itself in a physical disorder, such as TMS." (p. 52-53).

This is supported by electromyographic studies of muscle activity in relation to emotional inhibition and/or repression. Weinberger et al. (1979) measured frontalis muscle electromyography (EMG) during resting and during a phrase association task in repressors, truly low anxious, high anxious, and defensive high anxious subjects. They found that repressors had the most EMG activity during the resting minutes and suggested that the "differences found in the resting baselines resulted from a tendency for the repressors to have relative difficulty relaxing" (p. 374). Traue (1995) related expressiveness (as measured by observer-ratings of head/hand gestures, smiling behavior, etc.) to electromyographic activity in the muscles of the back. An interesting finding emerged to indicate that factors related to positive expressiveness (e.g., smiling) showed positive correlations with muscles in the upper part of the back (e.g., at level C4) while inhibited gestures (i.e., negative expressiveness) showed positive correlations with the lower back (e.g., at level T10) muscle activity measures.

2.5.3.7 Research Implications

Due to the definition of repressive coping style (e.g., the reliance on physiological indicators of anxiety) and the associated empirical and theoretical findings, further research is required to explore what role this psychosocial trait might have on "externally observable" and "internally manifested" biomechanical indicators of task performance. Additionally, since repressors may reflect themselves more positively on self-report measures of anxiety and health, objective measures of "internal manifestation" of task performance seem especially critical in understanding the role of repression in the occupational task-injury process.

2.5.4 Other Psychosocial Factors

Many other psychosocial factors, both trait and state measures, may play a significant role in the development of musculoskeletal illness. A few of these are discussed briefly in the following sections.

2.5.4.1 The "Big-Five" Personality Dimensions

The "Big-Five" factor model of personality emerged from normal personality trait theory, which represents "a comprehensive framework for the description of individual differences" (Wade & Price, 2000, p. 94). This differs from the assessment of disease-based psychopathology. Aspects of normal personality rely on the premise that "an individual's interpersonal, experiential, and enduring emotional world consists of a set of basic dimensions" that essentially do not change (Wade & Price, 2000, p. 94). Many researchers over the past forty years have demonstrated 5-factor solutions regarding analysis and description of normal personality. Although labeling of the factors may differ slightly between instruments and some critics do exist, there appears to be evidence to support the "big-five" model. Brief labels and definitions of the five factors include the following: "Neuroticism, the tendency to worry excessively; Extraversion, an individual's inclinations to remain either relatively reserved and serious or outgoing and 'high-spirited'; Openness, the ability to view situations from other standpoints; Agreeableness, the capacity to demonstrate warmth interpersonally, to avoid conflict, and to trust others; and Conscientiousness, having high standards for oneself and others" (Weisberg & Keefe, 1999, p. 60).

Of these basic personality domains, neuroticism and extraversion appear to be the most prominent in studies of illness. Neuroticism is a "chronic condition of proneness to distress" and "reflects a tendency to experience chronic, negative, distressing emotions and to engage in a ruminative style that leads to fearfulness, low self-esteem, and feeling helplessness" (Wade & Price, 2000, p. 96). Neuroticism could play a significant role in the development, reporting, and exacerbation of musculoskeletal illness. At least three possible mechanisms can be considered. First, the emotional aspects of neuroticism (e.g., chronic irritability and distress) may directly impact the physiologic response (e.g., hormonal, muscular tension) of neurotic individuals. This could lead to increased risk of the actual experience of injury. Secondly, neuroticism could impact the lifestyle and behavior (e.g., unhealthy habits, breakdown and alienation of social support networks, non-compliance with medical treatment) of neurotic individuals thus predisposing them to experience and/or exacerbate physical illness. Third, neurotics may "magnify the negative aspects of their situations" (Wade & Price, 2000, p. 97) thus reporting higher levels of distress and illness (e.g., physical symptoms) than they actually have. Self-report measures (e.g., psychosocial state and trait measures, discomfort surveys, etc.) may be greatly influenced by the trait of neuroticism, or the underlying construct of negative affectivity (Watson & Pennebaker, 1989). Kasl and Amick (1996) support the "significance of the concept of neuroticism for the study of CTDs" by suggesting, among other reasons, that there "could be a true vulnerability effect, leading to higher rates of CTDs among those with high neuroticism and high exposure" (p. 267).

Extraversion may also play a significant role in the experience, reporting, and outcome of musculoskeletal disease. Extraversion and introversion are often defined according to social tendencies. Phillips and Gatchel (2000, p. 182) characterize extraverts according to Stone (1985) as "more outgoing, uninhibited, and socially active" while "introverts are quieter, more introspective, and more reserved." From the definition alone, it seems apparent that extraversion might impact the reporting and outcome associated with illness through its impact on disclosure comfort levels, lifestyle behaviors, and social support. According to Phillips and Gatchel (2000), "the general finding [is] that people who complain more about pain, who have higher tolerance for pain, and who have higher pain thresholds appear to be more extraverted" and "as pain becomes more chronic in nature, higher introversion scores are seen" (p. 197). At least three recent studies (Allread, 2000; Davis et al., 2002; Marras et al., 2000) support the possible influence of extraversion-introversion on one objective biomechanical indicator, muscle coactivity, believed to be significant in the experience of musculoskeletal injury.

2.5.4.1.1 Operationalizing the construct

One widely used instrument for measuring the five basic dimensions of personality is the revised NEO Personality Inventory (NEO PI-R Costa & McCrae, 1992b). This instrument contains 181 items with respondents choosing from a 5-point Likert scale from "strongly disagree" to "strongly agree." Scores are generated for the five basic domains: Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness and for individual facets of these domains. Two official versions of this form exist. Form S is the self-rating version while Form R requires ratings from knowledgeable "other" raters. An abbreviated 60-item version, the NEO Five Factor Inventory (NEO-FFI), generates only the five basic domain scores.

2.5.4.2 Body Awareness

Another individual trait that may impact the experience, reporting, and/or outcome of musculoskeletal injury is body awareness. The degree to which an individual is aware of signals from his/her own body may impact this phenomenon in several possible ways including (1) the way he/she approaches activities (whether work or play), (2) the attributions he/she makes about signals from the body, (3) the ability of the individual to know when to seek health care, and (4) the ability of the individual to know when to modify behaviors that may adversely affect illness or injury. It also seems reasonable that some of the potential effects of body awareness may act in contradicting ways. For example, it is possible that individuals high in body awareness are more aware of the presence of symptoms and thus report higher levels. At the same time, these same individuals may be more aware of "warning signs" from their bodies and thus reduce the experience of injury by modifying behaviors in ways that allow them to take better care of their bodies. In the specific case of musculoskeletal discomfort and illness, an individual's awareness to kinesthetic and proprioceptive cues provided by the body might be of particular interest. This might also be a significant factor in design of interventions. This possibility seems supported by already existing techniques such as biofeedback. For these reasons, body awareness and the specific aspect of kinesthetic and proprioceptive awareness are included in this study.

Measures that have been developed to assess some construct of body awareness include the 5-item Private Body Consciousness Scale (Miller, Murphy, & Buss, 1981), the 6-item Public Body Consciousness Scale (Miller et al., 1981), and the 18-item Body Awareness Questionnaire (Shields, Mallory, & Simon, 1989). No known measure exists for specifically measuring kinesthetic and proprioceptive awareness.

2.5.4.3 Potential Modifying Role of State Measure of Stress

It is well believed that stress impacts health. Stress has been measured in terms of "perceived stress" and "experience of stress." Perceived stress involves the individual's perception of what is stressful. Experience of stress is an objective indication of what is or has occurred in the individual's life that is judged by experts to be stressful. Life events can be deemed as stressful whether they are positive (e.g., getting married) or negative (e.g., death of a loved one). Situational stress may also be present, and the response of the individual emerges from the interaction of the individual with the environment (e.g., as described in a transactional model of stress). It is possible that stress directly impacts behaviors, physiological responses, attributions of symptoms, reporting of symptoms, and outcome status related to musculoskeletal illness. It is also possible that stress will impact these relationships differently for different types of individuals. Type A's are known for their need to control their environments. If this control is challenged (e.g., by forcing their pace with time stress or removing their control over the effects of their performance), impacts may be observed in frustration levels, performance, physiological responses, and/or self-reported assessments.

2.6 POTENTIAL RELATIONSHIPS BETWEEN PSYCHOSOCIAL TRAITS

As previously mentioned, the conceptual model proposed for this research presents a simplified view of a more complex reality of the relationships that actually exist. For example, relationships are certain to exist between "internal" psychosocial variables. For example, an individual might exhibit Type A personality while also being categorized as a repressor. Though not evident in this example, causal relationships may also exist.

Type A personality and repressive coping style were the main focus of this study. The potential relationship between these constructs is not evident. The definition of both constructs seems to rely on some aspect of "control." Type A's appear to act in a way to control their environment and the people around them. Repressors appear to act in a way such that they control their self-image. Neither of these individuals is necessarily aware of the need for control. According to Jenkins et al.

(1979), "Type A individuals are particularly lacking in insight regarding their own style of behavior. Similarly, many of them consciously deny having certain Type A traits about which they may feel defensive. On the other hand, Type B persons may feel it socially desirable to portray themselves as hard-driving achievement-oriented" (p. 5). Some overlap of these constructs seems apparent. Questions arise regarding relationships between many of the other constructs as well. For example, does body awareness correlate in some way with neuroticism? Is there a relationship between any of these constructs and discomfort reports? The need to understand and quantify some of these relationships and construct overlaps motivated the first phase of this research initiative.

3. GENERAL APPROACH TO THE RESEARCH

The major focus of this research was to explore the roles that psychosocial factors might have on biomechanical indicators of task performance. This is a fairly new area of research, and no "standard" methodology has been established for conducting these types of evaluations. An overall approach to the research needed to be carefully established to enable (1) development of suitable hypotheses for testing, (2) adequate planning for subject recruiting and assignment, (3) definition of the exact methods and tasks to allow the hypotheses to be tested, and (4) feasibility of the effort required to conduct and complete the study. Two general approaches were considered.

One approach would involve laboratory testing of *any and all* volunteers. This would require that an a priori decision be made regarding whether all of the participants would be subsequently used in the analysis regardless of how they scored on psychosocial measures or whether only those individuals meeting a certain psychosocial criteria would be used in the analysis. This approach does offer the advantage of not having to pre-test participants. This would save some time and reduce the risk of giving participants too much information regarding what the experimenter is investigating which might inadvertently alter the participants' behaviors. Though this approach eliminates the need for pre-testing and selection, it does have some disadvantages. The first disadvantage is related to the absence of perfect reliability in the self-report measures used to measure the psychosocial attributes. Using only extreme scoring individuals increases the reliability of "correctly" identifying an individual as demonstrating a certain attribute. For example, one can be more certain that an individual scoring extremely high (e.g., 95^{th} percentile) on a Type A personality measure actually exhibits the Type A behavior characteristics than one can be about a person scoring in the middle (e.g., 50^{th} percentile). Therefore, if all tested participants are included in the analysis, significant differences may be difficult to detect due to the imperfect reliability of the instrument. On the other hand, if only extreme scoring individuals are used in the analysis, then valuable laboratory time and equipment would be expended collecting data that is not needed. The magnitude of this problem would depend on how the psychosocial attribute(s) are distributed in the population to be tested. It might lead to inclusion of most of the tested pool or exclusion of a significant portion. One additional disadvantage involves the inability to counterbalance treatment orders across individuals of varying psychosocial attributes.

A second approach was considered to address some of these issues. This approach would involve pre-testing any and all willing participants and subsequently selecting from this pre-tested pool only those who meet specific scoring criteria to participate in the laboratory phases of the experiment. This approach would require an additional pre-testing phase to be planned and conducted, but it would also allow the experimenter to (1) address the issues related to reliability of the survey instrument used for categorizing individuals, (2) expend laboratory resources only on usable data, and (3) counterbalance treatment orders across participants.

In order to select the approach and establish a specific methodology, some questions needed to be answered. Many questions existed regarding the relationships between the psychosocial constructs/measures and their potential relationships with indicators of musculoskeletal injury. Do the psychosocial attributes correlate and/or overlap? Are there significant relationships among the psychosocial constructs and/or between these constructs and indicators of well being? Which instrument(s) should be used to measure the most relevant psychosocial attributes (e.g., Type A personality)? How many subjects would be excluded from the analysis if pre-testing was not used? Which body regions might be more relevant for further evaluation of these attributes and musculoskeletal injury/discomfort? It was apparent that some of these questions needed to be answered prior to conducting the laboratory-based evaluations of specific occupational tasks. This need motivated the first phase of this research initiative.

4. PHASE I EXPLORING RELATIONSHIPS BETWEEN PSYCHOSOCIAL ATTRIBUTES AND SELF-REPORTED MUSCULOSKELETAL DISCOMFORT

4.1 OBJECTIVES

As previously discussed, many questions needed to be answered in order to design laboratory studies that could address the major objectives of the research study. This motivated the first phase of the study which was conducted specifically to explore the relationships between a variety of psychosocial trait measures and indicators of well being, as defined by measures of stress and musculoskeletal discomfort. Several primary objectives, if met, would enable subsequent in-lab biomechanical studies to be focused and specifically defined. These primary objectives included the following: (1) to compute correlations between various psychosocial traits in order to better understand the overlap between constructs, (2) to identify the optimal instruments to use in subsequent studies to measure Type A behavior, (3) to identify the optimal instruments to use in subsequent studies to measure inhibition and/or repression, (4) to establish a data set that could be used for narrowing down surveys (i.e., eliminating questions) if time constraints should dictate the need to reduce the time spent by subjects on completing these surveys, (5) to develop and test an instrument for measuring kinesthetic and proprioceptive awareness, (6) to identify possible psychosocial traits that might be more related to self-reports of musculoskeletal discomfort, and (7) to identify general body regions that might be more relevant for this type of study. Secondary objectives included (1) gaining first-hand experience with the process of preparing, administering, and using self-report instruments for fairly large samples; (2) preparation of instruments in consistent media and format; and (3) development of automated tools and programs for scoring the survey instruments. All objectives were reasonably achieved. Results that relate directly to the formulation and design of subsequent phases of the current study will be discussed here.

4.2 METHODS

The study encompassed anonymous administration of a variety of surveys to assess psychosocial traits, stress, and discomfort. Subjects consisted of students from an introductory psychology class and other adults in the university community. The psychology students were recruited and tested in seven (7) group sessions using posted sign-up sheets. Other subjects were recruited via word of mouth. The study was conducted after obtaining approval from the university's Internal Review Board. All subjects provided their signed consent to participate. Scores were computed for a total of 83 subjects.

All instruments were transcribed from their original versions into consistent Microsoft Word format and administered in paper format. Most participants recorded responses on standard 5-item OPSCAN forms. A few subjects entered their responses directly into an automated spreadsheet or recorded their responses directly on the paper tests. Administrative information was collected for a subset of the participants. This included time to complete the surveys, time of administration (beginning or end of semester), and source of the subject (e.g., lab associate, friend, psychology student).

Several modifications were made to the survey instruments to allow for use of standard 5-item OPSCAN forms. First, any 7-item Likert response scales (e.g., Body Awareness Questionnaire – BAQ) were converted to 5-item response scales. All responses were labeled "A" through "E" to correspond with the choices on the OPSCAN form. Titles of the surveys were removed from the instruments and only acronyms remained to identify them. Instruments were ordered in a fixed order, stapled together, and continuously numbered. Two stapled sets of surveys and two OPSCAN forms were required for each subject. A unique subject number was entered on each of the two OPSCAN forms in order to link responses from each form to the same subject source. The first form accompanied a stapled set of surveys that required 233 total responses. The second form accompanied a stapled set of surveys that required 119 responses. Demographic information was collected and included gender, age, race, native language, student status, and work status.

4.2.1 Survey Instruments and Score Variables

The following standard and unique instruments were administered resulting in 352 total questions. Abbreviations used for the instruments and their computed test score variables are shown in bold.

JAS: A modified version of the 52-item Jenkins Activity Survey Form C (Jenkins et al., 1979). This scale has been widely used to measure Type A behavior in working adults. Internal consistency reliability coefficients have been estimated for the Type A subscale to be 0.83 to 0.85.

Test-retest reliability coefficients range from 0.66 to 0.76. The scale was revised slightly for this study to also include wording from the Form T student version such that one scale could be used for all subjects. Four subscale scores were obtained based on weighted contributions of the responses: **JASa** – Type A subscale, **JASs** – Speed and Impatience, **JASh** – hard driving and competitiveness, and **JASj** – job involvement. Key-items for three of the scales (Jenkins et al., 1979, p. 19) were used to calculate three sub-scores: **subS**, **subH**, and **subJ**. The JASa score was used in conjunction with normative tables (Jenkins et al., 1979) to compute the associated percentile score, **JASperc**.

MCSDS: The 33-item Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1964). This scale measures the tendency to present oneself in a socially desirable way. It has also been described as measuring "defensiveness" and as a "lie" scale in conjunction with other scales. Response choices are "true" and "false." An **MCSDS** score was computed by counting the responses that corresponded to the published responses purporting to reflect the need for social desirability (Crowne & Marlowe, 1964). This scale has routinely been administered in conjunction with a measure of trait anxiety in order to categorize subjects into specific coping styles including truly low anxious, repressors, high anxious, and defensive high anxious.

BMAS: The 20-item Bendig Short Form Manifest Anxiety Scale (Bendig, 1956). This scale has been widely used to measure trait anxiety. Response choices are "true" and "false." A **BMAS** score was computed by counting the responses that corresponded to the published responses purporting to reflect trait anxiety (Taylor, 1953). In conjunction with the MCSDS, scores on this scale were used to categorize subjects into coping styles.

FAS: A 16-item Type A scale used by Finnish researchers (Salminen et al., 1991; Wickström et al., 1989). These studies reported associations between Type A personality as measured by this scale (administered in Finnish language and translated to English for publication) and musculoskeletal injury indicators. No reliability information has been published for this scale and personal correspondence revealed that none is known to be available (Wickström, 2000). Each of the 16 items contains a 5-point rating scale with statements on the left and right of this rating scale reflecting "opposite" behaviors. Approximately half of the items are reverse scored. The total scale score, **FAS**, is then computed by summing the item responses. Highest (75th percentile) and lowest quartile (25th percentile) scores from Wickström et al. (1989) were used to calculate a mean and standard deviation. These were used to compute **FASper**, the percentile for each FAS score.

KAS: A 9-item Type A measure (Caplan et al., 1975) based on Caplan's 49-item scale derived from Sales 72-item Type A inventory. Correlation with the 49-item scale is 0.90 and internal consistency is around 0.80 (Caplan et al., 1975). Responses are presented on a 7-point Likert scale from "Very true of me" to "Not at all true of me." The response format was converted to a 5-point scale for this study.

BAQ: The 18-item Body Awareness Questionnaire (Shields et al., 1989). This scale measures awareness to normal nonemotive body processes. Internal consistency has been demonstrated by an alpha coefficient of 0.80. Test-retest reliability is 0.80. The 7-point Likert scale was modified to a 5-point Likert scale for this study.

KPAQ: A 12-item Kinesthetic and Proprioceptive Awareness Questionnaire (KPAQ) developed by this author and colleagues for this study. The concept and content of this scale was expanded and modified from three questions developed by Smith-Jackson (1998). Questions on this scale ask about specific awareness and attribution of kinesthetic and proprioceptive cues from the body's limbs, muscles, etc. Example items from this scale are "I am aware of my overall body posture" and "I know my own strength." Responses are provided on a 5-point Likert scale from "Never true about me" to "Always true about me." The version administered in this study constitutes the baseline version that can be used for further modification and development of this instrument. This survey is contained in Appendix 13.1.

NEOFFI: The 60-item NEO Five-Factor Inventory (Costa & McCrae, 1992b). This is a shortened version of the 181-item revised NEO Personality Inventory (NEO PI-R). The NEO-FFI produces scores on five subscales intended to represent the five major dimensions of personality (i.e., "big-five personality factors"). After the required items were reversed score, the following subscale scores were computed: **N** – Neuroticism, **E** – Extraversion, **O** – Openness to Experience, **A** – Agreeableness, and **C** – Conscientiousness. A total scale score would be meaningless and was not computed.

LSA: The 22-item Lifestyle Approaches scale (Williams, Moore, Pettibone, & Thomas, 1992). This scale provides scores on six factors related to self-management practices. Internal consistency coefficients range from 0.38 to 0.71 for the individual factor scales. After the required items were reversed scored, published item weights were used to compute scores for the following factors: **LSA1** – performance focus and efficiency, **LSA2** – goal directedness, **LSA3** – timeliness of task accomplishment, **LSA4** – organization of physical space, **LSA5** – written plans for change, and

LSA6 – verbal support. This measure, and most importantly goal directedness, was found to be a significant predictor of membership in a carpal tunnel syndrome group compared to controls (Vogelsang et al., 1994). A total scale score was not computed.

AEQ: The 28-item Ambivalence Over Emotional Expressiveness Questionnaire (King & Emmons, 1990). This scale measures the degree to which one's goals for expression are in conflict with other goals (e.g., social norms). Internal consistency for this scale is demonstrated by an alpha coefficient of 0.89. The construct underlying this scale is believed by some to be an important mediator between "emotional styles and psychological and physical well-being" (King & Emmons, 1990, p. 864).

SRRS-R: The 51-item revised Social Readjustment Rating Scale (Hobson, Kamen, Szostek, Nethercut, Tiedmann, & Wojnarowicz, 1998). This is a recently revised stressful life events scale. Subjects responded by selecting "Yes" or "No" regarding whether each event had occurred in their lives in the last six (6) months. The following scores were computed for this scale: **SRRSct** – a count of the "Yes" responses and **SRRSwt** – a weighted score computed by summing the rank order means presented in (Hobson et al., 1998) for each "Yes" event.

SRRSP: An 11-item list of stressful college-related events selected from a standard measure (Sarason, Johnson, & Siegel, 1979). These events were added on to the end of the SRRS scale. This scale generated one score labeled **SRRSPct** – a count of "Yes" responses.

MDS: A 16-item Musculoskeletal Discomfort Survey developed for this study. This survey requests responses regarding intensity and frequency of pain for eight body regions. Eleven MDS scores were generated from this scale. These are described in detail in subsequent sections of this manuscript.

Demographics: 4-item Demographics questionnaire. These questions included the following items: gender (male, female), race (White/Caucasian, Black/African-American, Hispanic, Other), student status (full-time, part-time, I am not a student), and work status (full-time ≥ 30 hours/week, part-time, I do not work).

4.2.2 Data Reduction and Analysis

A unique Borland C++ code was written to read in subject demographic and administrative information, read in subject responses to the surveys, generate scores for all of the survey instruments, and output all results into plain text files for subsequent analysis in SAS or other analysis tool. The 1100 line code was created such that modifications could be easily made if instruments were eliminated for later use (i.e., for later phases of the overall research study). The code generated an output file containing demographic information, test scores, factor scores, stress scores, and musculoskeletal discomfort scores for each subject. The code also created unique files containing individual item responses for the Finnish Type A scale and the Kinesthetic and Proprioceptive Awareness Questionnaire in order to allow reliability assessment of these instruments.

Survey data were analyzed with several different statistical analysis methods. Pearson correlation coefficients were computed between all continuous measures. Scores from selected instruments were used to categorize subjects into specific attributes. Categorical data were analyzed using analysis of variance (ANOVA) procedures and chi-square tests of independence.

4.3 RESULTS

4.3.1 Subject Demographics

Analysis was completed for 83 total subjects. Subjects ranged in age from 18 to 51 years with an average age of 22.3 years (standard deviation 6.34 years, N=79). Other demographic information is summarized in Table 4-1.

Table 4-1 - Phase I subject demographic information

Subject Demographics (total N = 83)			
	N		**N**
Gender		**Student status**	
Male	33	Full-time	69
Female	50	Part-time	8
		Not a student	6
Native language		**Work status**	
American English	67	Full-time	17
Other	16	Part-time	36
		Does not work	30

4.3.2 Relationships between Psychosocial Traits

4.3.2.1 Correlations between Continuous Measures

Correlations were computed between all continuous variables. Sample sizes (N's) ranged between 78 and 83 for each correlation except for those correlations with "time" which ranged between 63 and 66. Those findings that were significant to the design of the later phases of this study are presented in the following sections.

4.3.2.1.1 Correlations with Type A Personality Measures

Correlations between Type A personality variables and other continuous measures are provided in Table 4-2.

Age did not correlate significantly with any of the measures.

Time (to complete the tests) correlated negatively with several of the JAS scores as expected, but none of these were significant. However, it correlated positively with the FAS score. The only significant correlation was –0.276 with the Caplan (KAS) scale.

JAS. The JASa subscale correlated significantly with the JASs and JASh subscales. The critical item subscale scores subS, subJ, and subH correlated well (0.914, 0.841, and 0.922 respectively) with each of their larger scales. The JAS speed and impatience scores (JASs and subS) correlated negatively with social desirability (MCSDS) and positively with anxiety (BMAS).

FAS. The FAS correlated significantly and positively (0.613) with the JASa score representing good convergent validity. However, it also correlated significantly with many of the other scores including neuroticism (N) and trait anxiety (BMAS). The FAS correlated negatively with social desirability (MCSDS) and positively with anxiety (BMAS).

Stress. Several of the Type A measures (FAS, JASa, JASh, JASperc) correlated positively ($p<0.05$) with stress (SRRSct and SRRSwt). Interestingly, the FAS percentile score (FASper) did not even though the raw FAS score did. The JASj job involvement measure correlated negatively with the stress scores, but none of these correlations were significant.

Table 4-2. Correlations between Type A scores and other measures.

	FAS	KAS	JASa	JASs	JASj	JASh	subS	subJ	subH	JASperc	FASper
age	0.10	0.10	0.05	0.02	0.14	0.10	-0.02	0.13	0.14	0.04	0.14
time	0.19	**-0.28**	-0.07	-0.07	-0.05	0.15	-0.02	0.09	0.11	-0.07	0.20
FAS	-	0.16	**0.61**	**0.40**	0.14	**0.42**	**0.44**	**0.27**	**0.46**	**0.59**	**0.92**
KAS	0.16	-	0.20	0.02	**0.26**	**0.26**	-0.04	0.15	**0.31**	0.18	0.11
JASa	**0.61**	0.20	-	**0.60**	0.17	**0.49**	**0.57**	**0.25**	**0.53**	**1.00**	**0.60**
JASs	**0.40**	0.02	**0.60**	-	-0.08	-0.05	**0.91**	0.01	0.07	**0.60**	**0.41**
JASj	0.14	**0.26**	0.17	-0.08	-	0.17	-0.10	**0.84**	0.16	0.17	0.13
JASh	**0.42**	**0.26**	**0.49**	-0.05	0.17	-	-0.12	**0.22**	**0.92**	**0.48**	**0.35**
subS	**0.44**	-0.04	**0.57**	**0.91**	-0.10	-0.12	-	-0.03	-0.01	**0.56**	**0.41**
subJ	**0.27**	0.15	**0.25**	0.01	**0.84**	**0.22**	-0.03	-	0.21	**0.25**	**0.29**
subH	**0.46**	**0.31**	**0.53**	0.07	0.16	**0.92**	-0.01	0.21	-	**0.51**	**0.37**
JASperc	**0.59**	0.18	**1.00**	**0.60**	0.17	**0.48**	**0.56**	**0.25**	**0.51**	-	**0.60**
FASper	**0.92**	0.11	**0.60**	**0.41**	0.13	**0.35**	**0.41**	**0.29**	**0.37**	**0.60**	-
MCSDS	**-0.33**	0.12	-0.05	**-0.32**	0.10	**0.22**	**-0.35**	0.08	0.13	-0.04	**-0.31**
BMAS	**0.43**	-0.14	0.11	**0.30**	-0.17	0.02	**0.32**	0.04	0.05	0.10	**0.34**
AEQ	0.10	-0.17	-0.10	0.06	-0.19	-0.01	0.09	-0.21	-0.05	-0.11	0.01
BAQ	0.17	0.08	0.07	-0.17	0.01	**0.34**	-0.15	-0.06	**0.35**	0.07	0.11
KPAQ	0.13	0.07	-0.07	-0.15	-0.03	**0.26**	-0.18	-0.03	0.22	-0.08	0.13
LSA1	0.06	0.10	**0.23**	-0.03	**0.26**	0.21	-0.03	0.17	**0.22**	**0.23**	0.03
LSA2	-0.04	**0.28**	0.06	**-0.24**	0.09	**0.22**	**-0.23**	-0.05	0.17	0.03	-0.05
LSA3	0.05	**0.23**	0.03	-0.18	0.07	**0.40**	-0.19	-0.03	**0.44**	0.00	-0.04
LSA4	0.01	0.06	0.11	-0.12	0.06	**0.31**	-0.13	0.02	**0.27**	0.10	0.02
LSA5	0.01	0.04	-0.02	-0.21	-0.03	**0.25**	**-0.28**	-0.05	**0.26**	-0.02	-0.02
LSA6	**0.41**	0.04	**0.36**	0.21	0.10	0.15	0.21	0.13	0.21	**0.36**	**0.38**
N	**0.42**	**-0.23**	0.12	0.21	-0.21	0.08	0.20	-0.03	0.11	0.12	**0.39**
E	**0.22**	0.22	0.12	-0.11	0.16	**0.22**	-0.07	0.08	**0.24**	0.10	0.19
O	**0.30**	0.09	0.04	0.10	0.10	0.11	0.07	0.08	0.15	0.03	**0.28**
A	-0.11	0.17	**-0.25**	**-0.50**	**0.28**	0.18	**-0.51**	**0.22**	0.14	**-0.25**	-0.10
C	0.07	**0.33**	0.20	-0.14	0.10	**0.44**	-0.19	0.02	**0.45**	0.18	0.02
SRRSct	**0.24**	0.01	**0.27**	0.14	-0.06	**0.28**	0.14	0.02	**0.24**	**0.26**	0.19
SRRSwt	**0.22**	0.01	**0.23**	0.16	-0.08	**0.25**	0.15	-0.01	0.21	**0.23**	0.17
SRRSPct	0.06	**-0.24**	-0.04	0.12	-0.16	-0.18	0.16	-0.06	-0.15	-0.04	0.03

Significant ($p < 0.05$) correlations shown in bold.

4.3.2.1.2 Correlations between Other Psychosocial Measures

Correlations between NEO-FFI factor scores and other psychosocial measures are provided in Table 4-3. Correlations between remaining psychosocial measures are provided in Table 4-4.

Table 4-3. Correlations between NEO-FFI factor scores and other psychosocial measures.

	N	**E**	**O**	**A**	**C**
age	-0.08	0.07	0.21	**0.30**	0.22
time	**0.28**	0.13	0.18	0.08	-0.16
MCSDS	**-0.51**	0.19	-0.10	**0.31**	**0.40**
BMAS	**0.81**	**-0.31**	0.10	**-0.39**	**-0.45**
AEQ	**0.48**	**-0.27**	0.08	-0.16	**-0.29**
BAQ	-0.03	**0.31**	**0.28**	0.16	**0.36**
KPAQ	-0.03	**0.29**	**0.37**	**0.29**	**0.39**
LSA1	**-0.39**	0.18	0.12	**0.24**	**0.45**
LSA2	**-0.45**	**0.31**	-0.03	**0.33**	**0.60**
LSA3	**-0.34**	**0.24**	0.04	**0.39**	**0.68**
LSA4	-0.15	**0.27**	0.15	0.08	**0.50**
LSA5	0.00	0.02	-0.05	0.01	0.18
LSA6	0.08	0.19	**0.22**	-0.10	0.03
N	**-**	**-0.28**	0.18	**-0.31**	**-0.38**
E	**-0.28**	**-**	0.21	**0.36**	**0.39**
O	0.18	0.21	**-**	0.01	0.02
A	**-0.31**	**0.36**	0.01	**-**	**0.38**
C	**-0.38**	**0.39**	0.02	**0.38**	**-**
SRRSct	**0.23**	0.16	0.00	-0.09	-0.08
SRRSwt	**0.24**	0.14	0.02	-0.12	-0.10
SRRSPct	**0.23**	-0.09	0.01	-0.21	**-0.31**

Significant ($p < 0.05$) correlations shown in bold.

Neuroticism correlated positively with time suggesting that the more neurotic an individual is the more time to complete tasks or make decisions. It also correlated with many of the psychosocial measures in this study, supporting the belief that it might be an underlying trait that should be measured so that its contribution to experience/reporting of outcome measures can be evaluated. **Extraversion** correlated negatively with anxiety suggesting that the more extraverted an individual is the less anxiety he/she would report. **Conscientiousness** correlated significantly with almost all of the other measures.

MCSDS. This measure correlated significantly and negatively (-0.492) with BMAS, suggesting that the higher the need for social desirability the less reported anxiety. Since both of these instruments are used to categorize coping styles, this should be considered in subject recruiting and analysis of results.

Table 4-4. Correlations between other psychosocial measures.

	MCSDS	**BMAS**	**AEQ**	**BAQ**	**KPAQ**	**LSA1**	**LSA2**	**LSA3**	**LSA4**	**LSA5**	**LSA6**
age	0.07	-0.21	-0.21	0.05	0.16	0.18	0.10	**0.26**	0.04	-0.08	-0.03
time	0.05	0.24	0.20	0.18	0.21	**-0.28**	-0.07	-0.07	0.17	0.06	-0.05
MCSDS	**-**	**-0.49**	-0.18	0.17	0.17	**0.27**	**0.36**	**0.23**	**0.23**	0.13	-0.07
BMAS	**-0.49**	**-**	**0.42**	-0.12	-0.06	**-0.39**	**-0.49**	**-0.36**	**-0.23**	0.05	0.04
AEQ	-0.18	**0.42**	**-**	0.05	-0.01	**-0.38**	**-0.25**	**-0.26**	**-0.22**	-0.11	0.02
BAQ	0.17	-0.12	0.05	**-**	**0.64**	**0.22**	**0.29**	**0.29**	**0.22**	0.15	0.09
KPAQ	0.17	-0.06	-0.01	**0.64**	**-**	**0.25**	**0.31**	**0.27**	**0.22**	0.02	-0.10
LSA1	**0.27**	**-0.39**	**-0.38**	**0.22**	**0.25**	**-**	**0.44**	**0.50**	**0.31**	0.02	0.08
LSA2	**0.36**	**-0.49**	**-0.25**	**0.29**	**0.31**	**0.44**	**-**	**0.58**	**0.42**	0.16	0.03
LSA3	**0.23**	**-0.36**	**-0.26**	**0.29**	**0.27**	**0.50**	**0.58**	**-**	**0.41**	**0.25**	0.09
LSA4	**0.23**	**-0.23**	**-0.22**	**0.22**	**0.22**	**0.31**	**0.42**	**0.41**	**-**	0.15	-0.15
LSA5	0.13	0.05	-0.11	0.15	0.02	0.02	0.16	**0.25**	0.15	**-**	**0.23**
LSA6	-0.07	0.04	0.02	0.09	-0.10	0.08	0.03	0.09	-0.15	**0.23**	**-**
SRRSct	-0.17	**0.24**	0.18	-0.01	-0.09	-0.07	-0.12	-0.05	0.02	0.11	-0.01
SRRSwt	-0.16	**0.27**	0.19	-0.01	-0.07	-0.08	-0.12	-0.06	0.02	0.10	-0.04
SRRSPct	**-0.38**	**0.29**	**0.27**	-0.10	-0.12	**-0.23**	**-0.23**	**-0.22**	-0.16	-0.07	-0.07

Significant ($p < 0.05$) correlations shown in bold.

BMAS. Trait anxiety correlated 0.809 with neuroticism and with each of the stress measures. As previously mentioned, it correlated negatively with MCSDS.

KPAQ. The KPAQ showed significant positive correlation (N = 83, correlation = 0.635, p<0.0001) with the BAQ demonstrating acceptable convergent validity. Discriminant validity was demonstrated by the absence of significant correlations with the BMAS (correlation = -0.060), MCSDS (0.167), and AEQ (-0.005). Discriminant validity was also demonstrated by nonsignificant correlations (see Table 4-2) with the Finnish Type A scale (0.125) and the revised Jenkins Type A subscale (-0.069). Cronbach's coefficient alpha was calculated to be 0.82 for the usable sample data (N = 81), representing good internal consistency. Reliability could not be increased based on elimination of any one question from the scale.

LSA. Four of the factors in the LSA (LSA1 through LSA4) showed significant correlations with many of the other variables. LSA5 did not correlate significantly with other non-LSA measures and LSA6 only correlated with one (Openness to Experience). These two factors may be measuring constructs that are uniquely different from the other variables.

4.3.2.2 Overlap Between JAS- and FAS-determined Personality Type Categories

One fundamental objective of this initial phase of the research study was to determine which survey to use for measuring Type A personality. The Jenkins Activity Survey (JAS) is well known and has published reliability data. Although there is no published reliability for the Finnish scale (FAS), it has been reported to be associated with musculoskeletal discomfort. Thus, it seems to be measuring an important psychosocial attribute. The question arises as to whether the FAS and the JAS are measuring the same construct.

Percentile scores (JASperc) from the JAS were used to categorize all subjects into personality types A, B, or AB. Raw scores were converted to percentile scores using published population data (Jenkins et al., 1979). Subjects were then categorized as having Type A, B, or AB personality types. Subjects scoring 65th percentile and above were classified as Type A. Subjects scoring 35th percentile and below were classified as B. Those in the middle were classified as AB.

Percentile scores (FASper) from the FAS were used to categorize all subjects into FAS personality types A, B, or AB. Raw scores were converted to percentile scores using means and standard deviations obtained from studies that published this scale and reported associations with musculoskeletal discomfort (Wickström, 1989). Subjects were then categorized as having Type A, B, or AB personality types. Subjects scoring 65th percentile and above were classified as Type A. Subjects scoring 35th percentile and below were classified as B. Those in the middle were classified as AB.

4.3.2.2.1 Results

Table 4-5 provides a detailed breakdown of the numbers of subjects that fell into each of the personality type categories determined from these instruments.

Table 4-5. Overlap between JAS- and FAS-determined personality types.

	JAS Type A	JAS Type B	JAS Type AB	TOTAL	percentage
FAS Type A	35	7	16	58	69.9%
FAS Type B	0	6	1	7	8.4%
FAS Type AB	6	6	6	18	21.7%
TOTAL	41	19	23	83	
percentage	49.4%	22.9%	27.7%		

The data in this table were used to perform a chi-square test of independence between the FAS and JAS categories. The results produced a chi-square statistic of 22.3598 (df=4, p=0.0002), suggesting that the constructs measured by the JAS and FAS are related and are not independent of each other. However, 56 % of the cells had expected frequencies of less than 5. Therefore, the chi-square test may not be valid. Hatcher and Stepanski (1994) suggest that in classification tables larger than 2x2, “no more than 20% of the cells should have expected frequencies less than 5” (p. 171). Based on this, a new table (see Table 4-6) of observed frequencies was generated for only the extreme categories of interest. This resulted in a chi-square statistic of 18.4615 (df=1, p<0.0001). This suggests that the FAS and JAS categories are statistically related. However, 50% of the cells still had expected frequencies less than 5 which may mean that the chi-square test is not valid.

Table 4-6. Overlap between JAS and FAS extreme scoring personality categories.

	JAS Type A	**JAS Type B**	**TOTAL**
FAS Type A	35	7	42
FAS Type B	0	6	6
TOTAL	35	13	48

Still, some important findings emerge from inspecting the data in Table 4-5 and Table 4-6. First, regardless of whether the JAS or FAS was used to classify subjects, the categories were not evenly distributed within the population. Using the JAS, there were 35 Type A’s and only 13 Type B’s. Using the FAS, there were 42 Type A’s and only 6 Type B’s. It appears that the FAS tends to over predict towards the “Type A” classification. The FAS predicted that 69.9% of the individuals were “Type A” while the JAS classified only 49.4% as “Type A.” None of the individuals categorized by the JAS as “Type A” fell into the FAS “Type B” category. However, 7 individuals classified by the FAS as “Type A” fell into the JAS “Type B” category.

4.3.2.2.2 Conclusions

The results of this analysis suggested that the following findings should be considered when designing the remaining portions of the study: (1) Type A individuals are more prevalent in this particular population than Type B individuals, and this must be considered in estimating the number of subjects to be pre-tested; and (2) the Finnish scale tends to over predict towards Type A classification and should not be used to measure and categorize personality type as the primary independent variable.

4.3.2.3 Overlap between Personality Type and Coping Style

One fundamental objective of this phase of the study was to determine the potential overlap between the two traits of personality type and coping style. Percentile scores (JASperc) from the JAS were used to categorize all subjects into personality types A, B, or AB as previously described.

Coping style was defined using the method developed by Weinberger et al. (1979) that uses trait measures of anxiety and social desirability. Subjects with valid BMAS and MCSDS scores (N = 82) were categorized into their respective coping styles according to the following procedure. First, both BMAS and MCSDS scores for each subject were categorized as *low*, *middle*, or *high* based on splits used by Myers and Vetere (1997) and contained in Table 4-7:

Table 4-7. Scoring splits for defining coping style categories.

	low	**middle**	**high**
BMAS score	7 or under	8 to 11	12 or over
MCSDS score	11 or under	12 to 15	16 or over

These scoring splits were then used to classify subjects into the following four categories: *repressor* (high MCSDS, low BMAS), *truly low anxious* (low MCSDS, low BMAS), *high anxious* (low MCSDS, high BMAS), and *defensive high anxious* (high MCSDS, high BMAS). Subjects with a middle score on either or both measures were classified as *middle*. This resulted in the following groups: truly low anxious (tla), repressors (rep), high anxious (ha), defensive high anxious (dha), and middles (mid).

4.3.2.3.1 Results

Table 4-8 provides a detailed breakdown of each possible intersection of the two traits and the results that were found in this study. The data in this table were used to perform a chi-square test of independence between personality type and coping style. The results produced a chi-square statistic of 12.6841 (df=8, p=0.1232), suggesting that the constructs are independent of each other.

However, 53 % of the cells had expected frequencies of less than 5. Hatcher and Stepanski (1994) suggest that in classification tables larger than 2x2, "no more than 20% of the cells should have expected frequencies less than 5" (p. 171) and one should consider "combining similar categories of subjects in order to increase cell frequencies" (p. 170). Based on this suggestion, a new table (see Table 4-9) of observed frequencies was generated after combining the two high anxious ("defensive high anxious" and "high anxious") categories and eliminating the "truly low anxious" category. This resulted in a chi-square statistic of 8.8482 (df=4, p=0.0650) and only 22% of the cells with expected frequencies less than 5. Though the chi-square test may not be valid, this finding again suggests that the constructs of personality type and coping style are different constructs.

Table 4-8. Overlap between personality type and coping style

	Type A	Type B	Type AB	TOTAL	percentage
dha	2	1	2	5	6.0%
ha	6	1	3	10	12.0%
mid	22	11	6	39	47.0%
rep	8	5	12	25	30.1%
tla	3	0	0	3	3.6%
missing	0	1	0	1	1.2%
TOTAL	41	19	23	83	
percentage	49.4%	22.9%	27.7%		
Coping style categories include dha – defensive high anxious, ha – high anxious, mid – middles, rep – repressor, and tla – truly low anxious.					

Table 4-9. Overlap between personality type and coping style with high anxious categories combined and truly low anxious category deleted.

	Type A	Type B	Type AB	TOTAL
dha & ha	8	2	5	15
mid	22	11	6	39
rep	8	5	12	25
TOTAL	38	18	23	79
Coping style categories include dha – defensive high anxious, ha – high anxious, mid – middles, and rep – repressor.				

The results of this analysis provided information that was critical to deciding on the research approach that should be utilized for further work in this area. The information was especially significant in (1) deciding which construct(s) to explore as independent variables, (2) deciding whether to pre-test or not to pre-test subjects for the subsequent laboratory studies, and (3) determining the approximate number of subjects that should be pre-tested in order to yield the required number of subjects for those later studies.

First, these results revealed that individuals with certain coping styles might be very difficult to find. For example, only 3 out of 83 individuals were categorized as "truly low anxious." This category would mostly likely be the best category for comparing the other categories to in order to find differences in physiological indications of anxiety. If the results found here are representative of what would be found in other samples, then it would be very difficult to recruit enough of these individuals to generate sufficient statistical power for testing hypotheses related to the construct of coping style.

Second, the results were used to decide whether to pre-test for individuals of certain psychosocial attributes. For example, if a study were designed to test any and all willing participants but only to use the extreme scoring personality types (e.g., A's and B's but not AB's) and/or coping styles (i.e., no middles and no missing) in the analysis, a percentage of the tested subjects would not be used. If the assumption is made that the attributes are distributed in a similar fashion between the populations tested, then some general conclusions can be drawn regarding how many subjects would be included or excluded from the analysis. For example, if the study focused on analyzing results from only those subjects with Type A and B personalities, about 28% of the tested individuals would be excluded. If the study focused on coping style and used only those scoring in non-middle categories, about 47% would be excluded. If the study focused on interactions between personality type and coping style such that neither Type AB's nor middles would be used, then approximately 31% (26 out of 83) would be usable in the analysis. If this were the population tested, then only 19 Type A's and 7 Type B's would be acceptable for this analysis resulting in 3 defensive high anxious, 7 high anxious, 13 repressor, and 3 truly low anxious subjects.

Additionally, the results presented in Table 4-8 also show that the categories are not evenly distributed. Therefore, if equal numbers are required from each category (e.g., personality Type A and B) in order to adequately test the experimental hypotheses, then enough individuals would have to be tested in order to generate the required numbers for each category, including those categories with very low representation (e.g., Type B's with 22.9% and truly low anxious with 3.6%).

4.3.2.3.2 Conclusions

These results demonstrated that both the distribution of extreme scoring categories within constructs and the overlap between constructs must be considered in order to adequately plan for future studies of these and other psychosocial traits. Based on this, the decision was made to (1) design the laboratory studies to primarily explore hypotheses related to personality type but allow secondary exploration of coping style and (2) conduct the experiments after pre-testing a large number of individuals and recruiting only those meeting specific criteria.

4.3.3 Musculoskeletal Discomfort

Subjects were provided a musculoskeletal discomfort survey (MDS) containing an eight-region body diagram, a pain intensity rating scale, and a frequency of pain rating scale. The eight regions included head (h), neck/shoulder (ns), arm/elbow (ae), legs/feet (lf), hand/wrist (hw), mid/upper back (ub), low back (lb), and hips/buttocks (hb). Written instructions asked subjects to "rate both the intensity and frequency of discomfort/pain you have experienced in the past six (6) months for each body region. Use the PAIN INTENSITY rating scale to describe, on average, the intensity of the pain you have experienced for each body region. Use the FREQUENCY rating scale to determine how often you have experienced discomfort in each body region." For both rating scales, subjects responded to a visual and verbally anchored 5-item response scale. Responses on the intensity scale ranged from "0 – No pain" to "4 – Worst pain ever in life." Responses on the frequency scale ranged from "0 – Never" to "4 – Almost always (daily)."

Each of these responses was used to compute 11 discomfort scores for each subject. First, for each body region a weighted discomfort score was computed. For example, for the neck and shoulder, MDSns = intensity rating x frequency rating reported by the respondent for the neck and shoulder. This resulted in the following possible scores for each body region: 0, 1, 2, 3, 4, 6, 8, 9, 12, and 16. Three additional general discomfort variables were obtained as follows for each subject:

MDSavgI = Average discomfort intensity across body regions
= sum of 8 intensity responses / 8
MDSavgF = Average frequency across body regions
= sum of 8 frequency responses / 8

MDSavgW = Average weighted discomfort across body regions
= sum of 8 weighted scores / 8
= (MDSh+MDSns+MDSae+MDSlf+MDShw+MDSub+MDSlb+MDShb) / 8

4.3.3.1 Correlations between Psychosocial Measures and Musculoskeletal Discomfort

4.3.3.1.1 General Description of Results

Correlations were computed between all psychosocial measures and musculoskeletal discomfort survey (MDS) variables. These correlations are presented in Table 4-10. The N's are provided to indicate how many subjects contributed valid scores for that measure's correlations with all of the MDS variables. Since no MDS responses were missing for any subjects, this N is the same for all MDS correlations with that measure. Several interesting findings emerged from this analysis and will be discussed here. Emphasis is placed on those findings that impact decisions regarding the remaining portions of this research study.

4.3.3.1.2 Social Desirability and Trait Anxiety

The MCSDS correlated significantly and negatively (-0.336) with discomfort in the neck/shoulder region (MDSns), but did not correlate significantly with any other MDS measure. Interestingly, most of the correlations were close to zero and/or slightly negative. This could be due to a general tendency for subjects high in social desirability to experience better health (i.e., less discomfort) or to report less discomfort even if it is present (i.e., to appear in a more socially desirable fashion). Additionally, since repressors are categorized based on high MCSDS scores but tend to reflect themselves in an overly positive fashion on self-report measures of health, they may be heavily influencing this correlation (or absence of a correlation). To evaluate this possibility, correlations were computed between variables using data from all subjects except repressors (N=58). No relationships between MCSDS and MDS variables were found to be significant.

Trait anxiety (BMAS) correlated significantly with 7 of the 11 MDS variables. This is not surprising due to its 0.809 ($p<0.0001$) correlation with neuroticism. The possible explanations for the relationships between neuroticism and discomfort scores also apply here. With repressors excluded only 5 of 11 MDS variables had significant correlations with BMAS (N=57). These included the 3 composite MDS variables and the neck/shoulder (MDSns) and mid/upper back (MDSub) variables.

Table 4-10. Correlations between psychosocial measures and musculoskeletal discomfort scores.

	N	h	ns	ae	lf	hw	ub	lb	hb	avgI	avgF	avgW
age	79	-0.09	0.12	-0.05	-0.01	0.07	-0.04	-0.09	-0.10	-0.08	-0.03	-0.03
time	66	0.02	-0.06	-0.15	-0.16	-0.14	-0.12	-0.09	-0.17	-0.18	-0.09	-0.18
MCSDS	83	-0.12	**-0.34**	-0.06	0.07	0.03	-0.17	-0.16	-0.06	-0.14	-0.20	-0.16
BMAS	82	**0.26**	**0.38**	0.21	0.09	0.16	**0.33**	**0.26**	0.18	**0.36**	**0.44**	**0.37**
AEQ	81	0.05	0.13	0.02	-0.03	0.16	0.02	0.11	0.12	0.10	0.15	0.12
FAS	83	0.08	**0.42**	0.06	0.12	-0.03	**0.23**	0.18	0.03	0.17	0.22	**0.23**
KAS	80	-0.03	**0.40**	0.11	0.21	0.14	0.21	-0.11	0.12	0.17	0.22	0.21
BAQ	83	-0.07	0.11	0.03	0.11	0.03	-0.01	0.05	0.08	0.00	0.00	0.06
KPAQ	83	-0.17	0.08	0.00	0.10	0.00	0.01	0.16	0.06	-0.04	-0.02	0.04
LSA1	83	**-0.31**	-0.05	-0.08	-0.02	-0.10	-0.08	0.08	0.02	-0.07	-0.14	-0.12
LSA2	83	**-0.28**	-0.04	-0.22	0.08	-0.11	-0.05	-0.15	-0.02	-0.17	**-0.22**	-0.16
LSA3	83	**-0.34**	0.03	-0.07	-0.05	0.07	0.07	0.06	-0.04	-0.09	-0.05	-0.06
LSA4	83	-0.21	-0.09	0.08	0.07	0.03	-0.08	0.06	0.02	-0.02	-0.10	-0.03
LSA5	83	0.00	0.10	0.15	**0.23**	0.05	**0.28**	0.01	0.09	0.17	0.16	0.18
LSA6	83	0.09	0.03	0.05	0.10	-0.15	0.02	0.01	-0.09	-0.01	-0.03	0.02
N	83	**0.24**	**0.31**	0.19	0.05	0.18	**0.26**	**0.22**	0.17	**0.30**	**0.39**	**0.32**
E	83	-0.15	0.01	0.02	0.11	-0.11	-0.01	-0.06	-0.10	-0.14	-0.05	-0.06
O	83	0.14	**0.23**	0.14	0.21	0.08	-0.03	0.13	-0.10	0.08	0.14	0.18
A	83	**-0.25**	-0.03	0.00	**-0.23**	0.13	0.03	0.01	-0.09	-0.15	-0.03	-0.09
C	83	**-0.31**	-0.06	-0.14	0.03	0.00	-0.03	-0.01	-0.08	-0.17	-0.18	-0.12
JASa	83	0.02	0.08	-0.07	0.09	-0.17	-0.03	0.04	0.03	0.02	-0.04	0.00
JASs	83	0.13	0.03	-0.08	0.11	-0.17	-0.17	0.01	-0.03	-0.02	-0.08	-0.03
JASj	83	-0.01	0.05	0.14	-0.01	0.03	0.00	-0.02	-0.08	0.07	-0.01	0.03
JASh	83	-0.09	0.13	0.02	0.15	0.11	**0.23**	0.11	0.05	0.14	0.21	0.14
subS	83	0.06	0.08	-0.14	0.09	-0.20	-0.19	-0.02	-0.07	-0.08	-0.10	-0.07
subJ	83	0.06	0.05	**0.24**	0.04	0.18	0.14	0.07	0.03	0.19	0.12	0.16
subH	83	-0.11	0.20	0.02	0.12	0.09	0.21	0.04	0.02	0.11	0.17	0.12
JASperc	83	0.04	0.08	-0.06	0.09	-0.16	-0.04	0.04	0.03	0.03	-0.04	0.00
FASper	83	0.15	**0.34**	0.08	0.10	-0.04	0.18	0.18	0.06	0.20	0.19	0.21

Column headings are body region or composite suffixes for MDS scores.
Significant ($p < 0.05$) correlations shown in bold.

4.3.3.1.3 Type A Personality

Type A personality variables were based on scores from two instruments, the well-known Jenkins Activity Survey (JAS) and the translated Finnish scale (FAS). The JAS Type A scale (JASa) did not correlate significantly with any discomfort measures. Of the other three factors derived from the JAS, only one of them (the JASh hard-driving and competitiveness scale) correlated significantly with any discomfort measures (MDSub). The FAS Type A score correlated significantly with two upper extremity discomfort measures, MDSns and MDSub, as well as with one overall discomfort measure, MDSavgW.

4.3.3.1.4 Body Awareness (BAQ) and Kinesthetic and Proprioceptive Awareness (KPAQ)

No correlations between BAQ scores and discomfort variables were significant. This is also true for KPAQ. This may actually mean the absence of a relationship between awareness of one's body and experience of discomfort. However, several other explanations seem possible. One possible explanation for this result might be that individuals who are high in body awareness do pay more attention to their bodies and simultaneously reduce their risk of injury/discomfort while at the same time raising their awareness of any discomfort that is present (and essentially increasing the reporting of discomfort). One additional explanation involves a potential moderating role of body awareness, such that it has a different effect on discomfort experience/report for different types of individuals.

4.3.3.1.5 NEO-FFI

As expected, Neuroticism (N) correlated with many of the discomfort variables. This could be from the dispositional nature of individuals high in neuroticism to experience and/or report distress. It could also be related to some general physiological tendency to manifest anxiety in the body (e.g., through general muscle tension). This finding lends support to including a measure of this trait in further research, both for the purpose of exploring the contribution of the trait itself to outcome measures and also to allow its contribution to be extracted so that other relationships can be more accurately evaluated. An interesting result emerged when correlations were computed with repressors excluded. Only 1 (MDSavgF, correlation = 0.325, p<0.05) of the 11 correlations was significant in this case (N=58).

None of the correlations between Extraversion (E) and MDS scores were significant. Most of these correlations were very small or even negative. It is possible that extraversion offers both a protective measure (thus reducing the experience of injury) and a lower threshold for reporting pain (thus increasing the reporting of injury).

No consistent findings emerged for Openness to Experience (O) factor. Agreeableness (A) showed two significant negative correlations with MDSh and MDSlf and may offer some protective function or general reporting tendency as previously discussed.

4.3.3.1.6 Other Findings

AEQ. The Ambivalence Over Emotional Expressiveness Questionnaire (AEQ) did not correlate with any discomfort measures. **LSA**. Three factors within the Lifestyle Approaches (LSA) scale correlated with head discomfort. Many of the other correlations were very small or negative indicating that it is possible that discomfort is lower for subjects with higher self-management practices. However, LSA5 (written plans for change) correlated significantly and positively with MDSlf and MDSub. It is difficult to draw any conclusions regarding these relationships.

4.3.3.1.7 State Measures of Stressful Life Event Stress

Correlations (N=83) between the three measures of stress and discomfort scores are provided in Table 4-11. Only two correlations were significant. It seems possible that stress may not contribute to discomfort alone, but it may moderate the relationship between individual traits and the experience/reporting of discomfort.

Table 4-11. Correlations between measures of stress and discomfort.

	h	**ns**	**ae**	**lf**	**hw**	**ub**	**lb**	**hb**	**avgI**	**avgF**	**avgW**
SRRSct	-0.05	0.18	0.01	0.09	0.00	0.07	0.16	0.13	0.17	**0.29**	0.11
SRRSwt	-0.03	0.17	0.03	0.13	0.04	0.09	0.18	0.13	0.20	**0.32**	0.14
SRRSPct	-0.09	-0.06	0.00	-0.09	-0.11	-0.09	0.09	-0.05	-0.07	0.00	-0.08

Column headings are body region or composite suffixes for MDS scores.
Significant ($p < 0.05$) correlations shown in bold.

4.3.3.2 Relationships between Categorical Psychosocial Traits and Musculoskeletal Discomfort

4.3.3.2.1 Repressive Coping Style

Coping style was defined using the method described earlier. This resulted in the following groups: truly low anxious (tla), repressors (rep), high anxious (ha), defensive high anxious (dha), and middles (mid). Both high anxious groups ("ha" and "dha") were combined into a single *all high anxious* group (aha). The mean discomfort ratings for each coping style category (COPE) are presented in Figure 4-1.

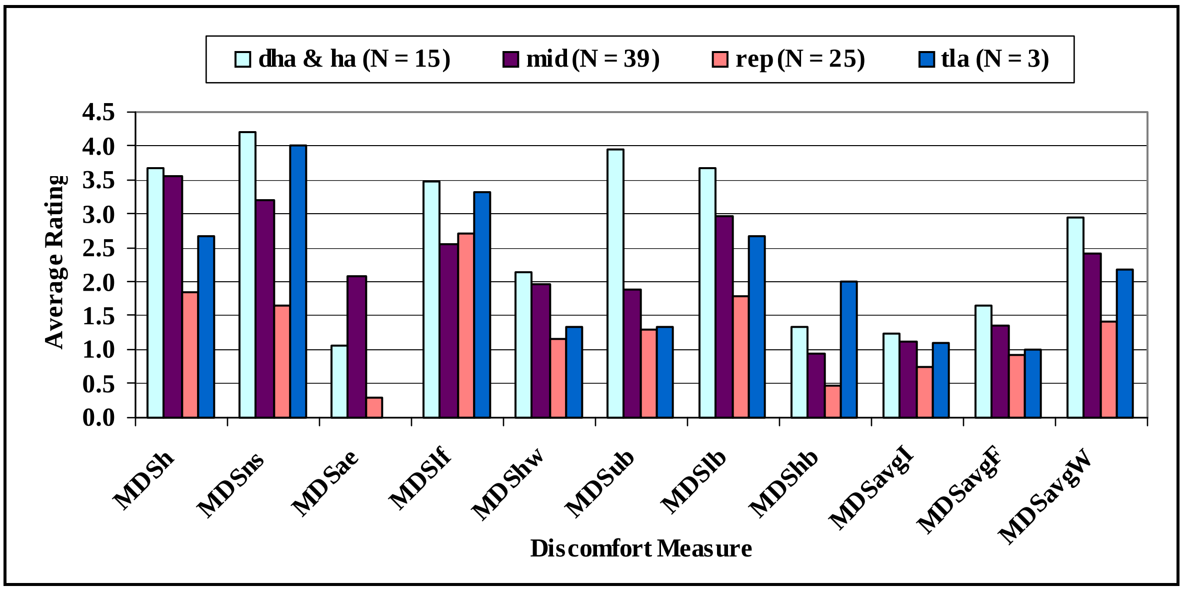


Figure 4-1. Mean discomfort reports by coping style category (COPE).

As can be seen in the figure, the trend between coping styles appears to be consistent across discomfort measures. Of the 11 MDS measures, 9 of them exhibit the same decreasing trend between the all high anxious, middle, and repressor groups. The truly low anxious group means were higher than the repressor means for all 11 MDS measures and sometimes even the highest or second highest of the four groups. This observation is based solely on the graphical representation of the mean values and not statistically evaluated here, but it does seem contrary to expectations. At least two explanations seem immediately plausible. First, the truly low anxious group only contained three subjects and it is possible that they are not representative of the "truly low anxious" population.

Second, the mean stress level measures for this group were higher than any other group, though the differences were not statistically significant. It is possible that stress moderates the relationship between stable individual differences and the experience of discomfort and contributed to this result.

To evaluate these findings statistically, a single factor (with 4 levels) analysis of variance (ANOVA) was used to examine the effect of coping style (COPE) on the dependent measures of musculoskeletal discomfort. Significant differences were found in the following relationships: MDSae (df=3, F=2.93, p=0.0387), MDSub (df=3, F=3.60, p=0.0171), MDSavgI (df=3, F=3.09, p=0.0318), MDSavgF (df=3, F=4.60, p=0.0051), and MDSavgW (df=3, F=2.90, p=0.0400). The means were examined using Tukey-Kramer adjustment for multiple comparisons to determine which means were significantly different. For MDSae, the mean rating for middles (2.10) was significantly higher than for repressors (0.28). For MDSub, the mean rating for the all high anxious group (3.93) was significantly higher than for repressors (1.28). For MDSavgI, the mean rating for the all high anxious group (1.24) was significantly higher than for repressors (0.73). For MDSavgF, the significant differences were between all high anxious (1.64) and repressors (0.92) and between middles (1.35) and repressors (0.92). For MDSavgW, the mean rating for the all high anxious group (2.93) was again significantly higher than for repressors (1.40). Due to the unequal sample sizes and the extremely low representation (N=3) of the truly low anxious group, results should be interpreted with caution. However, the trends consistently represent the "high" MDS reports by high anxious subjects and "low" reports by repressors. This may reflect individual differences in the actual experience of discomfort or "stable" reporting tendencies. Specific individuals might be less prone to discomfort or they may not report (or be able to report) it. This deserves further research focus with (1) objective measures of what the body is actually experiencing (e.g., muscle tension) that might somehow be related to the experience of musculoskeletal discomfort and (2) other measures that may reflect how these individuals vary in terms of reporting parameters associated with task performance.

4.3.3.2.2 Type A Personality

Individuals were categorized into personality types (TYPE A or B) based on scores from the Jenkins Activity Survey as previously described. The mean discomfort ratings for each personality type (TYPE) are presented in Figure 4-2.

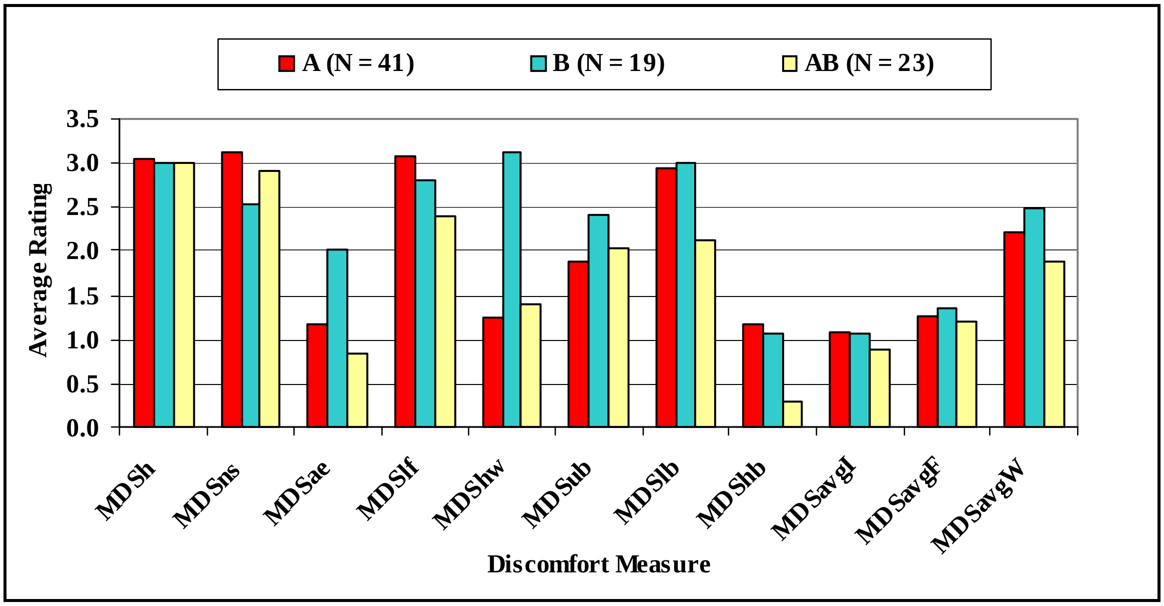


Figure 4-2. Mean discomfort ratings by personality type (TYPE).

Unlike the previous analysis of coping style, no trends were apparent regarding personality type (TYPE) and musculoskeletal discomfort. A single factor (with three levels) ANOVA confirmed this result. It is possible that there actually is no difference in the experience of musculoskeletal discomfort between individuals of different personality types. It could also be possible that personality type does contribute to the experience of musculoskeletal discomfort and injury but only after years of work. Since this subject population was rather young (mean age equal 22.3 years, N=79), the observed relationship might not adequately reflect the relationship that would exist in working age adults. One additional possibility might be that the Jenkins Activity Survey Type A scale (JASa) does not adequately measure the aspects of Type A behavior that are significant contributors to this relationship. Since the Finnish scale (FAS) did show some significant correlations with discomfort measures, it may capture some aspect of personality that is missing from the Jenkins Type A scale. Further work is required to examine both the factor structures of these two instruments that purport to measure the Type A construct and to examine their relationships to musculoskeletal discomfort.

4.3.3.3 Correlations between Musculoskeletal Discomfort Ratings

Correlations were computed between the MDS variables. These are presented in Table 4-12.

Table 4-12. Pearson correlations between musculoskeletal discomfort scores.

	h	ns	ae	lf	hw	ub	lb	hb	avgI	avgF	avgW
MDSh	-	**0.26**	**0.26**	**0.25**	**0.26**	**0.26**	0.20	-0.02	**0.53**	**0.37**	**0.53**
MDSns	**0.26**	-	**0.43**	0.15	**0.45**	**0.56**	0.15	0.19	**0.56**	**0.60**	**0.65**
MDSae	**0.26**	**0.43**	-	**0.26**	**0.63**	**0.39**	**0.22**	**0.24**	**0.56**	**0.59**	**0.68**
MDSlf	**0.25**	0.15	**0.26**	-	**0.28**	**0.33**	0.19	**0.27**	**0.47**	**0.47**	**0.56**
MDShw	**0.26**	**0.45**	**0.63**	**0.28**	-	**0.64**	**0.32**	**0.32**	**0.67**	**0.68**	**0.79**
MDSub	**0.26**	**0.56**	**0.39**	**0.33**	**0.64**	-	**0.35**	**0.42**	**0.69**	**0.71**	**0.78**
MDSlb	0.20	0.15	**0.22**	0.19	**0.32**	**0.35**	-	0.21	**0.43**	**0.50**	**0.53**
MDShb	-0.02	0.19	**0.24**	**0.27**	**0.32**	**0.42**	0.21	-	**0.52**	**0.51**	**0.47**
MDSavgI	**0.53**	**0.56**	**0.56**	**0.47**	**0.67**	**0.69**	**0.43**	**0.52**	-	**0.80**	**0.88**
MDSavgF	**0.37**	**0.60**	**0.59**	**0.47**	**0.68**	**0.71**	**0.50**	**0.51**	**0.80**	-	**0.88**
MDSavgW	**0.53**	**0.65**	**0.68**	**0.56**	**0.79**	**0.78**	**0.53**	**0.47**	**0.88**	**0.88**	-

Column headings are body region or composite suffixes for MDS scores.
Significant ($p < 0.05$) correlations shown in bold.

Several interesting results emerged from this analysis and deserve some discussion. Of 55 unique correlations, all but 6 were significant ($p<0.05$ or less). Several possible explanations seem plausible. First, this might represent a general physiological tendency within individuals to generate and experience pain throughout the body. If this explanation is accepted, then this might be accompanied by (e.g., either preceded by or resulting in) general muscle tension or other physiological response (e.g., hormonal). Second, this finding might represent a general disposition towards sensation and attribution of discomfort. Individuals may have pain threshold and signaling processes that are more similar within the individual than across individuals. They are also more likely to possess certain beliefs and attributions about pain (e.g., Is it acceptable to complain? Does it mean you're weak? Does it bring either positive or negative attention?). Third, this finding might reflect some common method variance. This is a known limitation of self-report measures and seems a little more likely in this case since all of the response scales across the eight body regions were exactly the same. However, many instruments (e.g., Likert scales) have the same response scale used across all items. Therefore, this is not considered to present any additional problem here. It is likely that all three of these explanations, among others, are contributing to the results.

Another interesting result that emerged involves the correlations between the individual body region discomfort scores and the general composite scores. The body regions that showed the highest correlations (greater than 0.60) with the composite scores were consistently "above the waist." MDShw and MDSub correlated 0.670 and 0.688 respectively with MDSavgI, the average pain intensity score. They also correlated 0.676 and 0.707 with MDSavgF, the average pain frequency score, and 0.786 and 0.781 with MDSavgW, the averaged weighted discomfort score. MDSns and MDSae correlated 0.650 and 0.684 with MDSavgW. No other correlations between composite scores and individual regions were greater than 0.60. No explanations seem immediately apparent. However, this finding does lend support to further study of physiological response (e.g., muscle tension) in the upper body and extremity in order to evaluate "general" tendencies and responses within certain types of individuals.

4.3.4 Conclusions Regarding Further Work

4.3.4.1 Constructs

Coping style appears to be independent of personality type. However, it may be a difficult construct to explore. Some of the coping style categories may be too scarce to allow enough subjects to be recruited in each category. This might result in insufficient statistical power for testing hypotheses related to the coping style construct.

4.3.4.2 Procedure

Subjects should be pre-tested if only extremes within the domains of personality type and/or coping style will be used in the data analysis in order to prevent potentially large numbers of subjects to be unnecessarily tested in the laboratory.

4.3.4.3 Instruments

Type A personality. The Jenkins Activity Survey should be used to measure Type A behavior. Though it did not correlate with any discomfort measures, it is a well-known instrument for measuring Type A behavior and it has known reliability. Its predictions for extreme ends of the behavior have been shown to correlate well with structured interview (Jenkins et al., 1979). It also showed no significant correlation with neuroticism.

The FAS should be administered and used with caution because of (1) the lack of published reliability information for the scale, (2) its correlation with neuroticism, and (3) its tendency to potentially "over predict" Type A behavior. However, it did show significant correlations with three discomfort measures and it has been reported in two occupational studies to be a significant factor in experience of musculoskeletal discomfort. No results indicate any advantages to using the 9-item Caplan (KAS) scale over the other measures of Type A personality. This scale correlated negatively with neuroticism and did not correlate at all with the JAS Type A scale. If time is limited, the reduced subset of items for the JAS Speed and Impatience, Job Involvement, and Hard Driving and Competitiveness scales can be administered. Further efforts should include additional analysis of the factor structures of the JAS and the FAS.

Coping style. Coping style should be measured with the BMAS and the MCSDS. None of the results indicate any overwhelming reason to pursue the Ambivalence Over Emotional Expressiveness Questionnaire (AEQ) as an alternative to measuring the repressive coping style construct with the method established by Weinberger et al. (1979).

Kinesthetic and Proprioceptive Awareness Questionnaire (KPAQ). The 12-item Kinesthetic and Proprioceptive Awareness Questionnaire (KPAQ) was developed for this study. This original version demonstrated convergent validity, discriminant validity, and good internal consistency and shows promise for further development. Future efforts should be made to (1) identify sub-factors that may be present and (2) eliminate/modify items.

Body Awareness Questionnaire (BAQ). None of the results contradict or support use of this scale in future work. However, since the Kinesthetic and Proprioceptive Questionnaire must demonstrate convergent validity, it may be useful to administer this published scale to use for comparing the modified KPAQ. Additionally, future efforts should attempt to identify whether body awareness offers a protective benefit (e.g., making one more aware of potential injury) and/or an increased awareness and reporting of discomfort.

NEO-FFI. Selected scales from the "big-five" NEO-FFI may be of significant interest in further work. Measuring Neuroticism will offer the possibility of factoring out the contribution of this tendency to experience distress from other self-report measures. Since the neuroticism factor correlated quite significantly with the BMAS scale, it might be sufficient to use the BMAS to "measure" neuroticism. However, because the NEO is widely used and purports to measure the five basic dimensions of personality, this scale should be administered if time permits. Extraversion should be measured because it may impact both experience of discomfort and reporting of discomfort and to compare with other recent laboratory findings regarding introverts and extraverts. Agreeableness and Conscientiousness should be explored further due to their potential positive effect on the experience/reporting of discomfort.

LSA. Results do not provide overwhelming reasons to administer the Lifestyle Approaches (LSA) scale in its entirety. However, selected factors (LSA5 and LSA6) may be measuring unique constructs, one of which correlated with discomfort. These could be administered if time permits.

4.3.4.4 Discomfort Measures

Most of the significant findings regarding psychosocial traits and discomfort measures involved the upper extremity, neck/shoulder, and upper back. These also showed the highest correlations with the overall composite measures of discomfort. These may reflect a general experience of discomfort across body regions. Further work should focus on these areas of the body in order to explore the relationship between psychosocial traits, discomfort, and objective indicators (e.g., muscle tension/activity) that might be related to discomfort.

5. RESEARCH FOCUS AND GENERAL DESIGN

The previously described findings warranted further investigation into the specific effects of individual psychosocial characteristics on biomechanical indicators typically believed to be significant factors in the occupational injury process. Individuals may perform the same tasks differently as indicated by directly observable "external" measures and "internal" responses of task performance. Certain psychosocial aspects of the task (e.g., time pressure, controllability, frustration) may moderate the relationship between individual traits and biomechanical response. Individuals may also report different levels of discomfort, which may be reflective of general tendencies and/or may result from performing the task.

The remaining phases of this study were designed to explore some of these issues. This involved formulation of hypotheses, methods, and tasks to specifically explore the effects of personality type on direct biomechanical measures of task performance under varying conditions of psychosocial stress. Personality type would be defined as the primary independent variable. Subjects would be pre-tested, recruited, and assigned accordingly. Each experiment would also include an independent variable that represented a psychosocially imposed stress nature of the task. Dependent variables to evaluate externally observable workstyle would include measures of performance times and wrist motion kinematics. Dependent variables to evaluate aspects of the internally experienced physiological response of muscle tension would include measures of electromyography. Dependent measures would also include self-report indicators of discomfort and state anxiety. Specific hypotheses were formed containing these variables. The study would be conducted in the following three separate phases: (1) pre-testing for specific psychosocial attributes and selected criteria, (2) a laboratory-based assembly experiment to explore wrist motion kinematics and performance, and (3) a laboratory-based upper extremity experiment to explore muscle tension/activity and performance. The general research hypotheses and experimental design are described in this section. This section also provides references to the specific questions that are explored in each of the remaining experimental phases of the study. The details of each of these phases are described in individual sections that follow this section.

5.1 DESIGN

Each of the laboratory experiments was conducted using a mixed design. The psychosocial trait of personality type was the primary between-subjects variable. Potential subjects were pre-tested and classified into "levels" of the personality type variable based on their scores. Each laboratory task also included a within-subjects independent variable representing the psychosocially imposed "stress" nature of the task. This STRESS variable was included specifically to (1) evaluate the feasibility of manipulating the stressful nature of the task in the laboratory and (2) explore how individuals of different characteristics might respond under certain potentially stressful conditions.

Due to the exploratory nature of this area of research, the experiments also included administration of surveys and collection of some data that were not critical to achieving the primary objectives. This was considered desirable for exploring some secondary research questions. The collection of these pieces of information will be described in the specific methods contained in this manuscript. However, the analyses and results contain only those related to the primary objectives.

5.2 TASKS

The laboratory tasks were designed specifically to explore the effects of the independent variables on workstyle, muscle tension/activity, and self-report measures of discomfort/anxiety. The first study involved a gross assembly task. The major focus of designing this study was to explore observable indicators of workstyle. The second study involved fine motor tasks including a pipetting task and a computer data entry task. The major focus of this study was to explore electromyographic aspects of muscle tension. Each of the studies included methods for exploring externally observable measures of workstyle that might be reflected in task performance (e.g., performance times). Each of the studies was also designed to allow evaluation of hypotheses related to reporting of perceived discomfort and perceived state anxiety.

5.3 INDEPENDENT VARIABLES

The primary independent variables were the between-subjects psychosocial trait of personality type (TYPE) and the within-subjects variable representing the psychosocially imposed stress (STRESS) associated with the task. Additional between-subjects independent variables included gender (GENDER) and stress condition order (ORDER) which defined whether the subject performed the stress or no-stress condition first. An additional independent variable (SURVEY) represented the specific administration during each experiment of the discomfort and anxiety surveys (e.g., which of 5 administrations during the Phase II experimental session or which of 7 administrations during the Phase III experimental session). Table 5-1 provides a list of each independent variable, its levels, and the task where it appears.

Table 5-1. Cross-reference between independent measures and associated experimental tasks

Independent Variable	Label	Levels	Phase II Gross Assembly Task	Phase III Pipetting Task	Phase III Computer Entry Task
Personality type	TYPE	A – Type A B – Type B	X	X	X
Gender	GENDER	M – Male F – Female	X	X	X
Stress condition order	ORDER	1 – no-stress then stress 2 – stress then no-stress	X	X	X
Psychosocially imposed time stress	STRESS	N – no stress S – stress	X	X	
Psychosocially imposed frustration stress	STRESS	N – no stress S – stress			X
Specific Discomfort or Anxiety Survey	SURVEY	1, 2, 3N, 3S, 4	X		
Specific Discomfort or Anxiety Survey	SURVEY	1, 2, 3pN, 3pS, 3cN, 3cS, 4		X	X
Shaded cells represent "between-subjects" variables.					

5.4 DEPENDENT VARIABLES

The dependent variables in the study were established to measure some aspect(s) of the overall constructs of (1) externally observable workstyle, (2) internally experienced muscle tension, (3) perceived discomfort, and (4) perceived state anxiety. The specific dependent variables that were explored in each laboratory task are shown in Table 5-2. These are described in detail in the specific sections describing the experiments.

Table 5-2. Cross-reference between dependent measures and associated experiments

Dependent Measure	Overall Construct	Phase II Gross Assembly Task	Phase III Pipetting Task	Phase III Computer Entry Task
Wrist kinematics	workstyle	X		
Electromyographic measures	muscle tension		X	X
Performance time	workstyle	X	X	X
Perceived discomfort	reporting behavior	X	X	X
Perceived state anxiety	reporting behavior	X	X	X

5.5 STATISTICAL MODELS AND ANALYSES

5.5.1 General Description

All statistical analysis was performed using The SAS System for Windows, Release 8.01. Analysis of Variance (ANOVA) procedures were used to test for significant differences between levels of the independent variables for each dependent variable. The specific statistical models are described in detail in the following sections.

5.5.2 Model #1 - Evaluating the Effects of TYPE, GENDER, ORDER, and STRESS on Workstyle, Muscle Tension, and Discomfort/Anxiety Reporting Behaviors

The statistical model for evaluating the effects of the primary independent variables on dependent measures associated with workstyle, muscle tension, and reporting behaviors is described here. The model includes three between-subjects variables (TYPE, GENDER, and ORDER), one within-subjects variable (STRESS), and all possible interactions. The model also includes two error terms – one associated with the between-subjects effects (errorB $_{ijkl}$) and one associated with the within-subjects effects (errorW$_{ijklm}$). The various dependent variables were represented in separate analyses as y_{ijklm} in the following linear model:

Model #1: $y_{ijklm} = \mu + TYPE_i + GENDER_j + ORDER_k +$

$+ (TYPE \times GENDER)_{ij} + (TYPE \times ORDER)_{ik} + (GENDER \times ORDER)_{jk} +$

$+ (TYPE \times GENDER \times ORDER)_{ijk}$

$+ errorB_{ijkl}$

$+ STRESS_m + (TYPE \times STRESS)_{im} + (GENDER \times STRESS)_{jm} + (ORDER \times STRESS)_{km}$

$+ (TYPE \times GENDER \times STRESS)_{ijm} + (TYPE \times ORDER \times STRESS)_{ikm}$

$+ (GENDER \times ORDER \times STRESS)_{jkm} + (TYPE \times GENDER \times ORDER \times STRESS)_{ijkm}$

$+ errorW_{ijklm}$

Due to the mixed design (i.e., containing both between-subjects and within-subjects independent variables), separate error terms were required in the linear model. All between-subjects effects (e.g., any main or interaction effects comprised only of TYPE, GENDER, and/or ORDER) were tested using the $errorB_{ijkl}$ error term. All within-subjects effects (e.g., any terms consisting of the STRESS term) were tested using the $errorW_{ijklm}$ error term. All analyses using this model were performed using the PROC MIXED procedure in SAS. Using this procedure, fixed effects were included in the MODEL statement and random effects (i.e., related to "subject") were included in the RANDOM statement. The PROC MIXED procedure generated the appropriate error terms for testing all specified effects and accommodated for unbalanced cell sizes. The results of the PROC MIXED analyses were verified for selected data having balanced cell sizes using PROC GLM. Using this procedure, the model was completely specified to include "subject" terms in the MODEL statement. Error terms for testing each effect were specified in separate TEST statements. All between-subjects effects were tested using the subject(TYPE*GENDER*ORDER) term. All within-subjects effects were tested using the STRESS*subject(TYPE*GENDER*ORDER) term.

Since the independent variables each only had two levels, post-hoc comparison tests were not required to examine specific differences between a given dependent variable's group means for each level of the independent variable. To examine the nature of significant interactions, tests of simple effects were obtained by formulating F-tests on partitioned LSMEANS effects for each independent variable (using the SLICE option on the LSMEANS statement in PROC MIXED in SAS).

5.5.3 Model #2 - Evaluating the Potential for Confounding between Groups

This model was employed to evaluate potential confounding explanations of anthropometry differences between groups that may have resulted due to a failure of randomization to produce groups with no differences. The primary statistical model for evaluating the effects of the independent variables on the subject anthropometry dependent variables included the three between-subjects variables (TYPE, GENDER, and ORDER) and all interactions. The various dependent variables were represented in separate analyses as y_{ijkl} in the following linear model:

Model #2: $y_{ijkl} = \mu + TYPE_i + GENDER_j + ORDER_k +$

$+ (TYPE \times GENDER)_{ij} + (TYPE \times ORDER)_{ik} + (GENDER \times ORDER)_{jk} +$

$+ (TYPE \times GENDER \times ORDER)_{ijk} + \varepsilon_{ijkl}$

All analyses using this model were performed using the PROC GLM procedure in SAS. All main and interaction effects were tested using the model-generated error term, ε_{ijkl}. Since the independent variables each only had two levels, post-hoc comparison tests were not required to examine specific differences between a given dependent variable's group means for each level of the independent variable. The nature of significant interactions was not evaluated since this analysis was not related to specific testing of any pre-specified hypotheses.

5.5.4 Verification of Analysis of Variance (ANOVA) Assumptions

The assumptions require that the model residuals be normally and independently distributed with a mean of zero and a constant variance. Selected data were tested for compliance with assumptions underlying the Analysis of Variance (ANOVA) procedures. These evaluations are described in Appendix 13.9.

5.6 EXPERIMENTAL HYPOTHESES

Each of the experimental tasks was designed specifically to explore one or more primary hypotheses related to the effects of personality type (TYPE) and stress (STRESS) on the general constructs of workstyle, muscle tension, and discomfort/anxiety reporting behaviors. These hypotheses are outlined in Table 5-3 and described in the section following the table.

Table 5-3. General hypotheses explored in each experimental task.

Hypothesis	Independent Variable	Dependent Variable	Phase II Gross Assembly Task	Phase III Pipetting Task	Phase III Computer Entry Task
(H1)	**TYPE**	*workstyle* performance time	X	X	X
(H2)	**TYPE**	*workstyle* wrist motion kinematics	X		
(H3)	**TYPE**	*physiological response* muscle tension		X	X
(H4)	**TYPE**	*reporting behaviors* discomfort	X	X	X
(H5)	**TYPE**	*reporting behaviors* state anxiety	X	X	X
(H6a) – (H10a)	**time STRESS**	as above for (H1) through (H5)			
(H6b) – (H10b)	**frustration STRESS**	as above for (H1) through (H5), except (H2)			
(H11) specified	**STRESS x TYPE**	as above for (H1) thru (H5)			
none specified	**GENDER & ORDER**	as above for (H1) thru (H5)			

5.6.1 Main Effects of TYPE: Hypotheses (1) through (5)

(H1) **Aim**: Investigate the main effect of personality type (TYPE) on observable workstyle task performance parameters (e.g., speed) during a variety of occupationally-simulated free dynamic task(s).

Hypothesis: It is hypothesized that Type A individuals will demonstrate faster workstyles than Type B individuals as represented by task performance times.

H$_o$: Dependent Variables (y_{ijklm} = performance times) will be equal for TYPE A and B groups.

Model: Model #1

(H2) **Aim**: Investigate the main effect of personality type (TYPE) on observable workstyle body segment motion parameters during an occupationally-simulated assembly task.

Hypothesis: It is hypothesized that Type A individuals will demonstrate faster, more accelerated, and more deviated wrist motions than Type B individuals.

H$_o$: Dependent Variables (y_{ijklm} = 12 wrist kinematics parameters and 8 wrist range of motion parameters) will be equal for TYPE A and B groups.

Model: Model #1

(H3) **Aim**: Investigate the main effect of personality type (TYPE) on internal physiological response of muscle activity during a variety of occupationally-simulated fine motor control tasks.

Hypothesis: It is hypothesized that Type A individuals will demonstrate higher muscle activity levels than Type B individuals.

H$_o$: Dependent Variables (y_{ijklm} = normalized electromyographic activity for each of 10 muscles) will be equal for TYPE A and B groups.

Model: Model #1

(H4) **Aim**: Investigate the main effect of personality type (TYPE) on subjective measures of musculoskeletal discomfort during a variety of occupationally-simulated free-dynamic tasks.

Hypothesis: It is hypothesized that Type A individuals will report lower levels of discomfort than Type B individuals.

H_o: Dependent Variables (y_{ijklm} = discomfort ratings) will be equal for TYPE A and B groups.

Model: Model #1

(H5) **Aim**: Investigate the main effect of personality type (TYPE) on subjective measures of anxiety during a variety of occupationally-simulated free-dynamic tasks.

Hypothesis: It is hypothesized that Type A individuals will report lower levels of anxiety than Type B individuals.

H_o: Dependent Variables (y_{ijklm} = state anxiety ratings) will be equal for TYPE A and B groups.

Model: Model #1

5.6.2 Main Effects of STRESS: Hypotheses (6a/b) through (10a/b)

Aims: Investigate the main effect of psychosocial task stress (STRESS) on all dependent measures (as described in each of the "aims" for main effect of TYPE).

Hypotheses: It is hypothesized that performance times (H6a) and wrist motions (H7) will be faster under conditions where time stress is imposed. It is hypothesized that performance times (H6b) will be slower when psychosocially-imposed frustration stress is imposed. It is hypothesized that muscle activity will increase during both the time (H8a) and frustration (H8b) stress conditions. It is hypothesized that self-reported discomfort will increase for both the time (H9a) and frustration (H9b) stress conditions. It is hypothesized that self-reported state anxiety will increase for both the time (H10a) and frustration (H10b) stress conditions.

H_o: Dependent Variables will be equal between the stressed (S) and non-stressed (N) conditions.

Model: Model #1

5.6.3 Interactive Effects of STRESS x TYPE: Hypotheses (11a/b)

Aims: Investigate the interactive effect of psychosocial task STRESS and personality type (TYPE) on all dependent measures (as described in each of the "aims" for main effect of TYPE).

Hypotheses: It is hypothesized that muscle activity will increase during the stressed condition more so for Type A subjects than for Type B subjects (H11a/b). No specific hypotheses are formulated regarding task performance times, wrist motion kinematics, self-reported discomfort, or self-reported anxiety.

H_o: Dependent Variables will be equal between all STRESS x TYPE conditions.

Model: Model #1

5.7 PROCEDURE AND TIME LINE

The study was conducted to include a pre-testing phase and two laboratory studies (Phase II and Phase III). The pre-testing phase involved numerous sessions to administer the surveys, scoring of the surveys, notification of eligible subjects, and scheduling of laboratory participants. The general time frame for completing the pre-testing and the laboratory sessions is provided in Table 5-4.

Table 5-4. Schedule for completing pre-testing and Phase II and III laboratory experiments.

	2001					2002			
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Pre-testing sessions									
N = 92 (3 Sep – 15 Sep)	xxxxx								
N = 10 (5 Feb – 15 Mar)						xxxxxxxxxx			
Notification/scheduling Phase II (15 Sep – 15 Nov)		xxxxxxxxxxxxxx							
Phase II laboratory sessions (26 Oct – 15 Nov)			xxxxxx						
Notification/scheduling Phase III (20 Oct – 10 Dec)			xxxxxxxxxxxxx						
Phase III laboratory sessions									
(28 Nov – 13 Dec)				xxxxxx					
(25 Feb – 20 Apr)							xxxxxxxxxxxxxx		

6. PRE-TESTING FOR SPECIFIC PSYCHOSOCIAL ATTRIBUTES

6.1 OBJECTIVES

Based on the previously described results of the initial phase of this study, pre-testing was conducted in order to score, select, and assign participants of specific attributes for the laboratory experiments. Although a number of surveys were administered during this pre-testing phase, only scores from the modified Jenkins Activity were used in categorization and selection of subjects for the remaining laboratory experiments. Administration of multiple survey instruments supported additional objectives of (1) allowing for further evaluation of the feasibility of including other attributes in this type of study and (2) providing a data set for use in future exploration of secondary research questions.

6.2 METHOD

6.2.1 Participants

Subjects (N = 102) from an introductory psychology course were pre-tested by administering a battery of self-report surveys. Most of the participants (N = 92) were tested during the Fall 2001 semester. A small number (N = 10) were tested during the following Spring 2002 semester. Subjects were recruited via a combination of written sign-up sheets and web-based sign-up procedures. All subjects participated voluntarily and received research credits for their participation.

6.2.2 Survey Instruments

A fixed set of self-report surveys was administered in paper form. Questions from all of the instruments were combined and renumbered consecutively into a single, continuously numbered order. The specific surveys administered during the pre-testing session included the following: a slightly modified version of the 52-item Jenkins Activity Survey (JAS), the 16-item Finnish Type A Scale (FAS: Wickström et al., 1989), the 20-item Bendig Short Form Manifest Anxiety Scale (BMAS: Bendig, 1956), the 33-item Marlowe-Crowne Social Desirability Scale (MCSDS: Crowne & Marlowe, 1964), the 18-item Body Awareness Questionnaire (BAQ: Shields et al., 1989), and the 12-item baseline Kinesthetic and Proprioceptive Awareness Questionnaire (KPAQ) developed for this study.

Each of the survey instruments was briefly described earlier for the Phase I study. However, since the Jenkins Activity Survey was modified slightly and was the only survey used to select participants, it will be described in more detail here.

6.2.2.1 Jenkins Activity Survey (JAS)

Personality type was assessed using a slightly revised version of the Jenkins Activity Survey Form C (Jenkins et al., 1979). This is a 52-item forced-response survey that asks questions about behavioral tendencies such as "When you are under pressure or stress, what do you usually do?" (question #5) and "Would people who know you well agree that you tend to do most things in a hurry?" (question #23). Response formats vary between questions in wording and number of response options (which varies from 2 to 8). For example, responses for the previous example question #5 are "Do something about it immediately" and "Plan carefully before taking any action." Responses for question #23 are "Definitely yes," Probably yes," "Probably no," and "Definitely no." Form C is intended for adult working populations. The 21-item Form T (Glass, 1977) is intended for student populations, and certain job-specific questions from Form C are modified on Form T to address student-specific behaviors instead. For this study, the Form C version was slightly revised to include wording that applies to both job-related and student-related activities (by adding Form T wording where appropriate). This slightly reworded version allowed the same instrument and scoring methods to be used for all subjects and allowed scores to be computed for subscale factors of the JAS.

The survey generates scores on four subscales including Type A personality (A), Speed and Impatience (S), Hard Driving and Competitiveness (H), and Job Involvement (J). Some items overlap between subscales. Internal consistency reliability coefficients have been estimated for the Type A subscale to be 0.83 to 0.85. Test-retest reliability coefficients range from 0.66 to 0.76.

The Type A subscale raw score was converted to a standardized score that corresponds to a percentile value associated with a normative population. The percentile score ranges on a continuum from 0 to 100 with 0 signifying the most B-type personality and 100 signifying the most A-type personality. The subjects were selected from two "extreme" scoring groups in order to increase the reliability of the measure's assessment. The B level group consisted of those subjects scoring from 0 to 35 on the JAS percentile scale. The A level group consisted of those subjects falling into the 65 to 100 percentile range.

6.2.3 Procedure

Introductory psychology students volunteered for group testing sessions using standard signup sheets or web-based signup procedures. Nineteen pre-testing sessions were conducted over portions of two semesters in order to pre-test the required number of subjects. During these sessions, subjects provided their signed consent to participate in the pre-testing phase of this study and then completed the survey instruments. Subjects documented their responses to the survey questions on standard 5-item OPSCAN sheets. Subjects also responded to a question regarding their willingness to be contacted for participation in the laboratory portion of this experiment. Those who were willing to be contacted were asked to provide their contact information. Subjects were also asked to provide information about any significant history of injury in specific body regions, the presence of skin allergies/sensitivities, and native language.

6.2.4 Data Analysis

The OPSCAN sheets were electronically read into a text file for 92 subjects. The sheets for 10 subjects were entered into a file by hand. Scores were computed from these data files using previously described automated C programs and output to a file. The results were used to generate a list of participants who were eligible for the laboratory studies. Eligible subjects were considered to be those who (1) were willing to be contacted and provided contact information, (2) had no significant injury that would preclude their participation, (3) had no significant skin sensitivities or allergies that would preclude their participation, and (4) scored as personality Type A or B based on the Jenkins Activity Survey. All scoring results (e.g., personality type) were maintained on a list that contained each participant's uniquely generated identification number. This number was also included on another list that contained only the participant's name, contact information, and participation status (e.g., notified but waiting for response, declined participation, scheduled, completed, etc.). This was done to ensure confidentiality of responses and to ensure that participants were recruited and assigned to experimental conditions such that their personality type remained unknown to the experimenter. Scores on all instruments also remained unknown to the subjects.

Subject scheduling to ensure the double-blind status was accomplished by maintaining the two previously described lists and a separate third list. Task condition sequences for all required experimental sessions were generated on the third list. Each sequence was assigned gender and personality type combinations to meet counterbalancing requirements. The list was then randomly sorted. Eligible subjects were added to this list by unique identification number using the first list of attribute information. An automated macro was created to use the experimental session list and the second list to generate a new list of subjects by name and task sequence, with attribute information hidden. These subjects were then contacted for participation. Those subjects that would not or could not participate were removed from the experimental session list. Those slots were filled with new unique identification numbers for eligible subjects. This procedure was repeated until all experimental sessions (i.e., gender by personality type by task sequence combinations) were scheduled.

6.3 RESULTS

6.3.1 Subject Demographics

Demographic information for the pre-tested subjects is contained in Table 6-1.

Table 6-1 - Phase II Pre-testing - Subject Demographic Information

Subject Demographics (total N = 102)			
	N		**N**
Gender		**Student status**	
Male	47	Full-time	95
Female	55	Part-time	3
		Not a student	2
		missing	2
Race			
White/Caucasian	82	**Work status**	
Black/African-American	5	Full-time	4
Hispanic	4	Part-time	41
Other	9	Does not work	52
missing	2	missing	5

6.4 CONCLUSIONS

One fundamental objective of this research effort was to determine the feasibility of investigating various psychosocial traits in laboratory-based biomechanical studies. Two specific components of meeting this objective involved (1) determining the distributions of traits in the population of interest and (2) exploring the potential overlap between trait constructs (e.g., between the two traits of personality type and coping style). Though not described here, the pre-testing phase yielded the opportunity to better explore certain questions related to the feasibility of investigating the constructs of personality type and coping style in similar studies. By combining the results of the initial Phase I study with the results obtained during the pre-testing phase, the sample size was increased for exploring the distribution and overlap of these constructs in the studied population. This again confirmed that personality type and coping style, as measured here, appear to be different constructs. It also revealed difficulties associated with exploring the construct of coping style categories (e.g., due to low representation of some required categories). However, categorization by personality type yielded fairly even distribution among the three categories.

The main objective of the pre-testing phase was to recruit subjects of specific personality types for the laboratory experiments. This effort yielded a list of eligible subjects who could be contacted for voluntary participation in those experiments. All of the eligible subjects were contacted via email for subsequent participation in the laboratory experiments. All individual psychosocial attribute information remained unknown to the experimenter until the individual completed the assigned laboratory experiment.

7. PHASE II – LABORATORY-BASED EXPERIMENT TO INVESTIGATE WRIST KINEMATICS AND PERFROMANCE DURING ASSEMBLY

7.1 SPECIFIC STUDY ABSTRACT

Psychosocial factors are becoming increasingly more prevalent in studies that explore occupational musculoskeletal injury/illness. The research presented here explores the relationships between two psychosocial factors and externally observable biomechanical indicators of task performance, or workstyle. The psychosocial factors included (1) personality type, a trait measure of the individual and (2) time stress, a state measure of the environment. Twenty-four subjects participated in this laboratory study. Personality type was assessed prior to the study using a slightly modified version of the Jenkins Activity Survey Form C. Individuals were categorized as personality Type A, B, or AB based on their scores. Eligible Type A and B individuals were contacted for participation in this study. Each subject's personality type was unknown to the experimenter and to the subject.

Twenty-four participants (12 Type A and 12 Type B) performed an assembly task under verbally imposed "no time stress" and "time stress" conditions. The order of these conditions was perfectly counterbalanced across subjects by gender and personality type. Between-subjects independent variables included personality type, gender, and stress condition order. The within-subjects independent variable represented the stress condition. Dependent measures included performance times, wrist motion parameters, and self-report indicators of discomfort and state anxiety.

Personality type and time stress demonstrated significant effects on mean performance times. Type A individuals demonstrated 12 – 14% faster performance times than Type B individuals. Performance times were 11 – 18% faster under the "time stress" condition than under the "no time stress" condition. Time stress also significantly and consistently impacted the wrist motion parameters while personality type did not. The effects of personality type on discomfort and anxiety reports were limited to females.

Both trait and state psychosocial factors were found to directly impact the biomechanical indicators of task performance that were evaluated in this study. This study demonstrates the

feasibility of this laboratory-based approach to explore the relationships between psychosocial factors and biomechanical indicators of task performance.

7.2 BRIEF REVISIT TO SPECIFIC INTRODUCTORY CONCEPTS

Occupational musculoskeletal injuries/illnesses are a major problem for industry. Some task-related risk factors (e.g., high force, awkward postures, excessive repetition) are well understood and accepted as targets for ergonomic interventions. Still, situations exist where individuals become injured in the same or similar jobs where other individuals do not. This poses the question of whether there are characteristics of individuals that may put them at risk. One area that is receiving increased attention is the possible roles that psychosocial factors may play in the injury process.

Psychosocial factors are those characteristics of the worker, work environment or home life that may influence the response of the worker to the demands of the workplace. The research presented here focuses on efforts to explore the relationship between psychosocial factors and workstyle. Workstyle represents "how the individual worker approaches work" (Feuerstein, 1996) and is characterized by "an individual pattern of cognitions, behaviors, and physiological reactivity that co-occur while performing job tasks" (p. 179). The current study limits its scope to the behavioral aspect of workstyle and includes measurable indicators of the individual's approach to work such as task performance times and aspects of posture and movement.

With this definition of workstyle, it seems likely that both stable traits of individuals and transient states associated with their environments might be of interest. For example, individuals who are characterized as having Type A personalities may demonstrate faster workstyle behavior patterns. The Type A behavior pattern is characterized by extremes of competitiveness, high performance standards, time urgency, impatience, and hurried motor and speech patterns. Specific support of its possible relationship with workstyle can be seen in observations that Type A individuals experience "more frequent tense, hyperactive movements (Sparacino, 1979, p. 46), "vigorous … psychomotor mannerisms" (Dembroski et al., 1979, p. 28), and "hurried motor movement" (Jenkins et al., 1971, p. 194). Wickström et al. (1989) hypothesized that their findings of back pain in Type A workers might be related to tissue trauma resulting from Type A workers being "more prone to use all their strength than the less competitive type B workers" (p. 203).

Though the relationship between such personality traits and actual injury can only be inferred at best, it does seem plausible that certain individuals might demonstrate workstyle characteristics that are thought to be associated with a higher risk of injury. One way to approach this research area is to utilize a laboratory-based study to explore potential relationships between psychosocial attributes and biomechanical indicators of task performance as demonstrated in a previous study that looked at personality type and muscle activity during a controlled exertion (Glasscock et al., 1999). The purpose of the present study was to explore the relationships between personality type and other biomechanical indicators of task performance during more realistic task scenarios. Specifically, this study investigated the effect of specific characteristics of subjects (e.g., personality type and gender) on workstyle as measured by performance time and wrist motion kinematics during a laboratory-simulated assembly task under varying conditions of psychosocially-imposed time stress. Since self-report measures are often used to "measure" the presence of potential injury indicators (e.g., discomfort) and feelings of stress/anxiety, this study also investigated the effects of the subject characteristics on general discomfort/anxiety reporting behaviors and specific reporting responses under the various stress conditions.

7.3 METHOD

7.3.1 Experimental Design

7.3.1.1 Design

This experiment was conducted using a mixed design containing both between-subjects independent variables and within-subjects independent variables.

7.3.1.2 Independent variables

The between-subjects independent variables in this study were the individual's personality type (TYPE: levels A and B), gender (GENDER: levels Female and Male), and stress condition order (ORDER: levels 1 and 2). Personality TYPE was determined using scores from the Jenkins Activity Survey (JAS) Form C (Jenkins et al., 1979). Using scores from this survey, subjects were categorized as having either Type A or B personalities. Raw scores were converted to population percentiles (Jenkins et al., 1979). Subjects scoring 35th percentile or below were categorized as Type B and those scoring 65th percentile or above were categorized as Type A. The resulting personality type category remained unknown to the experimenter and the subject.

ORDER indicated the order in which the participants performed the task stress conditions. For the order 1 condition, subjects performed the no-stress condition first followed by the stress condition. For the order 2 condition, subjects performed the stress condition first followed by the no-stress condition. Equal numbers of subjects of each TYPE x GENDER combination were randomly assigned to each ORDER condition. The within-subjects independent variable described the time stress condition (STRESS: levels N and S). The no-stress (N) condition was invoked by administering the following verbal script to the subject prior to beginning the task: "During this task you will be disassembling and assembling this reciprocating saw, just like you practiced. Assume that you are performing this task in a factory on an *ordinary* workday. Perform the task at a pace that you would feel comfortable if you had to perform the task for 8 hours. Continue to perform the task until I tell you to stop." Likewise, the time stress (S) condition was invoked with the following change in script: "… Assume that you are performing this task in a factory on an *accelerated-production* workday. Perform the task *as quickly as you can to meet today's production needs*. Continue to perform the task *as quickly as you can* until I tell you to stop." Each subject performed each of the time stress conditions for 15 minutes.

This study also included an independent variable, SURVEY, representing the specific point in time of administration for the discomfort and anxiety surveys. These surveys were administered five separate times during the experimental session. The levels of survey administration (SURVEY) were as follows:

1 – first time, directly following consent form signing

2 – second time, directly following training

3N – third or fourth time depending on task order, directly following "no-stress" condition

3S – third or fourth time depending on task order, directly following "stress" condition

4 – fifth time, end of experiment but prior to debriefing

7.3.1.3 Dependent variables

The dependent variables in this study included measures for evaluating the constructs of (1) biomechanical workstyle, (2) discomfort and anxiety reporting behaviors, and (3) subject physical traits. Workstyle was represented by wrist motion kinematics and performance time. Wrist motion kinematic parameters were mean angular positions (degrees), velocities (degrees/second) and accelerations (degrees/ second^2) of both hands and wrists. Angular positions reflected values obtained from both positive and negative data (with this indicated by an "n" beginning the variable name). Velocities and accelerations reflected values that were obtained from the absolute values of the data (with this indicated by an "a" beginning the variable name). The wrist motion dependent variables included left and right radial/ulnar position (nLRUpos and nRRUpos), velocity (aLRUvel and aRRUvel), acceleration (aLRUacc and aRRUacc), range of motion (romLRU and romRRU), and normalized range of motion (nromLRU and nromRRU) as well as left and right flexion/extension position (nLFEpos and nRFEpos), velocity (aLFEvel and aRFEvel), acceleration (aLFEacc and aRFEacc), range of motion (romLFE and romRFE), and normalized range of motion (nromLFE and nromRFE). Performance was measured by mean assembly time per unit (avgASSYtpu) and mean disassembly time per unit (avgDIStpu). Reporting behaviors were represented by measures of self-reported state anxiety and musculoskeletal discomfort. State anxiety was measured as a single score (ANXtot). Discomfort measures included composite scores representing average overall discomfort (MDSavg), average upper extremity discomfort (MDSupx), and average back discomfort (MDSbak). Physical traits included 17 measurements of anthropometry.

7.3.1.4 Specific Hypotheses

Several governing hypotheses were formulated for this specific study as described in Section 5.6. The following specific hypotheses relating to personality TYPE were formulated for this experiment:

- **H1**: It was hypothesized that Type A individuals would demonstrate faster workstyles than Type B individuals as represented by task performance times.
- **H2**: It was hypothesized that Type A individuals would demonstrate faster, more accelerated, and more deviated motions than Type B individuals.

- **H4**: It was hypothesized that Type A individuals would report lower levels of self-reported discomfort than Type B individuals.
- **H5**: It was hypothesized that Type A individuals would report lower levels of self-reported state anxiety than Type B individuals.

The following specific hypotheses related to psychosocial STRESS were formulated for this experiment:

- **H6a**: It was hypothesized that performance times would be faster under the condition where time stress was imposed.
- **H7a**: It was hypothesized that wrist motions would be faster under the condition where time stress was imposed.
- **H9a**: It was hypothesized that self-reported discomfort would increase under the condition where time stress was imposed.
- **H10a**: It was hypothesized that self-reported state anxiety would increase under the condition where time stress was imposed.

No specific TYPE x STRESS hypotheses were formulated for this study.

7.3.2 Participants

Subjects participating in this experiment were recruited from a pre-tested pool of students enrolled in an introductory psychology course. Subjects ranged in age from 18.4 to 21.4 years (mean 19.3 (0.78) years). All subjects participated voluntarily, provided their written consent, and received research credits for their participation. The study was conducted in two phases. During the pre-testing phase described earlier, potential subjects (N=92) were tested on a battery of surveys including the 52-item Jenkins Activity Survey (JAS) Form C (Jenkins et al., 1979). Using scores from this survey, subjects were categorized as having either Type A or B personalities as previously described. Subjects were deemed eligible to participate in a second laboratory phase if they were categorized as Type A or B personalities and if they had no significant injuries or skin allergies that would (1) preclude them from safely participating and/or (2) possibly confound the results. Those eligible subjects were contacted regarding their willingness to participate in the laboratory experiment. Of those willing subjects, 12 Type A and 12 Type B participants were randomly assigned to two experimental task orders in a counterbalanced fashion such that equal numbers of male and female Type A and Type B subjects performed each task order. The laboratory experiment was conducted in the Ergonomics Laboratory located in the university's Department of Industrial Engineering. Subjects who completed the laboratory experiment received all of their required research credits and a laboratory t-shirt.

7.3.3 Task

The task required subjects to assemble and disassemble non-functioning reciprocating saws currently used in class projects in the industrial engineering department (see Figure 7-1 and Figure 7-2). Subjects were standing at a height-adjustable workstation. The work surface was adjusted such that the top surface of the saw jig was positioned 15 centimeters below the subject's standing elbow height.

Figure 7-1. Standing assembly/disassembly task.

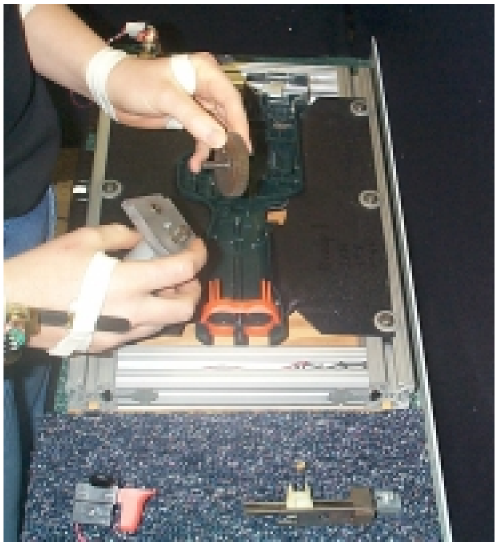


Figure 7-2. Close-up view of hands, monitors, and saw parts during assembly/disassembly task.

7.3.4 Apparatus

7.3.4.1 Bioinstrumentation

7.3.4.1.1 Wrist Motion Monitors

Wrist motion parameters were collected using wrist motion monitors (see Figure 7-3), developed in the Biodynamics Laboratory at The Ohio State University (Marras & Schoenmarklin, 1993). Each monitor consists of two thin metal segments that are affixed to the hand and forearm with hypoallergenic tape. These metal segments are joined by a rotary potentiometer that measures the angle between the two segments. Two wrist monitors were affixed to each of the subject's hands/wrists in order to measure angular movement in the radial/ulnar (R/U) and flexion/extension (F/E) planes. Data from the monitors were passed through an analog-to-digital (A/D) board, sampled and collected at 300 Hz, and stored to the computer in binary file format for later processing and analysis.

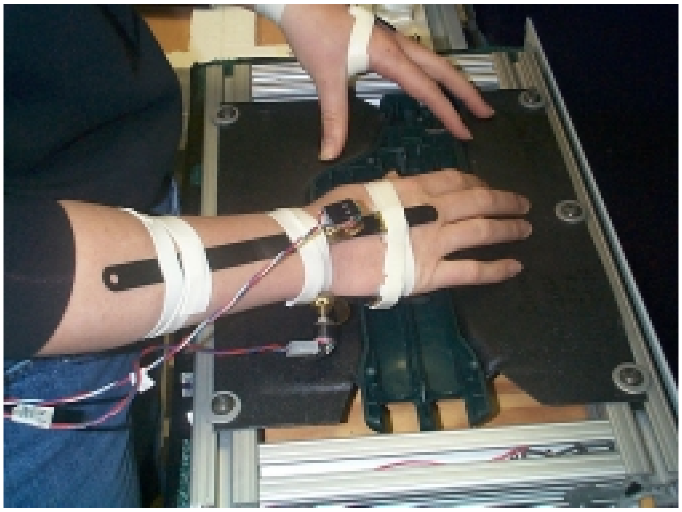


Figure 7-3. Right-hand Wrist Motion Monitor shown while subject performs the task.

7.3.4.1.2 Anthropometer

A variety of anthropometric measurements were obtained using a high-precision anthropometer (model GPM 101) from Seritex, Inc. Recorded measurements included subject stature, a number of hand/wrist/arm/shoulder body segment dimensions, and a number of distances relative to the floor and work surface. A standard bathroom scale was used to measure subject weight. Circumference measurements were obtained with a standard seamstress-type tape measure. All anthropometric measurements were obtained on the subject's dominant-hand side. For a complete list of the anthropometric measures, see Table 7-2 in the Results section.

7.3.4.1.3 Blood Pressure and Pulse Monitor

Blood pressure and pulse were measured using an Omron HEM 757 automatic blood pressure monitor equipped with "intelligent" monitoring. The cuff was placed approximately 0.5 inches above the elbow crease of the left arm such that the pulse-monitoring portion was over the brachial artery. The monitor cuff inflates automatically to the required pressure and then deflates automatically. When the measurement is complete, the diastolic and systolic blood pressure values are displayed on the device. The pulse is also displayed. These values were measured and recorded at various times during the session as outlined in Section 7.3.5.

7.3.4.2 Survey Instruments

Self-report measures of discomfort, anxiety, and various psychosocial attributes were administered in written form. Discomfort and state anxiety were measured several times during the experiment. Subjects also completed the 60-item NEO-FFI and a modified 62-item stressful life events inventory where they were asked to mark events that have occurred in their lives recently. At the end of the session, subjects were provided with an additional proxy survey to provide to someone else for completion. This was intended to explore "knowledgeable other" ratings of personality type and expressiveness. Each of the survey instruments is described here.

7.3.4.2.1 Revised NEO Personality Inventory

The NEO Five-Factor Inventory (NEO-FFI), a short form of the Revised NEO Personality Inventory (NEO PI-R), was used to assess the "big-five" personality dimensions (Costa & McCrae, 1992a). This widely used 60-item instrument contains statements such as "I am not a worrier" and "I like to have a lot of people around me" to which subjects select from a 5-point Likert scale with responses ranging from "strongly disagree" to "strongly agree." Scores are provided for five factors, each containing twelve unique items. These factors are (1) Neuroticism, (2) Extraversion, (3) Openness to experience, (4) Agreeableness, and (5) Conscientiousness. This short form correlates 0.77 to 0.92 with the larger NEO PI-R Form S domain scales and demonstrates internal consistency with values ranging from 0.68 to 0.86 (Psychological Assessment Resources Inc., 2001).

7.3.4.2.2 Life Events Stress

Life Events Stress was assessed using the 51-item revised Social Readjustment Rating Scale (SRRS-R: Hobson et al., 1998) with 11 additional items added to reflect events specific to college students (Sarason et al., 1979). Subjects were presented with the combined 62-item scale and asked to report which of the events they had experienced in their lives "within the past six months." A count score is obtained by summing the number of checked events.

7.3.4.2.3 Self-reported Musculoskeletal Discomfort

At various times throughout the experiment, subjects were asked to rate their perceived level of discomfort in specific body regions using a visual analogue scale (VAS). The survey included a unilateral rating scale for the head region and bilateral rating scales for each of the neck/shoulder, arm/elbow, hand/wrist, upper/mid back, low back, and legs/feet regions. Each region's visual analogue scale consisted of a 10-centimeter long horizontal straight line with vertical line endpoints. The left endpoint was labeled "NO pain at all" and the right endpoint was labeled "WORST imaginable pain." A numerical rating for each region was derived from this visual scale by measuring the distance from the left endpoint. This instrument is contained in Appendix 13.2.

7.3.4.2.4 Self-reported State Anxiety

Subjects were asked to rate their perceived level of anxiety using a 15-item scale created for this study. This survey included selected items from the 20-item "state" measure of anxiety from the Spielberger State-Trait Anxiety Inventory (STAI: Spielberger, 1983) and selected and modified items from the Endler Multidimensional Anxiety Scales (EMAS: Endler, Edwards, & Vitelli, 1991). The STAI is the most common measurement for anxiety worldwide. Example items include "I feel calm" and "I feel nervous." Responses are chosen from a 4-item response scale ranging from "Not at all" to "Very much." Selected EMAS items were also included with the STAI items to represent individual ratings of specific somatic indications of anxiety (e.g., moist hands). These were slightly reworded to reflect first-person statements. For example, "hands feel moist" was modified to "My hands feel moist." For consistency, the 4-item response STAI response scale was used in lieu of the 5-item scale published for the EMAS.

7.3.4.2.5 Proxy Measure of Personality Type and Emotional Expressiveness

Subjects were provided with an additional 16-item proxy survey to provide to someone who knew them well for completion. This was intended to explore "knowledgeable other" ratings of personality type and emotional expressiveness. Subjects who participated in the experimental sessions were asked if they were willing to provide this survey to someone who knew them well for completion. Subjects documented their consent to participate on a separate consent form. They were allowed to review the survey questions, cautioned on reviewing and/or interpreting the responses provided by the person who completed it, and instructed on how to return the survey. They were provided with the survey, an instruction letter, and a pre-stamped addressed envelope to deliver to the person who would complete the survey. Appendix 13.3 contains the letter and the survey.

A short proxy measure of Type A behavior was developed for this study and included in the proxy survey to explore the possibility of assessing Type A personality with this approach. This measure included 10 questions about the subject's Type A behavioral tendencies as observed by someone "close" to the subject. Questions consisted of significant items from the revised JAS survey, reworded to reflect third person ratings. The JAS response scales were modified as necessary such that each item included a 4-item response scale. The responses varied in wording across items. For example, item number 44 from the JAS was reworded to "Compared to others, he/she hurries" with a 4-item response scale that varied from "much more of the time" to "much less of the time."

Six items were also developed for this study and included in this proxy measure to explore the possibility of assessing an individual's emotional expressiveness with a proxy measure. These items included statements about the subject's emotional and behavioral inhibitory tendencies as observed by someone "close" to the subject. An example item was "He/she always tells me how he/she feels." The response scale for these six items was a 5-item Likert scale that varied from "NEVER true" to "ALWAYS true."

7.3.5 Procedure

Each subject participated in the experiment in a single session. Upon arrival in the laboratory, the subject was provided with a brief explanation of the experiment and then asked to read and sign a written consent form. The subject was seated while baseline blood pressure and pulse measurements were recorded. The subject then completed baseline anxiety and discomfort surveys. A second blood pressure and pulse reading was recorded. Next, a variety of anthropometric dimensions were measured and recorded. The subject was then fitted with wrist motion monitors on both hands/wrists. Once fitted, the subject performed a series of wrist motions to confirm that everything was connected and working accurately. Next, one of the subject's hands and wrists was positioned on a platform positioned at seated shoulder height next to the subject. The hand/wrist was adjusted to a neutral posture. This neutral wrist posture was recorded to the computer for 5 seconds.

The hand/wrist was then removed from the platform and repositioned. This neutral posture was also recorded to the computer. This procedure was then repeated for the opposite hand. The subject then moved his/her hands and wrists simultaneously through a fixed series of maximum deviation motions as demonstrated by the experimenter. This 20-second trial was recorded to the computer.

The experiment was video taped beginning at this point. The subject was positioned standing at a height-adjustable workstation with the work surface height set at 15cm below the individual's lateral epicondyle height. The subject was then introduced to the task and allowed to practice for 10 to 12 minutes. The participant was instructed to disassemble the saw completely, note this by saying "done," and then begin assembling the saw without interruption. He/she was instructed to continue this process until told to stop. The subject was encouraged to ask any questions at this time and told that the purpose of this portion of the experiment was to learn how to perform the task. After practicing this task for 7 to 10 minutes, the subject was instructed to practice doing this "as fast as you can." Upon completion of the task training, the subject was seated in a chair. Blood pressure and pulse were recorded. The subject then completed anxiety and discomfort surveys.

The subject was repositioned at the standing workstation. An introductory script was verbally provided to the subject as follows: "Today, you will be asked to perform a task that is similar to what you might see in industry. It is important that you approach this task as you would if you were actually asked to perform it in the workplace. You will be given specific instructions prior to beginning the task. You will be performing the task twice."

The participant then performed each time stress condition, as previously described, in the assigned order. Prior to beginning each condition, the experimenter read a specific instruction script (as previously described to define each STRESS condition) verbally aloud to the participant. The subject performed each condition for 15 minutes. While the subject performed the task, data from the wrist monitors was recorded and stored on the computer continuously (at 300 Hz) during each of the 15-minute conditions. Performance times were captured and processed using a uniquely developed Visual Basic application on a separate computer. Upon completion of each disassembly or assembly cycle, the experimenter pressed the ENTER key to capture the performance times. After each condition, the subject was seated while (1) blood pressure and pulse were recorded, (2) he/she completed anxiety and discomfort surveys, and (3) neutrals were collected for each hand/wrist.

At the end of the experiment, the wrist monitors were removed and the subject completed the NEO-FFI and modified SRRS-R surveys. The subject was then informed about the proxy survey and asked whether he/she was willing to participate by providing this survey to someone else to complete. The subject documented his response on a separate consent form. A final blood pressure and pulse measure was recorded. The subject also completed a final anxiety and discomfort survey. Prior to leaving the laboratory, the subject was provided with the proxy survey, given a t-shirt, and allowed to ask questions. The entire session lasted approximately 2 hours.

7.3.6 Data Reduction

7.3.6.1 Generating Dependent Variables

Data was processed and analyzed using customized files and codes created for this experiment to generate specific dependent variables. The analyses are described here for generating the dependent variables that represented each construct evaluated in this study.

7.3.6.1.1 Physical traits - Anthropometry

Anthropometry variables were used as recorded, with the exception of body weight which was converted from pounds to kilograms. The specific variables are provided in the Results section.

7.3.6.1.2 Workstyle - Performance

Workstyle-related performance variables were calculated for each participant for each condition by averaging all of the individual unit assembly/disassembly cycle times achieved by the subject for the condition resulting in the following dependent variables:

avgDIStpu: average disassembly time per unit in seconds

avgASSYtpu: average assembly time per unit in seconds

7.3.6.1.3 Workstyle – Wrist Motion Kinematics

Twenty (20) workstyle-related wrist motion variables were computed to describe wrist motion in the flexion/extension and radial/ulnar planes for both hands. Stored wrist monitor voltages were converted to angular position, velocity, and acceleration of the hand/wrist using uniquely developed codes based on a previously developed and verified algorithm (Allread, 2000; Schoenmarklin, 1991). These data contained both positive and negative values and were used to generate position variables. The absolute values of these data were used to generate velocity and acceleration variables. Twelve mean wrist motion parameters (four each of position, velocity, and acceleration) were calculated by averaging this converted data across each of the 15-minute conditions. The position data were also used to compute four angular range of motion and four normalized range of motion variables for each condition. This resulted in the following dependent variables describing wrist motion:

nLRUpos: mean non-absolute value of left radial/ulnar position (degrees)
nLFEpos: mean non-absolute value of left flexion/extension position (degrees)
nRRUpos: mean non-absolute value of right radial/ulnar position (degrees)
nRFEpos: mean non-absolute value of right flexion/extension position (degrees)
aLRUvel: mean absolute value of left radial/ulnar velocity (degrees/second)
aLFEvel: mean absolute value of left flexion/extension velocity (degrees/second)
aRRUvel: mean absolute value of right radial/ulnar velocity (degrees/second)
aRFEvel: mean absolute value of right flexion/extension velocity (degrees/second)
aLRUacc: mean absolute value of left radial/ulnar acceleration (degrees/second^2)
aLFEacc: mean absolute value of left flexion/extension acceleration (degrees/second^2)
aRRUacc: mean absolute value of right radial/ulnar acceleration (degrees/second^2)
aRFEacc: mean absolute value of right flexion/extension acceleration (degrees/second^2)
romLRU: left radial/ulnar range of motion (degrees)
romLFE: left flexion/extension range of motion (degrees)
romRRU: right radial/ulnar range of motion (degrees)
romRFE: right flexion/extension range of motion (degrees)
nromLRU: left radial/ulnar normalized range of motion (fraction of maximum)
nromLFE: left flexion/extension normalized range of motion (fraction of maximum)
nromRRU: right radial/ulnar normalized range of motion (fraction of maximum)
nromRFE: right flexion/extension normalized range of motion (fraction of maximum)

The following section provides further details describing the wrist motion data collection and processing.

7.3.6.1.3.1 Detailed Description of Wrist Motion Data Processing

7.3.6.1.3.1.1 Processing Raw Data into Dependent Variables

The wrist motion data was collected and stored in binary format during the experimental sessions using an Analog-to-Digital (A/D) collection system. Eleven binary files were collected, exported to ASCII text format, and processed further with uniquely developed codes to generate the dependent variables. The data included eight neutral wrist posture files, one maximum wrist motion file, and two experimental task files. The neutral and maximum position files contained four columns of data that corresponded to the following signals collected from the wrist monitors: left radial/ulnar (LRU), left flexion/extension (LFE), right radial/ulnar (RRU), and right flexion/extension (RFE). The task files contained an extra column that allowed artificial signals (“triggers”) to be inserted between cycles.

Average values were computed for each neutral file, the first two left hand neutral files combined, the first two right hand neutral files combined, and all neutral files combined. Neutral offsets were generated by using the average values from the first two neutral files collected during the experiment for each hand.

Processing of the wrist motion data occurred in two major iterations. During the first iteration, the data was converted from bits representing wrist monitor displacement to actual wrist positions (in degrees), velocities (in degrees/second), and accelerations (in degrees/second^2). In order to accomplish this task, a previously developed algorithm (Allread, 2000; Marras & Schoenmarklin, 1993; Schoenmarklin, 1991) was coded in Matlab. This new code allowed files of much greater length (e.g., 15 minutes @ 300 Hz resulting in 270,000 lines of data) to be processed. The new code was verified by comparing its output for a reduced (6000 lines) data file to the output generated by the previous code. The code generates the positions, velocities, and accelerations by passing wrist monitor position data through two passes of the basic computational algorithm. The first pass uses the neutral offsets in conjunction with the original motion displacement data to generate a first pass of positions, velocities, and accelerations. The position data from the first pass is passed through the algorithm again to generate a more smoothed set of positions, velocities, and accelerations. These data represented the actual positions, velocities, and accelerations for each of the posture or task trials that were processed. An excerpt of data from one of the resulting output files can be found in Figure 7-4.

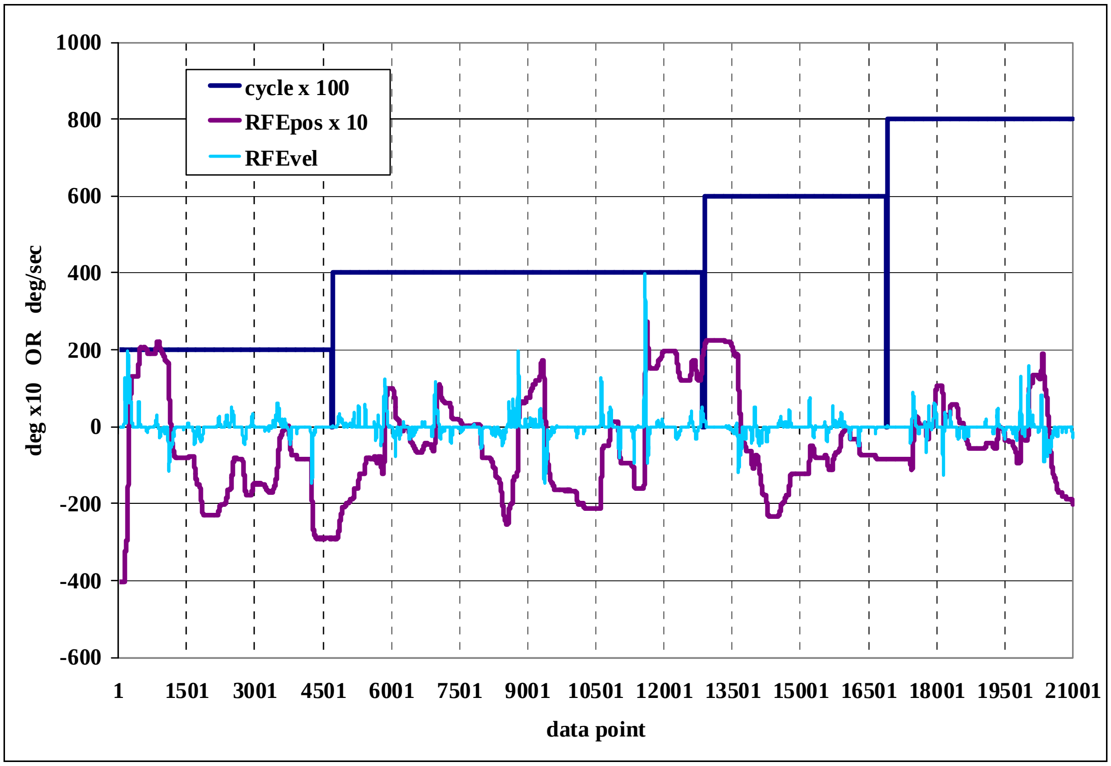


Figure 7-4. Excerpt of processed Right Flexion/Extension position (RFEpos, scaled by a factor of 10) and velocity (RFEvel) data from one subject's trial ("G21TPAS2.TXT").

The second iteration involved steps to compute the actual dependent variables from the processed data. This analysis generated two summary data sets for each subject. One data set contained the results of the analysis that was performed on the basic (i.e., non-absolute value) data. A second data set contained the results of the analysis that was performed on the absolute values of the data. Means of the non-absolute values were used for all position variables. Means of the absolute values were used for velocity and acceleration variables. This resulted in a data set containing the dependent measures describing mean position, velocity, and acceleration (e.g., nLRUpos, aRRUacc).

Range of motion variables were computed within SAS. The angular position data from the maximum motion trial were used to compute maximum range of motion values in each of the four directions. The 1st percentile (i.e., value at which one percent of the observed values were less in magnitude) and 99th percentile values were used as the minimum and maximum angular wrist positions. This was done in order to eliminate the unrealistic spikes that can be obtained by taking the absolute minimum and maximum values from wrist motion data (Allread, 2000). Each maximum range of motion was then computed by subtracting the corresponding minimum (i.e., 1st percentile) value from the maximum (99th percentile) value. This process was also used to compute the range of motion values in each direction obtained for each stress condition. This resulted in the dependent variables reflecting absolute range of motions (e.g., romLFE) in degrees.

The above range of motion values obtained from each of the stress conditions were then normalized to the individual's maximum range of motion values. This resulted in the dependent variables representing normalized range of motion (e.g., nromRRU) as a fraction of maximum.

7.3.6.1.3.1.2 Verification of Data Collection

All neutral files were visually graphed and inspected in sequence for each subject. If a subject's neutral plots shifted substantially during the experiment (e.g., possibly indicating a mechanical shift of the monitor or a weak battery), the data collected after the shift for the affected hand/wrist direction were not used in the analysis. This was verified through a subsequent quantitative evaluation of these "shifts." All neutral file averages and overall averages were output to a file during processing to aid in process verification and troubleshooting. The values contained in this file were processed further to compute the percent deviations of the post-task neutrals from the original offset value that was obtained by averaging the first two neutrals collected at the beginning of the experiment. The results of this quantitative evaluation of the neutrals are shown in Figure 7-5 and Figure 7-6. From the figures it can be seen that most of the deviations were within ± 5 percent of the original offset value. If a post-task neutral value deviated more than ± 10 percent from the original offset value, then any data for the associated hand/wrist direction that was collected after the "shift" in neutral occurred was eliminated from the analysis. This resulted in eliminating the left radial/ulnar (LRU) data for both conditions for one subject.

Task trial data were inspected visually during collection and during subsequent analysis. If any anomalies (e.g., high amplitude spikes, increasing frequency of spikes, apparent shift in the mean of the displacement, etc.) were noted during the display of the data during the experiment, these files were inspected further and (1) mechanical equipment was tested/repaired as required and (2) portions of the data file or the data file in its entirety were eliminated as required from the valid data set.

7.3.6.1.3.1.3 Verification of Data Processing

The processing of the wrist motion data was verified through a series of steps. These are briefly described here. First, results were obtained using the processing codes developed in this study for a pilot subject. The appropriate files were created to allow a reduced amount (e.g., 6000 lines of the experimental trials) of this data to be processed using a previously developed and verified Fortran algorithm (Sommerich, 1994). This algorithm was modified slightly to (1) accommodate the format of the data collected during this experiment and (2) output all of the required position, velocity, and acceleration data. The results obtained from each of these approaches was compared and verified to be equivalent.

Second, a fictitious subject identifier was created. A real subject's files were copied and named as belonging to this subject. The task files were reduced in length from 15 minutes (270,000 lines) of data to 200 seconds (60,000 lines) of data during initial processing. This was done in order to allow the processed data to be read into a spreadsheet (with limited row number capability). In the spreadsheet, formulas were entered to generate calculations of the statistical measures. The files were also processed through the uniquely developed Matlab codes, slightly modified to run this specific subject. The output from the second iteration was compared to the spreadsheet calculations. The results were verified.

Third, the task data for this subject was reduced to 6000 lines in length. Additional files were created as required to run this subject in the modified Fortran algorithm. A unique Matlab code was created to graphically display the results obtained for the reduced fictitious subject. The results of the processing developed for this experiment were the same as those displayed for the previous algorithm.

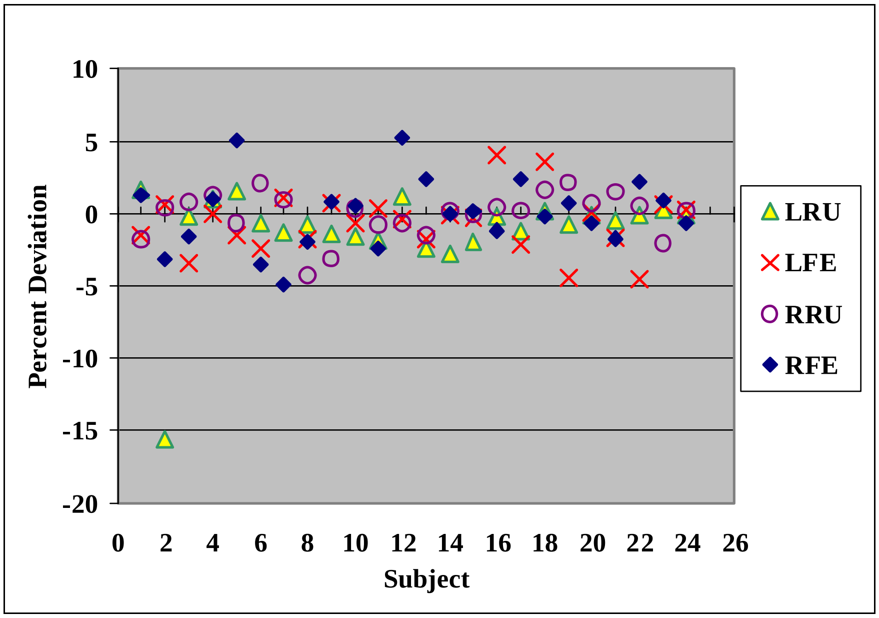


Figure 7-5. Percent deviations of post-task neutrals from original averaged neutral offset value for the "no-stress" condition.

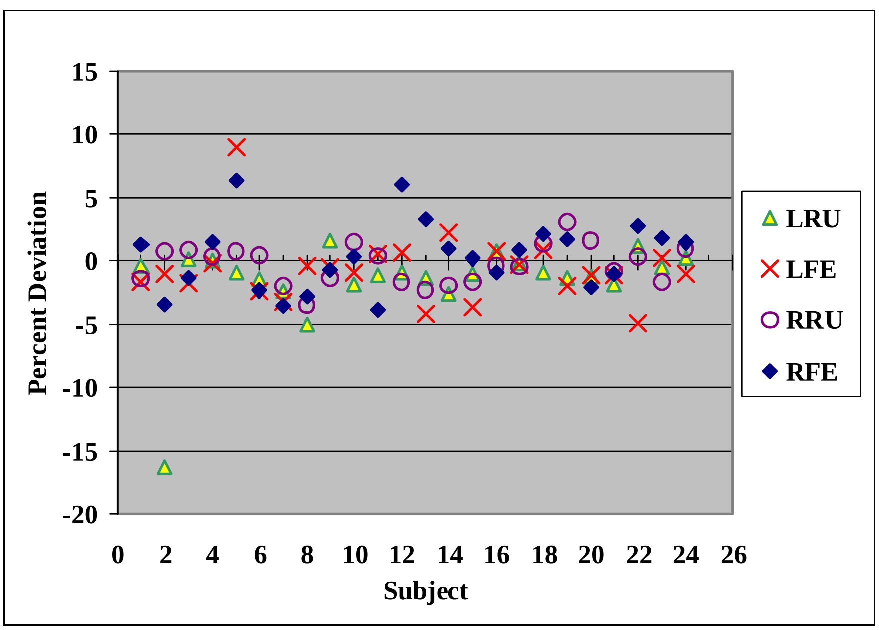


Figure 7-6. Percent deviations of post-task neutrals from original averaged neutral offset value for the "stress" condition.

7.3.6.1.4 Reporting Behaviors - Musculoskeletal Discomfort and State Anxiety

Discomfort and anxiety surveys were administered five separate times during the experimental sessions. Musculoskeletal discomfort survey (MDS) scores were generated for each of the 13 body regions for each of the five survey administrations that occurred during the experimental session. Each of the individual scores was recorded (in centimeters) from its corresponding Visual Analogue Scale (VAS). This resulted in the following individual body region scores:

MDSh – head (centimeters)

MDSnsL and MDSnsR – left and right neck/shoulder (centimeters)

MDSaeL and MDSaeR – left and right arm/elbow (centimeters)

MDShwL and MDShwR – left and right hand/wrist (centimeters)

MDSubL and MDSubR – left and right upper/middle back (centimeters)

MDSlbL and MDSlbR – left and right lower back (centimeters)

MDSlfL and MDSlfR – left and right feet/legs (centimeters)

Three composite musculoskeletal discomfort scores were generated for each observation for average overall discomfort (MDSavg), upper extremity discomfort (MDSupx), and back discomfort (MDSbak) by averaging the reported visual analog scale values (measured in centimeters from the left endpoint) for the appropriate body regions. This resulted in the following three dependent variables to evaluate musculoskeletal discomfort:

MDSavg – the average response score (in centimeters) across all 13 individual body regions

MDSupx – the average response score (in centimeters) across the 6 upper extremity body regions (MDSnsL MDSnsR MDSaeL MDSaeR MDShwL MDShwR)

MDSbak – the average response score (in centimeters) across the 4 back body regions (MDSubL MDSubR MDSlbL MDSlbR)

State anxiety scores (ANXtot) were generated for each observation by first reverse scoring the survey responses for items 1, 3, 7, and 9 and then summing all 15 responses.

7.3.6.2 Statistical Analysis

Analysis of variance (ANOVA) procedures were used to detect significant effects of the independent variables and their interactions on the dependent measures. Two different ANOVA models were used as described previously in Section 5.5 and as outlined for this specific study in

Table 7-1. One of the models was specifically used to evaluate the experimental hypotheses. Model #1 was employed to evaluate the effect of the between-subjects independent variables (TYPE, GENDER, and ORDER) and the within-subjects STRESS variable on performance, wrist motion kinematics, and discomfort/anxiety reporting behaviors. Selected data were evaluated at length for compliance with assumptions required for use of the analysis of variance (ANOVA) procedures. A second model, Model #2, was employed to evaluate the effect of the between-subjects independent variables (TYPE, GENDER, and ORDER) on subject anthropometry variables. This was done to evaluate the chance that random assignment may have produced groups that differed significantly in one or more of the anthropometry variables that could have confounded the results obtained in the analyses to test the hypotheses. The detailed linear models and specific error terms for testing the effects were described previously in Section 5.5. Pearson correlation coefficients were also computed among and between the composite discomfort scores and the state anxiety scores.

Table 7-1. Summary of specific analyses and statistical models utilized in Phase II experiment.

Statistical Model	Between-subjects Independent Variables	Within-subjects Independent Variables	Dependent Variables
#1	TYPE GENDER ORDER	STRESS	*workstyle* **performance time** (avgDIStpu, avgASSYtpu)
#1	TYPE GENDER ORDER	STRESS	*workstyle* **wrist motion kinematics** (nLRUpos, nLFEpos, nRRUpos, nRFEpos, aLRUvel, aLFEpos, aRRUvel, aRFEvel, aLRUacc, aLFEacc, aRRUacc, aRFEacc, romLRU, romLFE, romRRU, romRFE, nromLRU, nromLFE, nromRRU, nromRFE)
#1	TYPE GENDER ORDER	STRESS	*specific reporting behaviors* **musculoskeletal discomfort** (MDSavg, MDSupx, MDSbak)
#1	TYPE GENDER ORDER	STRESS	*specific reporting behaviors* **state anxiety** (ANXtot)
#2	TYPE GENDER ORDER		*physical traits* **anthropometry**

In the "Dependent Variables" column, the overall construct is shown in italics, the specific construct is shown in bold, and the dependent variables are listed in parentheses.

7.4 RESULTS

7.4.1 Physical Traits – Anthropometry

7.4.1.1 Overall Descriptive Statistics

The mean values across all subjects for each of the 17 anthropometry variables are provided in Table 7-2.

Table 7-2. Subject anthropometry.

Anthropometric Measurement	Label	Mean	Standard Deviation	Minimum	Maximum
Hand circumference (cm)	HC	20.4	1.5	17.4	23.4
Wrist circumference (cm)	WC	16.8	1.1	14.0	18.6
Forearm circumference (cm)	FC	26.5	2.3	20.6	30.2
Hand span (cm)	HS	21.1	1.6	16.9	24.2
Hand breadth (cm)	HB	8.1	0.6	6.8	9.4
Wrist width (cm)	WW	5.7	0.3	4.7	6.3
Hand length (cm)	HL	18.4	1.3	16.5	20.8
Forearm length (cm)	FL	44.5	3.3	39.0	51.7
Arm length (cm)	AL	75.5	5.6	66.4	87.2
Shoulder width (cm)	SW	41.6	3.0	35.9	48.6
Floor to finger tip height (cm)	FFT	68.1	4.0	61.8	78.2
Floor to elbow height (cm)	FE	111.5	6.5	100.8	123.8
Floor to shoulder height (cm)	FS	143.4	9.1	129.2	162.6
Work surface height (cm)	WSH	96.4	6.5	85.8	108.8
Standing eye height (cm)	SEH	163.0	9.9	147.4	183.6
Stature (cm) - *measured*	ST	174.7	10.1	160.2	196.0
Weight (kg) - *calculated*	WT	73.2	11.7	53.1	95.7
Stature (in) - *calculated*		68.8	4.0	63.1	77.2
Stature (ft) - *calculated*		5.7	0.3	5.3	6.4
Weight (lb) - *measured*		161.3	25.8	117.0	211.0

Units of measurement shown in parentheses (cm=centimeters, kg=kilograms, in=inches, ft=feet, lb=pounds).
All measurements taken from the dominant hand side.

7.4.1.2 General Statistical Analysis and Results

Anthropometry variables were evaluated using Analysis of Variance (ANOVA) with Model #2 as described in Section 5.5.3 to check for potential confounding. The purpose of this analysis was to evaluate the chance that random assignment may have resulted in groups of subjects that differed significantly in anthropometry. Since anthropometry plays a critical role in biomechanical findings, this analysis was considered necessary to assess the possibility that one or more anthropometry differences may have confounded the results obtained in the analyses to test the primary hypotheses. The model included TYPE, GENDER, and ORDER as between-subjects independent variables. The model also included all possible interactions. There was one observation of each of the dependent variables for each subject resulting in 24 total observations with 17 variables in each observation for this analysis. Results of the individual ANOVA's for the physical traits variables are summarized in Table 7-3. These results are described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.4.

7.4.1.3 Between-subjects Effects

Seventeen (17) anthropometry variables were analyzed using a between-subjects ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. Results of the analyses were summarized in Table 7-3.

The analysis revealed no significant main effects of TYPE for any of the variables. A significant main effect of GENDER was observed for all 17 variables. The means by GENDER for the anthropometric variables are provided in Table 7-4. As expected, mean values for males were consistently higher than mean values for females. A significant main effect of stress condition ORDER was observed for hand length (HL), forearm length (FL), and arm length (AL). These results can be seen in Figure 7-7. The ANOVA analysis revealed no significant 2-way interaction effects.

Table 7-3. Model #2 resulting p-values of individual ANOVA's for anthropometry variables (24 observations).

Anthropometric Measurement	**TYPE**	**GENDER**	**ORDER**	**TYPE X GENDER**	**TYPE X ORDER**	**GENDER X ORDER**	**TYPE X GENDER X ORDER**
HC	ns	**<0.0001**	ns	ns	ns	ns	ns
WC	ns	**0.0003**	ns	ns	ns	ns	ns
FC	ns	**0.0003**	ns	ns	ns	ns	ns
HS	ns	**0.0071**	ns	ns	ns	ns	ns
HB	ns	**0.0015**	ns	ns	ns	ns	ns
WW	0.0760	**0.0008**	ns	ns	ns	ns	ns
HL	ns	**<0.0001**	**0.0420**	ns	ns	ns	0.0799
FL	ns	**<0.0001**	**0.0117**	ns	ns	ns	0.0521
AL	ns	**0.0002**	**0.0210**	ns	ns	ns	**0.0414**
SW	ns	**<0.0001**	ns	ns	ns	ns	ns
FFT	ns	**0.0214**	ns	ns	ns	ns	ns
FE	ns	**0.0004**	ns	ns	ns	ns	ns
FS	ns	**0.0003**	ns	ns	ns	ns	ns
WSH	ns	**0.0004**	ns	ns	ns	ns	ns
SEH	ns	**0.0001**	ns	ns	ns	ns	ns
ST	ns	**0.0001**	ns	ns	ns	ns	ns
WT	ns	**0.0005**	0.0804	ns	ns	0.0684	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 7-4. Subject anthropometry by gender.

Anthropometric Measurement	Abbreviation	Female (N=12) Mean	Female (N=12) Standard Deviation	Male (N=12) Mean	Male (N=12) Standard Deviation
Hand circumference (cm)	HC	19.2	1.0	21.6	0.7
Wrist circumference (cm)	WC	16.0	0.9	17.6	0.5
Forearm circumference (cm)	FC	24.8	1.9	28.1	1.3
Hand span (cm)	HS	20.2	1.6	22.0	1.0
Hand breadth (cm)	HB	7.8	0.5	8.5	0.4
Wrist width (cm)	WW	5.4	0.3	5.9	0.2
Hand length (cm)	HL	17.5	0.8	19.3	1.0
Forearm length (cm)	FL	42.2	1.8	46.8	2.8
Arm length (cm)	AL	71.8	3.5	79.1	4.8
Shoulder Width (cm)	SW	39.2	1.9	43.9	1.9
Floor to finger tip height (cm)	FFT	66.0	2.8	70.1	4.0
Floor to elbow height (cm)	FE	106.9	3.9	116.0	5.2
Floor to shoulder height (cm)	FS	137.1	5.0	149.7	7.9
Work surface height (cm)	WSH	91.9	3.9	101.0	5.2
Standing eye height (cm)	SEH	155.8	5.3	170.2	8.0
Stature (cm) - *measured*	ST	167.4	5.5	182.0	8.3
Weight (kg) - *calculated*	WT	65.8	7.6	80.6	10.5
Stature (in) - *calculated*		65.9	2.2	71.7	3.3
Weight (lb) - *measured*		145.0	16.7	177.7	23.2

Units of measurement shown in parentheses (cm=centimeters, kg=kilograms, in=inches, lb=pounds).
All measurements taken from the dominant hand side.

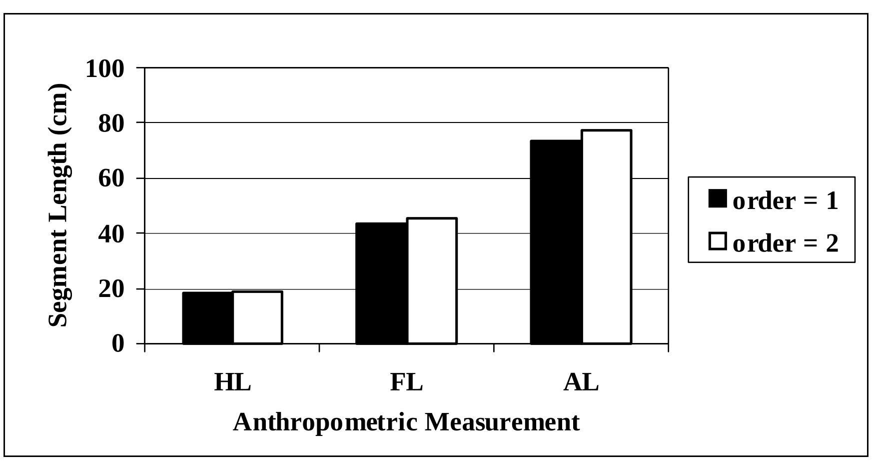


Figure 7-7. Significant main effects of stress condition order (ORDER) on specific segment-length anthropometric variables.

7.4.1.4 Summary of Findings for Physical Traits

As expected, gender significantly impacted physical traits as measured by anthropometry. Females were smaller across all measures. A main effect of condition order was unexpectedly obtained for three measures – hand length, forearm length, and arm length. Those individuals performing the no-stress condition first (order = 1) were smaller than those who performed it last.

7.4.2 Workstyle – Performance

7.4.2.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for each of the assembly task performance variables are contained in Table 7-5.

Table 7-5. Summary statistics for assembly task performance variables.

Performance Variable	units	N	Mean	Standard Deviation	Minimum	Maximum
avgDIStpu	seconds	48	13.28	2.56	8.81	21.34
avgASSYtpu	seconds	48	27.35	4.42	19.16	37.92

avgDIStpu = average disassembly time per unit in seconds.
avgASSYtpu = average assembly time per unit in seconds.

7.4.2.2 General Statistical Analysis and Results

The effects of the independent variables on task performance (avgDIStpu and avgASSYtpu) were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The performance data included two performance variables (avgDIStpu and avgASSYtpu) for each condition for each subject resulting in 48 observations for each ANOVA. The results of the analyses are summarized in Table 7-6 and Table 7-7 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.4.

7.4.2.2.1 Verification of the ANOVA Assumptions

The performance data were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Appendix 13.9. All plots and computed statistics indicate that the data meet the assumptions. Selected results are provided in Appendix 13.9.

Table 7-6. Model #1 resulting between-subjects p-values of assembly task performance ANOVA's.

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
avgDIStpu	**0.0119**	ns	ns	0.0830	ns	ns	ns
avgASSYtpu	**0.0466**	ns	ns	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 7-7. Model #1 resulting within-subjects p-values of assembly task performance ANOVA's.

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
avgDIStpu	**<0.0001**	ns	ns	**0.0185**	ns	ns	ns	ns
avgASSYtpu	**<0.0001**	ns	0.0558	0.0598	ns	ns	0.0517	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

7.4.2.3 Between-subjects Effects

Task performance times (avgDIStpu and avgASSYtpu) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. There was a significant main effect of personality type (TYPE) for both of the performance variables. There were no other significant main effects or 2-way or 3-way interaction effects.

The analysis for avgDIStpu revealed a significant main effect of personality TYPE ($F\{1,16\} = 8.05$, $p=0.0119$). The analysis for avgASSYtpu also revealed a significant main effect for personality TYPE ($F\{1,16\} = 4.65$, $p=0.0466$). These results are shown in Figure 7-8. From the figure it can be seen that Type A individuals performed faster than Type B individuals. The mean per-unit disassembly times were 12.26 seconds for Type A's and 14.29 seconds for Type B's. The Type A disassembly time was 85.8% of the Type B value. The mean Type A per-unit assembly time was 25.61 seconds. The mean Type B per-unit assembly time was 29.09 seconds. The Type A assembly time was 88.0% of the mean Type A value.

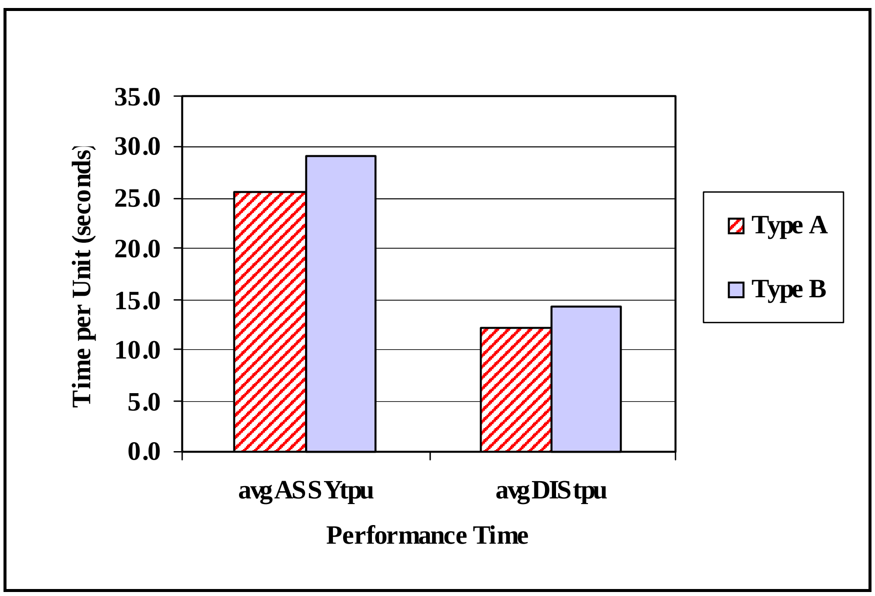


Figure 7-8. Significant effects of personality type (TYPE) on task performance times.

7.4.2.4 Within-subjects Effects

Task performance times (avgDIStpu and avgASSYtpu) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed a highly significant main effect of STRESS for avgASSYtpu ($F\{1,16\} = 72.06$, $p<0.0001$) and avgDIStpu ($F\{1,16\} = 73.02$, $p<0.0001$). The mean scores by STRESS condition can be seen in Figure 7-9. From the figure, it can be seen that the mean performance times for the stress condition were lower than for the no-stress condition. The mean avgASSYtpu and avgDIStpu values for the stress condition were 88.6% and 81.5%, respectively, of the mean values for the no-stress condition. The mean per-unit assembly time (avgASSYtpu) was 29.0 seconds for the stress condition and 25.7 seconds for the no-stress condition. The mean per-unit disassembly time (avgDIStpu) was 14.6 seconds for the no-stress condition and 11.9 seconds for the stress condition.

The interaction of TYPE x STRESS was not significant for either performance variable. Type A individuals worked faster than Type B individuals under both STRESS conditions. Under the no-stress condition, the mean per-unit assembly times (avgASSYtpu) for Type A and Type B individuals were 27.04 and 30.98 seconds, respectively. The value for Type B's was 114.6% of the value for Type A's. During the time-stress condition, both Type A and Type B times were faster. The avgASSYtpu times were 24.19 for Type A's and 27.20 seconds for Type B's, approximately 10.5% and 12.2% faster than the no-stress condition times, respectively. Under the no-stress condition, the Type B time was 112.5% of the Type A value. Similar results were obtained for the disassembly performance time measure (avgDIStpu). Though the TYPE x STRESS interaction was nonsignificant for both variables, the results are shown in Figure 13-1 of Appendix 13.4.

The ANOVA analysis revealed a significant interaction effect of ORDER x STRESS for avgDIStpu ($F\{1,16\} = 6.87$, $p=0.0185$). The mean avgDIStpu performance times for each ORDER x STRESS combination can be seen in Figure 7-10. Subsequent analyses demonstrated that there was a simple effect of stress for both order 1 and order 2, indicating that the main effect obtained for STRESS held for both orders. However, there were no differences between orders for either of the stress conditions.

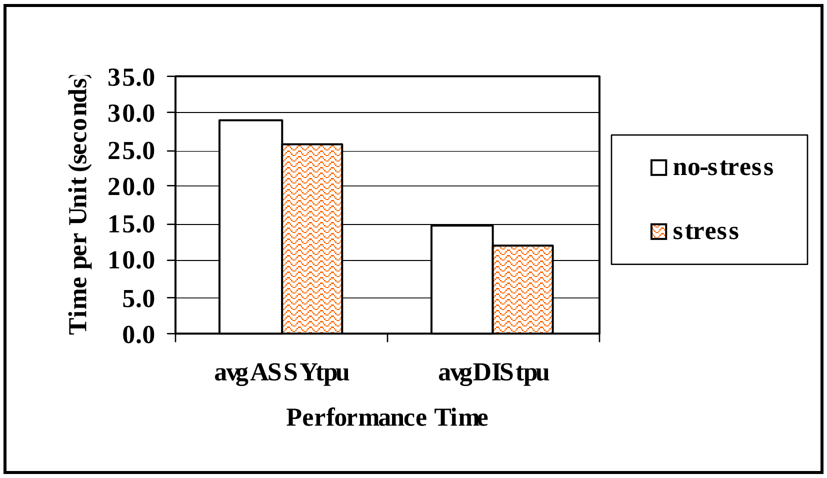


Figure 7-9. Significant effects of stress condition (STRESS) on task performance times.

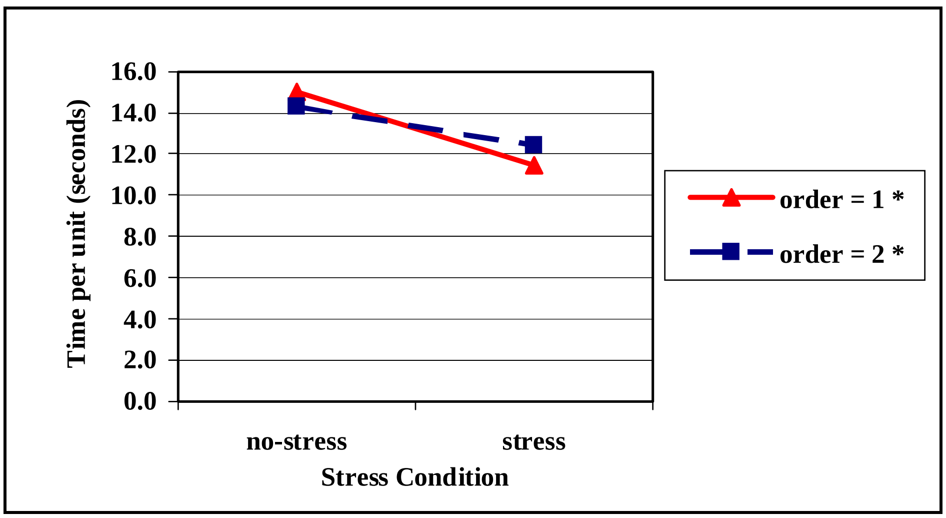


Figure 7-10. Significant interaction effect (p=0.0185) of stress condition order (ORDER) and stress condition (STRESS) on average disassembly performance time (avgDIStpu). (* indicates simple effect within this level of independent variable.)

7.4.2.5 Summary of Findings for Workstyle-related Performance

Personality type significantly impacted workstyle-related performance. Type A mean per unit performance times were approximately 12 – 14% faster than Type B times. Psychosocially-imposed time stress also significantly impacted performance. Mean per-unit times were 11 – 18% faster during the stress condition.

7.4.3 Workstyle – Wrist Motion Kinematics

7.4.3.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for each of the wrist kinematics variables are contained in Table 7-8.

Table 7-8. Summary statistics for wrist kinematics variables.

Wrist Motion Variable	units	N	Mean	Standard Deviation	Minimum	Maximum
nLRUpos ^^	degrees	46	-6.78	3.64	-16.06	-1.37
nLFEpos ^^	degrees	48	-3.64	6.37	-17.55	18.55
nRRUpos ^^	degrees	47	-9.10	4.08	-15.46	0.15
nRFEpos ^^	degrees	48	-8.90	5.69	-21.39	5.78
aLRUvel	deg/sec	46	10.72	3.15	4.04	15.57
aLFEvel	deg/sec	48	13.85	4.72	4.99	27.27
aRRUvel	deg/sec	47	14.69	3.70	7.70	22.43
aRFEvel	deg/sec	48	20.59	5.97	11.41	37.12
aLRUacc	deg/sec^2	46	180.66	49.76	76.09	271.09
aLFEacc	deg/sec^2	48	249.87	89.63	106.03	497.45
aRRUacc	deg/sec^2	47	252.16	68.64	133.00	414.76
aRFEacc	deg/sec^2	48	381.87	125.30	194.65	754.33
romLRU	degrees	46	36.13	7.01	24.33	53.90
romLFE	degrees	48	50.33	6.48	33.61	66.92
romRRU	degrees	47	39.78	5.18	27.36	51.41
romRFE	degrees	48	55.74	8.29	44.27	84.98
nromLRU	fraction	46	0.69	0.13	0.47	1.17
nromLFE	fraction	48	0.47	0.09	0.32	0.69
nromRRU	fraction	47	0.81	0.17	0.56	1.35
nromRFE	fraction	48	0.53	0.12	0.39	0.92
max LRU ROM **	degrees	46	52.16	5.69	40.90	62.16
max LFE ROM **	degrees	48	109.34	16.28	67.86	138.38
max RRU ROM **	degrees	48	50.38	9.18	31.21	71.79
max RFE ROM **	degrees	48	108.45	18.74	59.76	142.82

^^ Sign associated with angular position values indicates direction. For radial/ulnar position variables, positive sign indicates radial direction and negative sign indicates ulnar direction. For flexion/extension position variables, positive sign indicates flexion direction and negative sign indicates extension direction.

** Maximum range of motion (ROM) values are provided here but were not analyzed as dependent variables. These were computed using 1^{st} and 99^{th} percentile angular positions as minimum and maximum angular wrist deviations.

7.4.3.2 General Statistical Analysis and Results

The effects of the independent variables on wrist motion kinematics (20 variables) were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The wrist motion data included 20 variables (4 position, 4 velocity, 4 acceleration, 4 range of motion, and 4 normalized range of motion) for each condition for each subject resulting in 48 observations for each ANOVA, except for selected variables where one (RRU variables) or two (LRU variables) observations were missing due to previously described equipment problems. Each of these variables and the results of the analyses are summarized in Table 7-9 and Table 7-10 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.4.

7.4.3.2.1 Verification of the ANOVA Assumptions

The wrist motion kinematics data were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Appendix 13.9. All plots and computed statistics indicate that the data meet, or only moderately violate, the assumptions. Selected results are provided in Appendix 13.9.

Table 7-9. Model #1 resulting between-subjects p-values of wrist motion kinematics ANOVA's.

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
nLRUpos	ns	ns	ns	ns	ns	ns	ns
nLFEpos	ns	ns	ns	ns	ns	ns	ns
nRRUpos	**0.0355**	ns	ns	ns	ns	ns	ns
nRFEpos	ns	ns	ns	ns	ns	ns	ns
aLRUvel	ns	ns	ns	ns	ns	ns	ns
aLFEvel	ns	ns	ns	ns	ns	ns	ns
aRRUvel	ns	ns	**0.0457**	ns	ns	ns	ns
aRFEvel	ns	0.0605	**0.0038**	ns	ns	ns	ns
aLRUacc	ns	ns	ns	ns	ns	ns	ns
aLFEacc	ns	0.0958	ns	ns	ns	ns	ns
aRRUacc	ns	0.0953	**0.0242**	ns	ns	ns	ns
aRFEacc	ns	0.0636	**0.0086**	0.0804	ns	ns	ns
romLRU	ns	ns	ns	ns	ns	**0.0422**	ns
romLFE	ns	ns	ns	ns	ns	ns	ns
romRRU	ns	ns	ns	ns	ns	ns	ns
romRFE	ns	ns	ns	ns	ns	ns	ns
nromLRU	ns	ns	ns	ns	ns	**0.0297**	ns
nromLFE	ns	ns	ns	ns	ns	ns	ns
nromRRU	ns	ns	ns	ns	ns	ns	ns
nromRFE	ns	ns	**0.0182**	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 7-10. Model #1 resulting within-subjects p-values of wrist motion kinematics ANOVA's.

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
nLRUpos	ns	ns	ns	ns	ns	ns	ns	ns
nLFEpos	ns	ns	ns	ns	ns	ns	ns	ns
nRRUpos	**0.0314**	ns	ns	0.0916	ns	ns	ns	0.0925
nRFEpos	0.0535	0.0698	ns	ns	ns	ns	ns	ns
aLRUvel	**<0.0001**	ns	**0.0017**	ns	ns	ns	**0.0250**	ns
aLFEvel	**<0.0001**	ns	ns	ns	ns	ns	0.0664	ns
aRRUvel	**0.0004**	ns	ns	ns	ns	0.0602	ns	ns
aRFEvel	**0.0211**	ns	ns	ns	ns	ns	ns	ns
aLRUacc	**<0.0001**	ns	**0.0067**	ns	ns	ns	**0.0365**	ns
aLFEacc	**<0.0001**	ns	ns	ns	ns	ns	0.0757	ns
aRRUacc	**0.0001**	ns	ns	ns	ns	ns	ns	ns
aRFEacc	0.0505	ns	ns	ns	ns	ns	ns	ns
romLRU	**<0.0001**	ns	**0.0294**	**0.0139**	ns	ns	ns	ns
romLFE	ns	ns	ns	ns	ns	ns	**0.0448**	ns
romRRU	ns	ns	ns	ns	ns	ns	ns	ns
romRFE	ns	ns	ns	ns	0.0578	ns	ns	**0.0233**
nromLRU	**<0.0001**	ns	**0.0392**	**0.0166**	0.0856	ns	ns	ns
nromLFE	ns	ns	ns	ns	ns	ns	**0.0435**	ns
nromRRU	ns	ns	ns	ns	ns	ns	ns	ns
nromRFE	ns	ns	ns	ns	0.0553	ns	ns	**0.0239**

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

7.4.3.3 Between-subjects Effects

Wrist motion kinematics variables (20 variables) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. This resulted in a significant main effect of personality type (TYPE) for one position variable, no significant main effects of GENDER, and a significant main effect of ORDER for two velocity variables, two acceleration variables, and one normalized range of motion variable. There was a significant interaction of GENDER x ORDER for romLRU and nromLRU. There were no other significant 2-way or 3-way interaction effects.

The analysis revealed a significant main effect for personality TYPE ($F\{1,16\} = 5.34$, $p=0.0355$) for nRRUpos. The mean values by personality TYPE are shown in Figure 7-11 for all four position variables. The negative signs associated with the mean position values indicate that the mean positions were toward extension in the flexion/extension plane and toward ulnar deviation in the radial/ulnar plane. From the figure it can be seen that Type B individuals experienced significantly greater nRRUpos angular wrist deviations than Type A individuals. The mean Type B nRRUpos deviation was -11.06 degrees, which was 153% of the mean Type A value of -7.22 degrees. The Type B mean values were also higher for nLRUpos and nRFEpos, though these differences were not statistically significant. No significant main effects of personality TYPE were obtained for the velocity, acceleration, or range of motion variables. The mean angular velocities and accelerations by personality TYPE are shown in Figure 13-2 and Figure 13-3 of Appendix 13.4. Though not statistically significant, Type A mean values were higher for three velocity variables (LRU, LFE, and RRU) and two acceleration variables (LRU and LFE). The mean range of motion values by personality TYPE are shown in Figure 13-4 of Appendix 13.4. Though not significant, the mean values for all four values were lower for Type A individuals. The mean normalized range of motion values by personality TYPE are shown in Figure 13-5 of Appendix 13.4. The mean normalized values for all four values were higher for Type A individuals, though this difference was not statistically significant.

The analysis revealed no significant effects of GENDER.

The analysis revealed a significant main effect of stress condition ORDER for the two right-hand velocity variables, aRRUvel ($F\{1,16\} = 4.75$, $p=0.0457$) and aRFEvel ($F\{1,16\} = 11.48$, $p=0.0038$). The mean right hand velocities for those performing the no-stress condition first (order = 1) were 121.9% and 134.4% (for aRRUvel and aRFEvel) of the mean velocities who performed the stress condition first. Mean values by ORDER for all four velocity variables are shown in Figure 7-12. The mean values for those individuals performing the no-stress condition first (order = 1) were higher across all four velocity variables.

The analysis also revealed a significant effect of ORDER for the two right-hand acceleration variables, aRRUacc ($F\{1,16\} = 6.28$, $p=0.0242$) and aRFEacc ($F\{1,16\} = 8.96$, $p=0.0086$). The mean right hand accelerations for those performing the no-stress condition first (order = 1) were 126.6% and 132.7% (for aRRUacc and aRFEacc) of the mean accelerations who performed the stress condition first (order = 2). The mean values by ORDER for the acceleration variables are shown in Figure 7-13. Though only significant for aRRUacc and aRFEacc, the mean values for those individuals performing the no-stress condition first (order = 1) were higher across all four acceleration variables.

The analysis revealed a significant effect of ORDER for one normalized range of motion variable, nromRFE ($F\{1,16\} = 6.91$, $p=0.0182$). The mean nromRFE value for those individuals performing the no-stress condition first (order = 1) was 18.4% lower than for those performing it last (order = 1). The mean values by ORDER for the normalized range of motion variables are shown in Figure 7-14.

The analysis revealed a significant GENDER x ORDER interaction effect for romLRU ($F\{1,15\} = 4.93$, $p=0.0422$) and nromLRU ($F\{1,15\} = 5.77$, $p=0.0297$). The mean romLRU and nromLRU values for each GENDER x ORDER combination are shown in Figure 7-15 and Figure 7-16, respectively. Subsequent analyses demonstrated that there was a simple effect of gender for order 1 but not for order 2. There was also a simple effect of order for Males but not for Females. These same results were obtained for nromLRU.

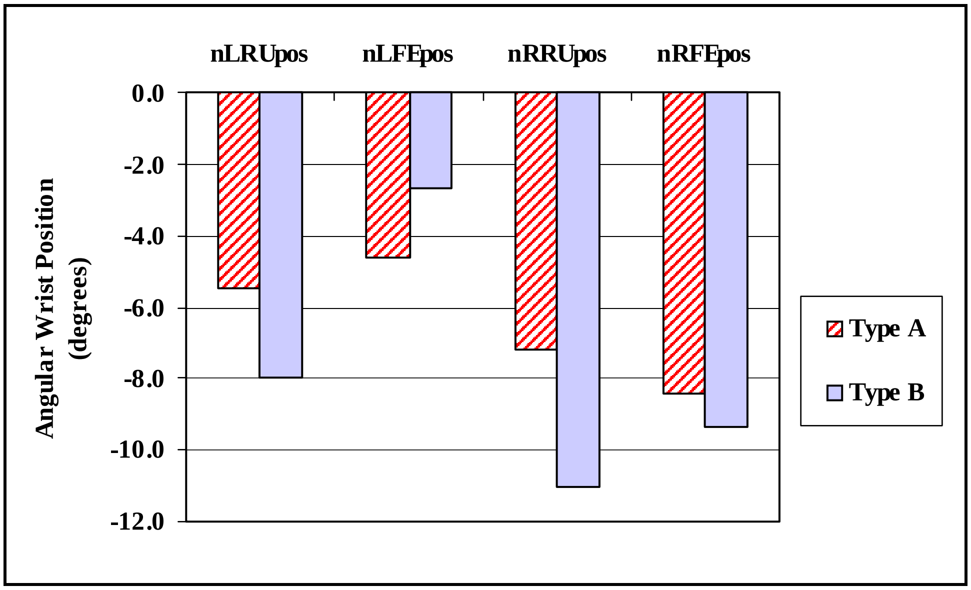


Figure 7-11. Significant (for nRRUpos) and nonsignificant (for others) effects of personality type (TYPE) on angular wrist positions.

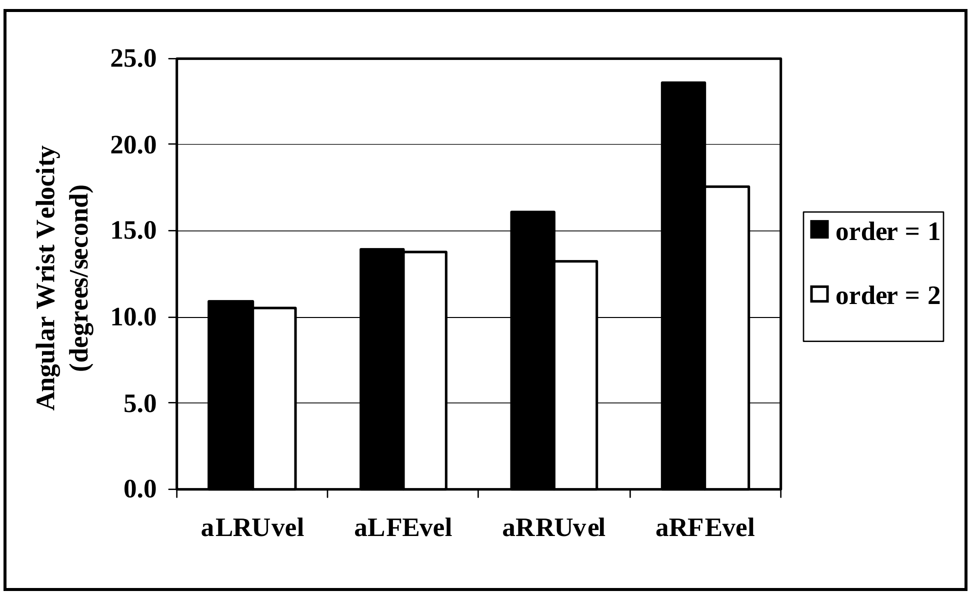


Figure 7-12. Significant (for aRRUvel and aRFEvel) and nonsignificant (for aLRUvel and aLFEvel) effects of stress condition order (ORDER) on angular wrist velocities.

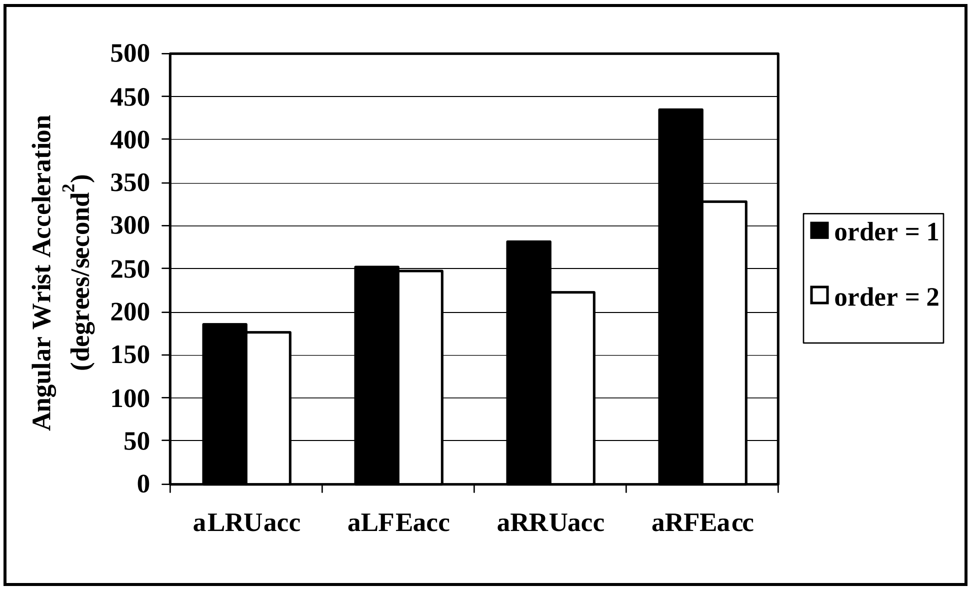


Figure 7-13. Significant (for aRRUacc and aRFEacc) and nonsignificant (for aLRUacc and aLFEacc) effects of stress condition order (ORDER) on angular wrist accelerations.

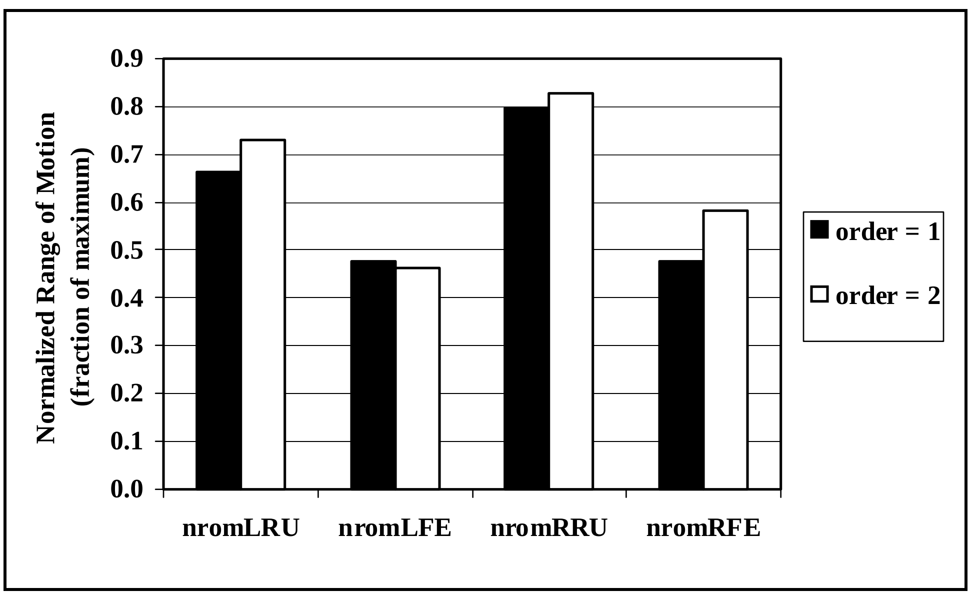


Figure 7-14. Significant (for nromRFE) and nonsignificant (for others) effects of stress condition order (ORDER) on normalized wrist range of motion values.

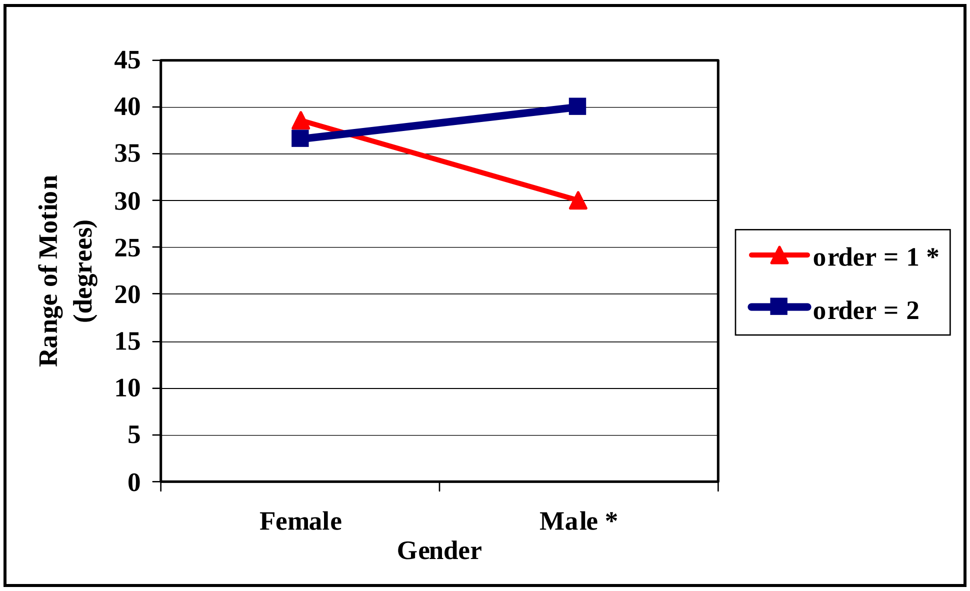


Figure 7-15. Significant interaction effect (p=0.0422) of gender (GENDER) and stress condition order (ORDER) for romLRU. (* indicates simple effect within this level of independent variable.)

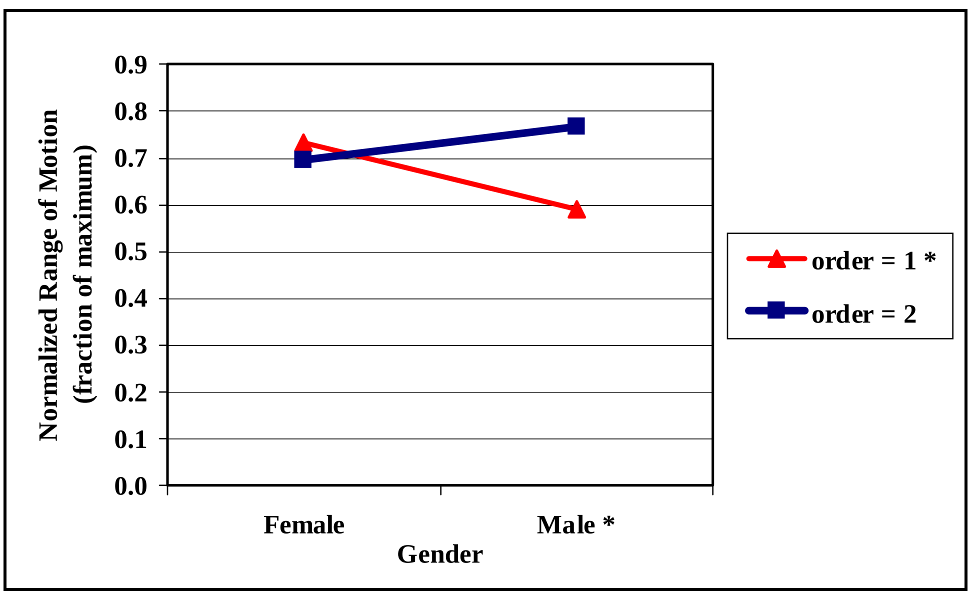


Figure 7-16. Significant interaction effect (p=0.0297) of gender (GENDER) and stress condition order (ORDER) for nromLRU. (* indicates simple effect within this level of independent variable.)

7.4.3.4 Within-subjects Effects

Wrist motion kinematic variables (20 variables) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed a highly significant main effect of STRESS for many of the variables. Some 2-way, 3-way, and 4-way interaction effects were also obtained. These are described here.

The analysis revealed a significant main effect of STRESS for nRRUpos ($F\{1,15\} = 5.63$, $p=0.0314$) and an almost significant effect for nRFEpos ($F\{1,16\} = 4.34$, $p=0.0535$). The mean values by STRESS condition are shown in Figure 7-17 for all four position variables. From the figure, it can be seen that the mean position values were lower for the no-stress condition across all four variables. The mean no-stress positions ranged from -3.1 degrees to-8.8 degrees. The mean stress condition positions ranged from -4.2 degrees to -9.4 degrees. The stress condition values were 104.3% to 135.6% of the no-stress condition values. The mean nRRUpos for the stress condition was -9.4 degrees, 107.2% of the no-stress value. The right-hand angular deviations appeared to be greater than the left-hand deviations, though this was not evaluated statistically.

The analysis revealed a significant main effect of STRESS for all four velocity variables ($F\{1,15\} = 70.11$, $p<0.0001$ for aLRUvel; $F\{1,16\} = 34.29$, $p<0.0001$ for aLFEvel; $F\{1,15\} = 20.96$, $p=0.0004$ for aRRUvel; $F\{1,16\} = 6.53$, $p=0.0211$ for aRFEvel). The mean values by STRESS condition are shown in Figure 7-18 for all four velocity variables. From the figure, it can be seen that the mean velocity values were significantly lower for the no-stress condition across all four variables. The mean no-stress velocities ranged from 9.7 degrees/second to 19.6 degrees/second. The mean stress condition velocities ranged from 11.7 to 21.6 degrees/second. The stress condition velocities were 107.8% to 121.5% of the no-stress condition values. The right-hand angular velocities appeared to be greater than the left-hand velocities, though this was not evaluated statistically.

The analysis revealed a highly significant main effect of STRESS for three acceleration variables ($F\{1,15\} = 64.63$, $p<0.0001$ for aLRUacc; $F\{1,16\} = 35.16$, $p<0.0001$ for aLFEacc; $F\{1,15\} = 25.34$, $p=0.0001$ for aRRUacc) and an almost significant ($F\{1,16\} = 4.47$, $p=0.0505$) effect for aRFEacc. The mean values by STRESS condition are shown in Figure 7-19 for all four acceleration variables. From the figure, it can be seen that the mean acceleration values were lower for the no-stress condition across all four variables. The mean no-stress accelerations ranged from 160.9 to 358.9 degrees/second^2. The mean stress condition accelerations ranged from 200.4 to 404.8 degrees/second^2. The stress condition accelerations were 112.8% to 126.4% of the no-stress condition values. The right-hand angular accelerations appeared to be greater than the left-hand accelerations, though this was not evaluated statistically.

The analysis revealed a significant ($F\{1,15\} = 31.66$, $p<0.0001$) main effect of STRESS for one range of motion variable, romLRU. The mean values by STRESS condition are shown in Figure 7-20 for all four range of motion variables. From the figure, it can be seen that the mean range of motion values were lower for the no-stress condition for the left-hand variables but higher for the right-hand variables when compared to the stress condition. The mean no-stress angular range of motion values ranged from 35.0 to 56.4 degrees. The mean stress condition values ranged from 37.2 to 55.1 degrees. The stress values were 106.3% and 102.7% of the no-stress values for romLRU and romLFE, respectively. The stress values were 99.6% and 97.8% of the no-stress values for romRRU and romRFE, respectively. The flexion/extension range of motion values appeared to be greater than the radial/ulnar range of motion values, though this was not evaluated statistically.

The analysis revealed a significant ($F\{1,15\} = 29.41$, $p<0.0001$) main effect of STRESS for one normalized range of motion variable, nromLRU. The mean values by STRESS condition are shown in Figure 7-21 for all four normalized range of motion variables. From the figure, it can be seen that the mean range of motion values were lower for the no-stress condition for the left-hand variables but higher for the right-hand variables when compared to the stress condition. The mean no-stress normalized range of motion values ranged from 0.46 to 0.81. The mean stress condition values ranged from 0.48 to 0.81. The stress values were 106.4% and 102.9% of the no-stress values for nromLRU and nromLFE, respectively. The stress values were 99.4% and 97.6% of the no-stress values for nromRRU and nromRFE, respectively. The flexion/extension normalized range of motion values appeared to be lower than the radial/ulnar normalized range of motion values, though this was not evaluated statistically.

The analysis revealed a significant 2-way interaction effect of GENDER x STRESS for aLRUvel ($F\{1,15\} = 14.60$, $p=0.0017$) and aLRUacc ($F\{1,15\} = 9.88$, $p=0.0067$). The mean aLRUvel values for each GENDER x STRESS combination can be seen in Figure 7-22. The mean aLRUacc values for each GENDER x STRESS combination can be seen in Figure 7-23. From the figures, it appears that Females and Males demonstrated similar left radial/ulnar angular velocities and accelerations under the stress condition, but responded differently under the no-stress condition. Under the stress condition, mean aLRUvel and aLRUacc values for Males were 101.9% and 99.9%, respectively, of the mean values for Females. However, Females experienced higher left radial/ulnar angular velocities and accelerations than males under the no-stress condition. Mean aLRUvel and aLRUacc values for Males were 83.4% and 81.6%, respectively, of mean values for Females. Subsequent analyses demonstrated that there was a simple effect of stress for both Females and Males, indicating that the main effect obtained for STRESS held for both genders. However, there were no differences between genders for either of the stress conditions. These same results were obtained for aLRUacc.

The analysis revealed a significant 2-way interaction effect of GENDER x STRESS for romLRU ($F\{1,15\} = 5.80$, $p=0.0294$) and nromLRU ($F\{1,15\} = 5.11$, $p=0.0392$). The mean romLRU values for each GENDER x STRESS combination can be seen in Figure 7-24. The means ranged from 33.4 to 38.2 degrees. The mean nromLRU values for each GENDER x STRESS combination can be seen in Figure 7-25. The mean nromLRU values ranged from 0.65 to 0.73. From the figures, it appears that Females and Males demonstrated more similar left radial/ulnar range of motion values under the stress condition than under the no-stress condition. Subsequent analyses demonstrated that there was a simple effect of stress for both Females and Males, indicating that the main effect obtained for STRESS held for both genders. However, there were no differences between genders for either of the stress conditions. The same results were obtained for nromLRU.

The analysis revealed a significant 2-way interaction effect of ORDER x STRESS for romLRU ($F\{1,15\} = 7.76$, $p=0.0139$) and nromLRU ($F\{1,15\} = 7.26$, $p=0.0166$). The mean romLRU values for each ORDER x STRESS combination can be seen in Figure 7-26. The means ranged from 33.7 to 40.0 degrees. The mean nromLRU values for each ORDER x STRESS combination can be seen in Figure 7-27. The mean nromLRU values ranged from 0.65 to 0.77. From the figures, it can be seen that mean left radial/ulnar range of motion values were consistently higher for those individuals who performed the stress condition first (order=2). Means for the two stress condition orders were more similar under the stress condition than under the no-stress condition. Under the stress condition, mean romLRU and nromLRU values for those performing the stress condition first (order=2) were 114.7% and 114.6%, respectively, of the mean values for those performing the no-stress condition first (order=1). Under the no-stress condition, mean romLRU and nromLRU values for those performing the stress condition first (order=2) were 108.4% and 108.0%, respectively, of mean values for those performing the no-stress condition first (order=1). Subsequent analyses demonstrated that there was a simple effect of stress for order 2 but not for order 1. However, there were no differences between orders for either of the stress conditions. The same results were obtained for nromLRU.

No other significant 2-way interaction effects of ORDER x STRESS were obtained.

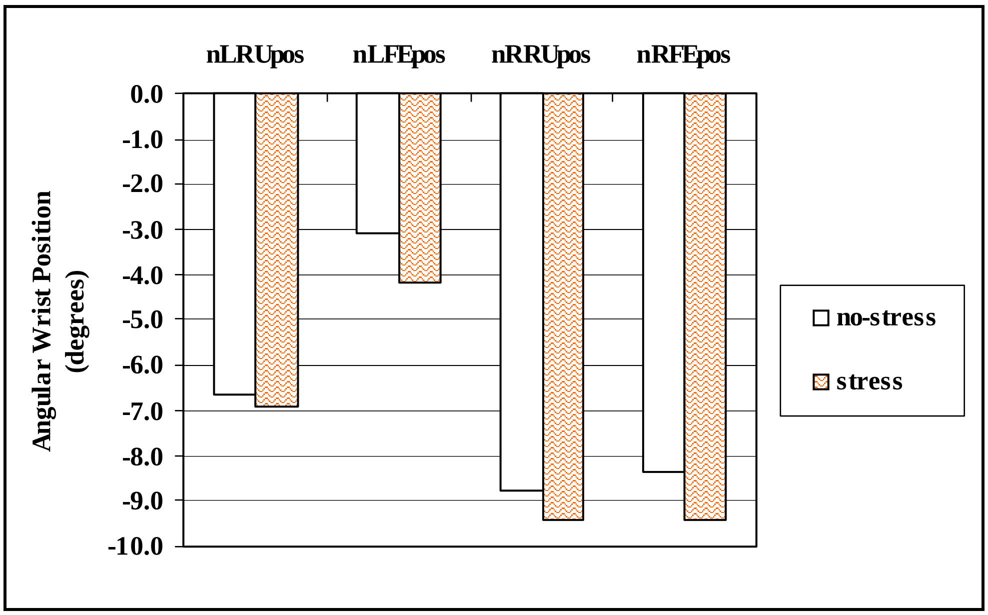


Figure 7-17. Significant (for nRRUpos), almost significant (for nRFEpos), and nonsignificant (for others) effects of stress condition (STRESS) on angular wrist positions.

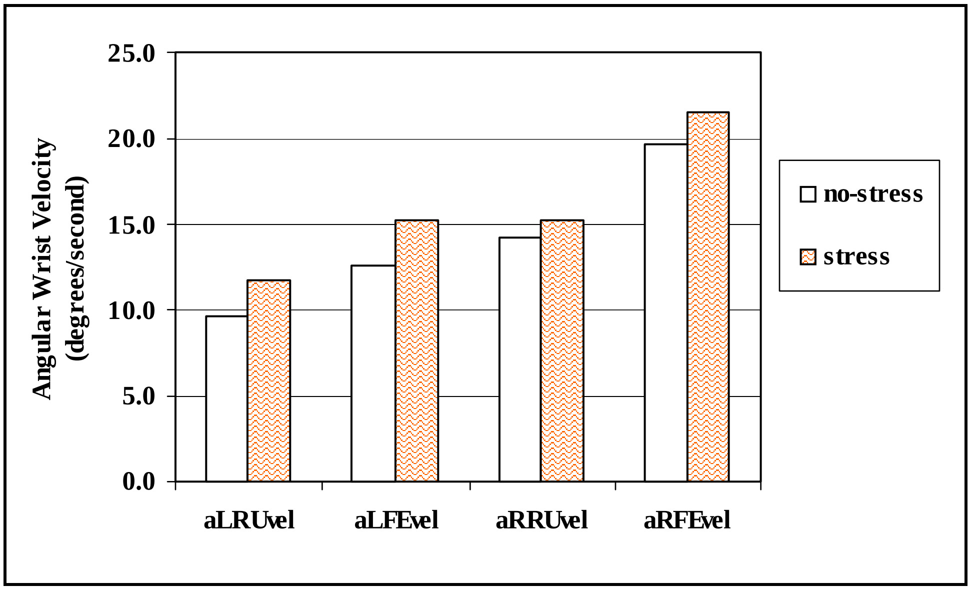


Figure 7-18. Significant effects of stress condition (STRESS) on angular wrist velocities.

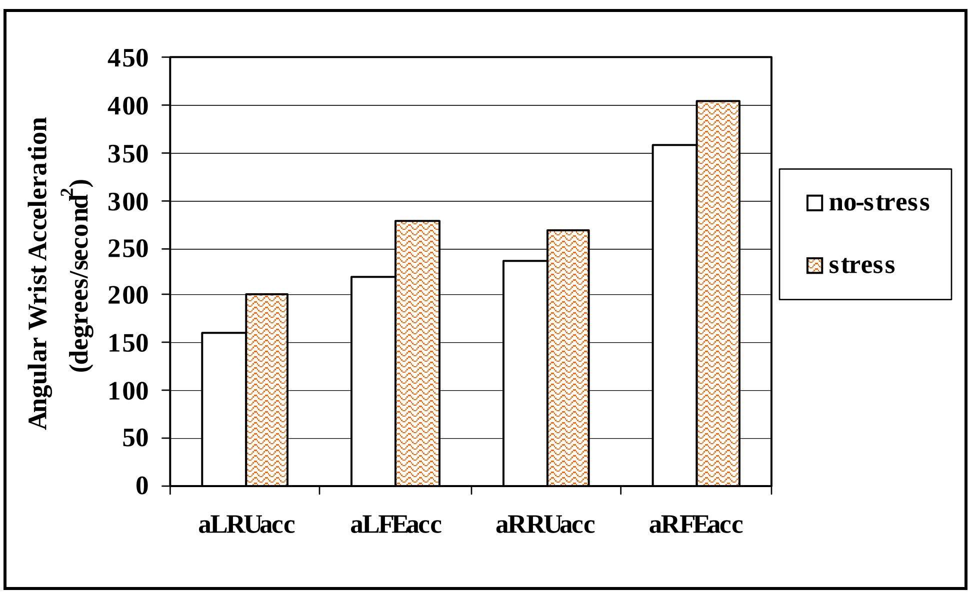


Figure 7-19. Significant (except p=0.0505 for aRFEacc) effects of stress condition (STRESS) on angular wrist accelerations.

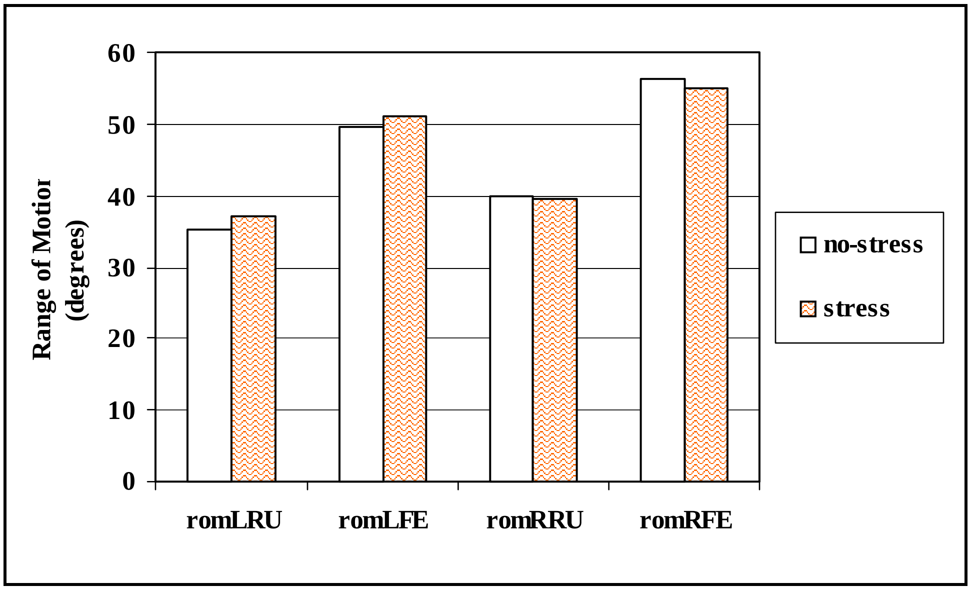


Figure 7-20. Significant (for romLRU) and nonsignificant (for others) effects of stress condition (STRESS) on wrist range of motion values.

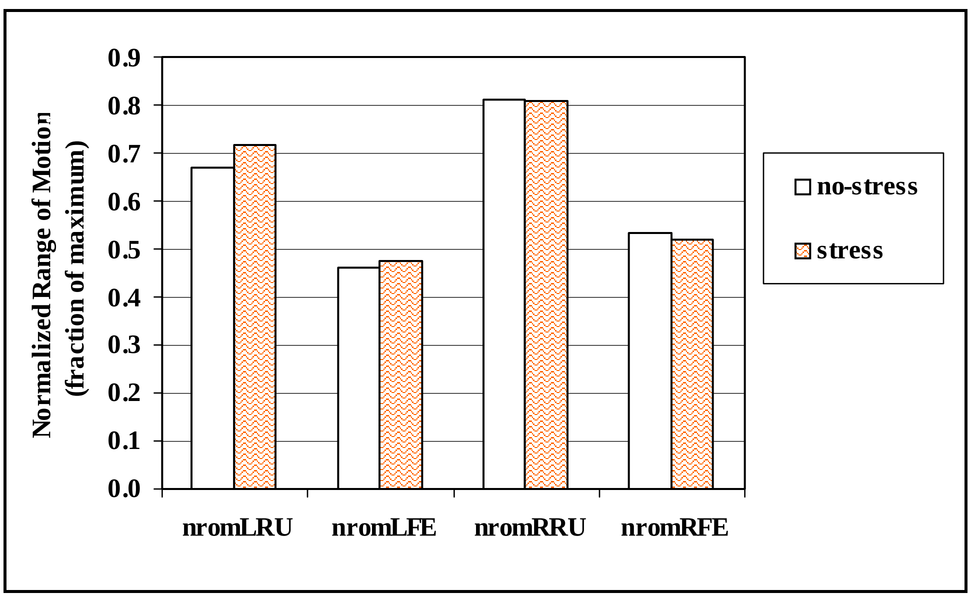


Figure 7-21. Significant (for nromLRU) and nonsignificant (for others) effects of stress condition (STRESS) on normalized range of motion values.

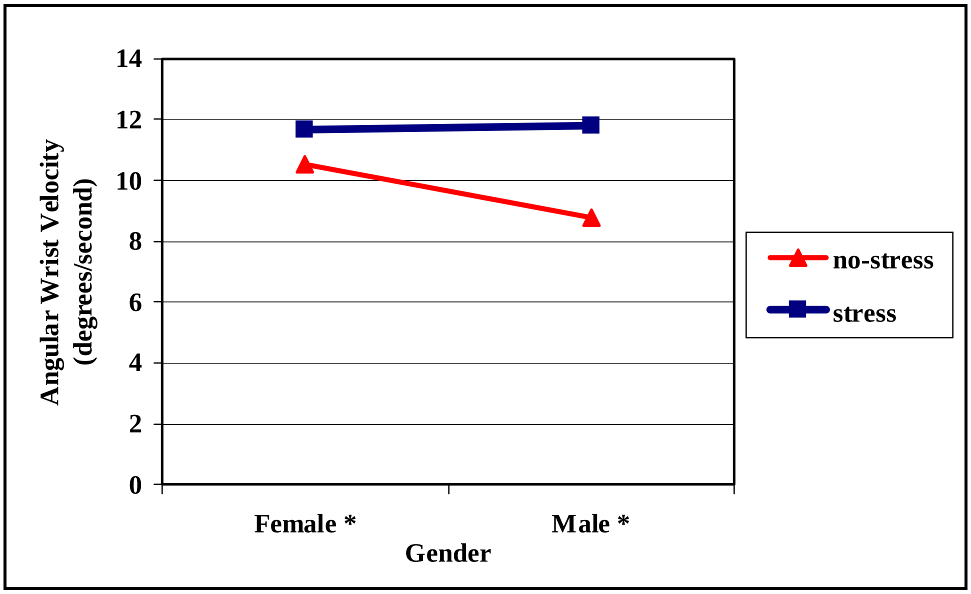


Figure 7-22. Significant interaction effect ($p=0.0017$) of gender (GENDER) and stress condition (STRESS) for aLRUvel. (* indicates simple effect within this level of independent variable.)

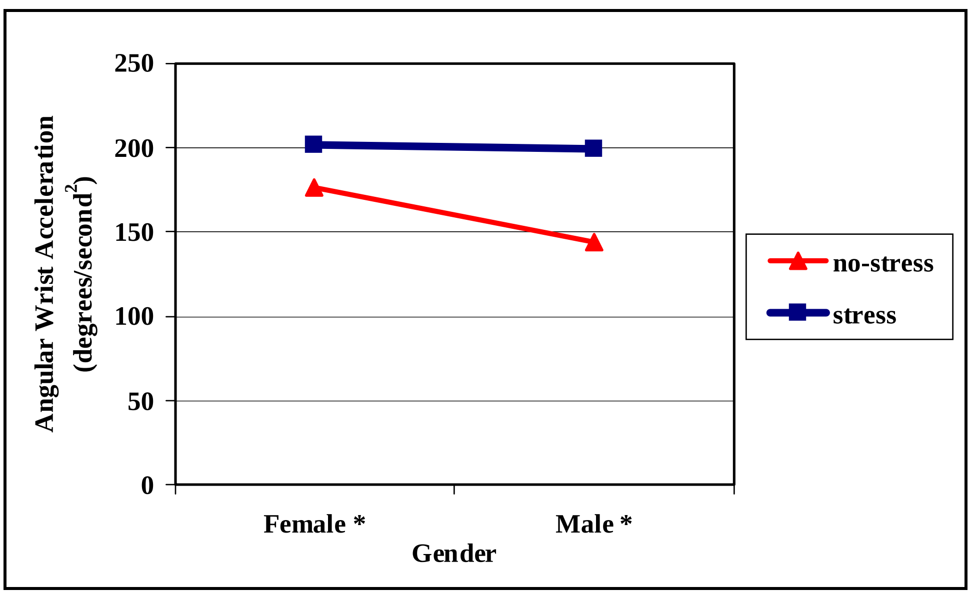


Figure 7-23. Significant interaction effect ($p=0.0067$) of gender (GENDER) and stress condition (STRESS) for aLRUacc. (* indicates simple effect within this level of independent variable.)

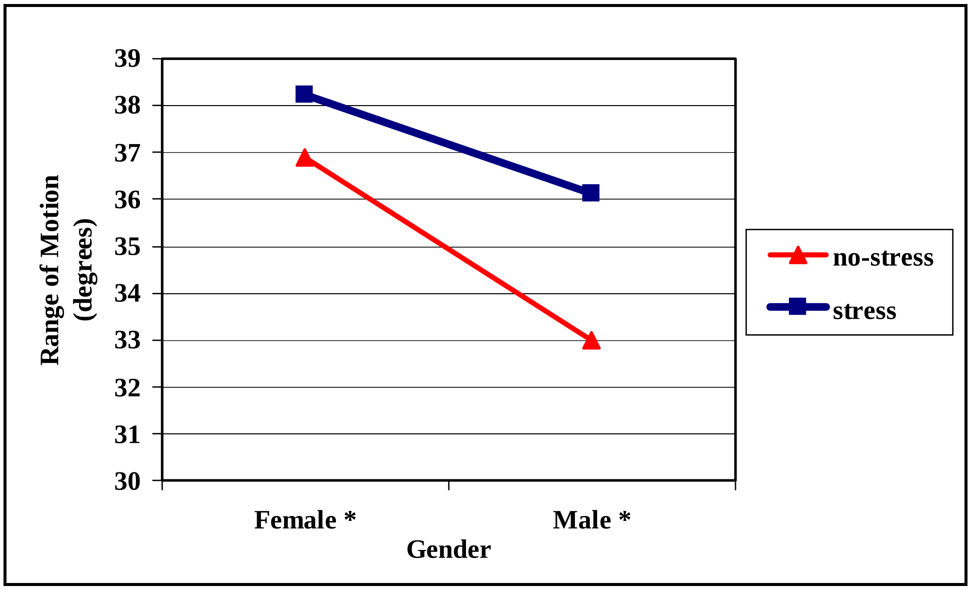


Figure 7-24. Significant interaction effect (p=0.0294) of gender (GENDER) and stress condition (STRESS) for romLRU. (* indicates simple effect within this level of independent variable.)

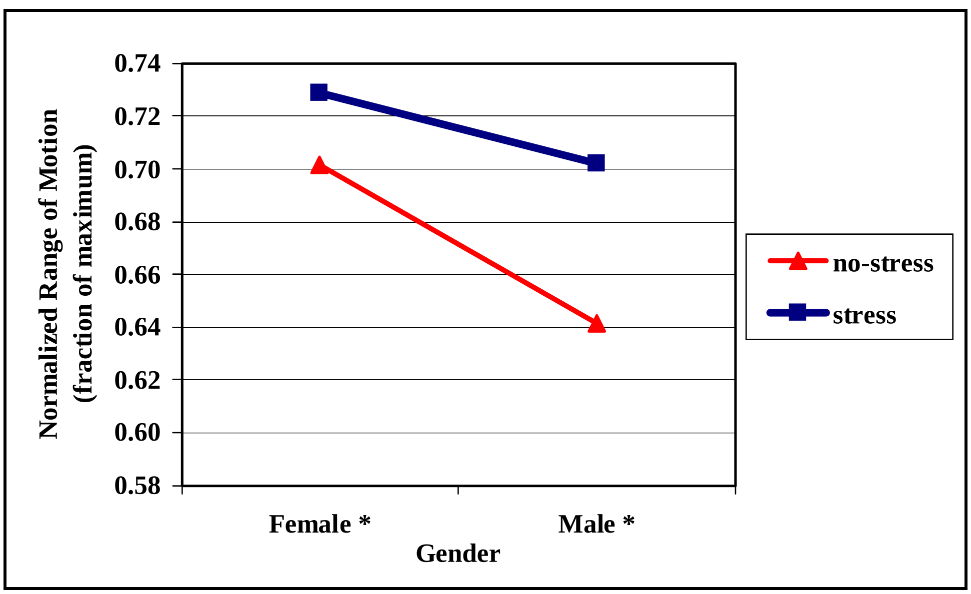


Figure 7-25. Significant interaction effect (p=0.0392) of gender (GENDER) and stress condition (STRESS) for nromLRU. (* indicates simple effect within this level of independent variable.)

Figure 7-26. Significant interaction effect (p=0.0139) of stress condition order (ORDER) and stress condition (STRESS) for romLRU. (* indicates simple effect within this level of independent variable.)

Figure 7-27. Significant interaction effect (p=0.0166) of stress condition order (ORDER) and stress condition (STRESS) for nromLRU. (* indicates simple effect within this level of independent variable.)

7.4.3.5 Summary of Findings for Workstyle-related Wrist Motion Kinematics

Personality type did not significantly impact workstyle as measured by wrist motion kinematics. Only one of the measures was significantly different between personality types. Type B's had 53% greater (approximately 4 degrees) mean right-hand ulnar deviation (negative value for nRRUpos) than Type A's.

Psychosocially-imposed time stress had a consistent effect on wrist motion velocities and accelerations, but not on hand/wrist positions. Velocities and accelerations increased by 8 to 26% under time stress. Though the mean positions during the stress condition were 104.3% to 135.6% of the mean no-stress values, only nRRUpos was found to be significantly higher (by 7%). Stress also increased left radial/ulnar absolute and normalized range of motion, but only significantly (by 9%) when the stress condition was performed first.

Stress condition order had additional effects for some findings. Right-hand velocity and acceleration variables were 22 to 34 % *higher* for those who performed the no-stress condition first (order = 1) compared to those who performed it last (order = 2). Order also impacted right flexion/extension normalized range of motion, which was 18% *lower* for those who performed the no-stress condition first.

7.4.4 Specific Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety

7.4.4.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for the post-task survey administrations for each of the self-report musculoskeletal discomfort and anxiety variables are contained in Table 7-11.

Table 7-11. Summary statistics for self-report musculoskeletal discomfort and anxiety variables for post-task survey administrations (48 observations).

Discomfort Measure	units	N	Mean	Standard Deviation	Minimum	Maximum
MDSh	centimeters	48	0.263	0.821	0.000	3.800
MDSnsL	centimeters	48	0.613	1.247	0.000	4.700
MDSnsR	centimeters	48	0.696	1.575	0.000	5.500
MDSaeL	centimeters	48	0.000	0.000	0.000	0.000
MDSaeR	centimeters	48	0.000	0.000	0.000	0.000
MDShwL	centimeters	48	0.000	0.000	0.000	0.000
MDShwR	centimeters	48	0.000	0.000	0.000	0.000
MDSubL	centimeters	48	0.329	1.147	0.000	7.300
MDSubR	centimeters	48	0.148	0.456	0.000	2.300
MDSlbL	centimeters	48	0.894	1.288	0.000	4.600
MDSlbR	centimeters	48	0.908	1.412	0.000	5.500
MDSlfL	centimeters	48	0.558	1.242	0.000	5.600
MDSlfR	centimeters	48	0.708	1.357	0.000	5.300
MDSavg	centimeters	48	0.394	0.413	0.000	1.908
MDSupx	centimeters	48	0.218	0.432	0.000	1.700
MDSbak	centimeters	48	0.570	0.684	0.000	2.525
ANXtot		48	20.06	4.51	15	32

Possible MDS visual analogue scale scores ranged from 0 to 10 centimeters. Possible ANXtot score ranged from 15 to 60. Actual dependent variables are MDSavg, MDSupx, and MDSbak. Others provided for reference.

7.4.4.2 General Statistical Analysis and Results

The effects of the independent variables on self-reported musculoskeletal discomfort and state anxiety were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The discomfort scores (MDSavg, MDSupx, and MDSbak) and the state anxiety scores (ANXtot) obtained from the two post-task administrations (3N and 3S) were evaluated with individual ANOVA's. The results of the analyses for those 48 observations are summarized in Table 7-12 and Table 7-13 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.4.

Table 7-12. Model #1 resulting between-subjects p-values of individual discomfort and anxiety ANOVA's for post-task administrations only (48 observations).

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
MDSavg	ns	ns	ns	**0.0180**	ns	ns	ns
MDSupx	ns	ns	ns	ns	ns	**0.0360**	ns
MDSbak	ns	ns	ns	0.0636	ns	ns	ns
ANXtot	ns	ns	**0.0181**	**0.0122**	ns	ns	**0.0122**

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \le p \le 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 7-13. Model #1 resulting within-subjects p-values of individual discomfort and anxiety ANOVA's for post-task administrations only (48 observations).

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
MDSavg	ns	ns	ns	**0.0006**	ns	**0.0271**	**0.0088**	ns
MDSupx	ns	ns	ns	ns	ns	ns	ns	ns
MDSbak	ns	ns	ns	**0.0203**	ns	ns	ns	ns
ANXtot	**0.0076**	ns	ns	ns	0.0679	ns	**0.0273**	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \le p \le 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

7.4.4.3 Self-reported Musculoskeletal Discomfort

7.4.4.3.1 Between-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. There were no significant main effects for the between-subjects variables for any of the three composite discomfort scores.

The means for the composite discomfort scores by personality TYPE ranged from 0.210 to 0.776. Though statistically nonsignificant, all three mean composite discomfort scores were higher for Type B individuals than Type A individuals. The mean Type B MDSavg score was 191% of the mean Type A score. The mean Type B MDSupx score was 107% of the mean Type A score. The mean MDSbak score was 213% of the mean Type A score. This trend can be seen in Figure 13-6 of Appendix 13.4.

The means for the composite discomfort scores by GENDER ranged from 0.145 to 0.731. Though statistically nonsignificant, mean composite discomfort scores by GENDER are shown in Figure 13-7 of Appendix 13.4. The mean MDSavg and MDSbak scores were lower for males than for females. The mean MDSavg for males was 72% of the mean score for females. The mean MDSbak score was 56% of the mean score for females. However, the mean MDSupx score for males was 200% of the mean score for females.

The means for the composite discomfort scores by ORDER ranged from 0.172 to 0.684. Though statistically nonsignificant, mean composite discomfort scores by ORDER are shown in Figure 13-8 of Appendix 13.4. The mean MDSavg and MDSbak scores were lower (ratio of 86% and 66%, respectively) for those who performed the stress condition first (order = 2). The mean MDSavg score for those performing the stress condition first (order = 2) was 86% of the mean score for those performing the no-stress condition first (order = 1). The mean MDSbak score for those performing the stress condition first (order = 2) was 66% of the mean score for those performing the no-stress condition first (order = 1). The mean MDSupx score was higher for those who performed the stress condition first. The mean MDSupx score for those performing the stress condition first (order = 2) was 153% of the mean score for those performing the no-stress condition first (order = 1).

The ANOVA analysis also revealed a significant interaction effect of TYPE x GENDER ($F\{1,16\} = 6.95$, $p=0.0180$) for MDSavg. The mean scores for each TYPE x GENDER combination can be seen in Figure 7-28. Subsequent analyses demonstrated that there was a simple effect of personality type for Females but not for Males. There was also a simple effect of gender for Type B's but not for Type A's. The ANOVA analysis also revealed a significant interaction effect of GENDER x ORDER ($F\{1,16\} = 5.24$, $p=0.0360$) for MDSupx. The mean scores for each GENDER x ORDER combination can be seen in Figure 7-29. Subsequent analyses demonstrated that there was a simple effect of gender for order 2 but not for order 1. However, there were no differences between orders for either gender.

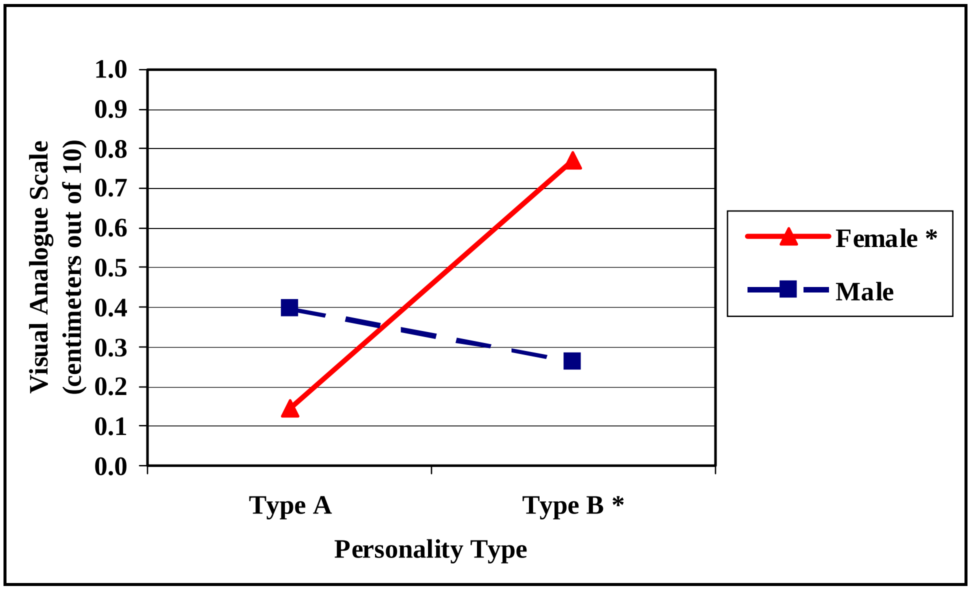


Figure 7-28. Significant interaction effect (p=0.0180) of personality type (TYPE) and gender (GENDER) on MDSavg discomfort scores for post-task administrations only (48 observations). (* indicates simple effect within this level of independent variable.)

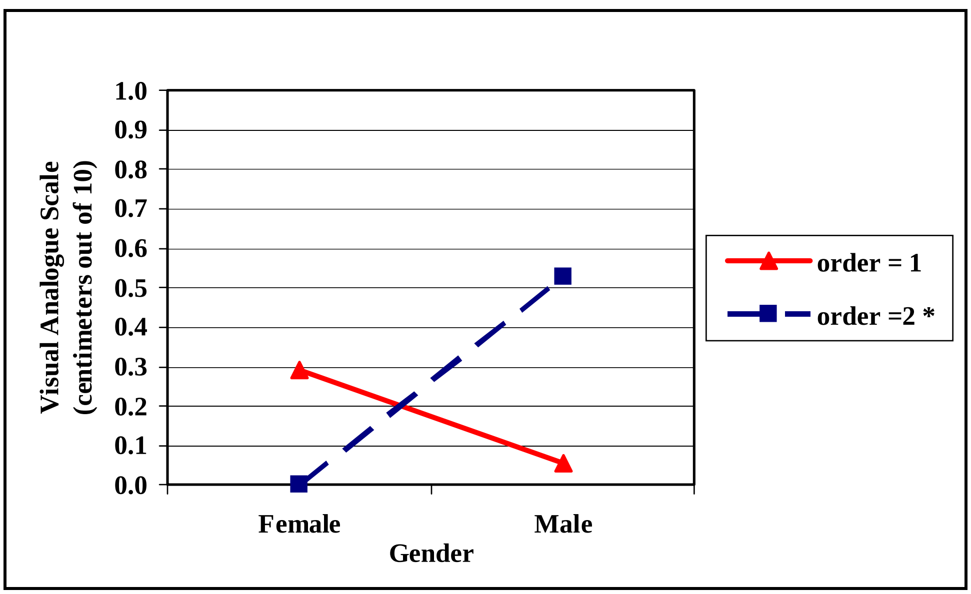


Figure 7-29. Significant interaction effect (p=0.0360) of gender (GENDER) and stress condition order (ORDER) on MDSupx discomfort scores for post-task administrations only (48 observations). (* indicates simple effect within this level of independent variable.)

7.4.4.3.2 Within-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed no significant main effects of STRESS for MDSavg ($F\{1,16\} = 0.23$, $p=0.6363$), MDSupx ($F\{1,16\} = 0.00$, $p=0.9544$), and MDSbak ($F\{1,16\} = 0.99$, $p=0.3356$). The mean scores by STRESS condition can be seen in Figure 13-9 of Appendix 13.4. From the figure, it can be seen that the mean scores for the stress condition were similar across all three discomfort measures and ranged from 0.217 to 0.608. The mean MDSavg, MDSupx, and MDSbak scores for the stress condition were 96%, 101%, and 114%, respectively, of the means for the no-stress condition.

The ANOVA analysis revealed a significant interaction effect of ORDER x STRESS for MDSavg ($F\{1,16\} = 18.32$, $p=0.0006$) and MDSbak ($F\{1,16\} = 6.63$, $p=0.0203$). The mean MDSavg scores for each ORDER x STRESS combination can be seen in Figure 7-30. The mean MDSbak scores for each ORDER x STRESS combination can be seen in Figure 7-31. Subsequent analyses demonstrated that there was a simple effect of stress on MDSavg for both order 1 and order 2, but in opposite directions. However, there were no differences in MDSavg between orders for either of the stress conditions. Subsequent analyses demonstrated that there was a simple effect of stress on MDSbak for order 1 but not for order 2. However, there were no differences in MDSbak between orders for either of the stress conditions.

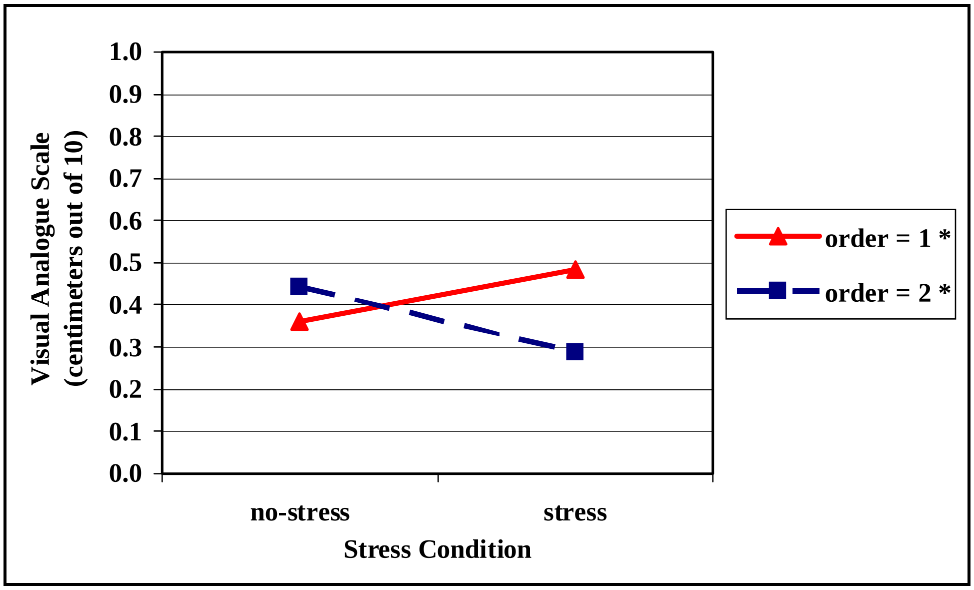


Figure 7-30. Significant interaction effect (p=0.0006) of stress condition order (ORDER) and stress condition (STRESS) on MDSavg discomfort scores for post-task administrations only (48 observations). (* indicates simple effect within this level of independent variable.)

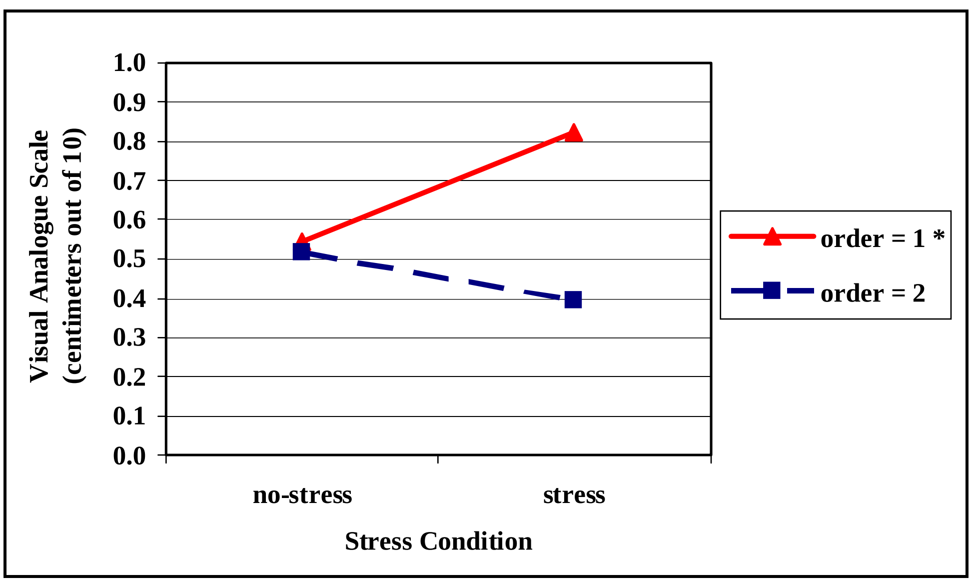


Figure 7-31. Significant interaction effect (p=0.0203) of stress condition order (ORDER) and stress condition (STRESS) on MDSbak discomfort scores for post-task administrations only (48 observations). (* indicates simple effect within this level of independent variable.)

7.4.4.4 Self-reported State Anxiety

7.4.4.4.1 Between-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. This analysis revealed no significant main effects of personality TYPE ($F\{1,16\} = 0.17$, $p=0.6854$) or GENDER ($F\{1,16\} = 0.36$, $p=0.5550$). The mean Type A and B scores were 20.333 and 19.792, respectively. The mean Female and Male scores were 20.5 and 19.7, respectively.

The analysis revealed a significant main effect for stress condition ORDER ($F\{1,16\} = 6.94$, $p=0.0181$). The mean score was 21.8 for those subjects who performed the no-stress condition first (order = 1), 19% higher than the mean score of 18.3 obtained for those who performed the stress condition first (order = 2). This effect can be seen in Figure 7-32.

The ANOVA analysis also revealed a significant interaction effect of TYPE x GENDER ($F\{1,16\} = 7.98$, $p=0.0122$). The mean scores for each TYPE x GENDER combination can be seen in Figure 7-33. Subsequent analyses demonstrated that there was a simple effect of personality type for Females but not for Males. Type A females reported 56% higher anxiety levels than Type B females. There was also a simple effect of gender for Type A's but not for Type B's.

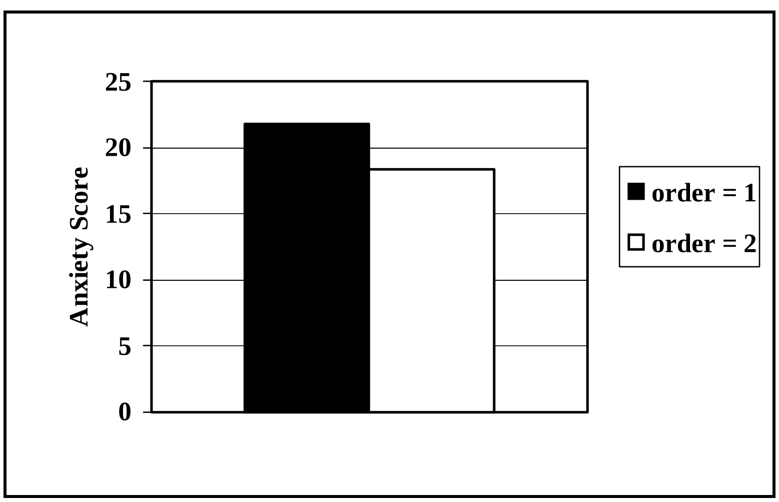


Figure 7-32. Significant effect (p=0.0181) of stress condition order (ORDER) on state anxiety scores for post-task administrations only (48 observations).

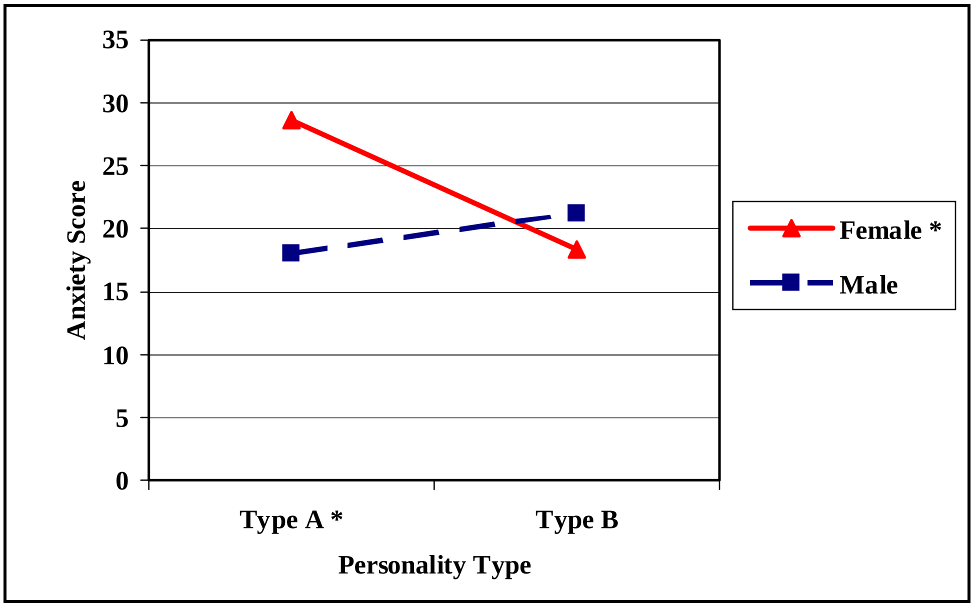


Figure 7-33. Significant interaction effect (p=0.0122) of personality type (TYPE) and gender (GENDER) on state anxiety scores for post-task administrations only (48 observations). (* indicates simple effect within this level of independent variable.)

7.4.4.4.2 Within-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed a significant main effect ($F\{1,16\} = 9.33$, $p=0.0076$) for STRESS. Mean ANXtot scores by stress condition are shown in Figure 7-34. The mean anxiety score for the stress condition was significantly higher than the mean for the no-stress condition. The mean values were 20.9 and 19.2 for the stress and no-stress conditions, respectively. The stress condition score was 108.4% of the no-stress condition score.

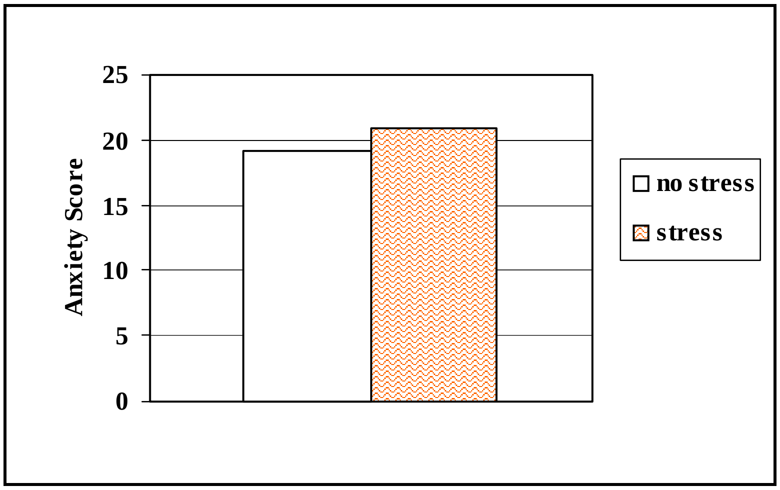


Figure 7-34. Significant effect (p=0.0076) of stress condition (STRESS) on state anxiety scores for post-task administrations only (48 observations).

7.4.4.5 Summary of Findings for Specific Discomfort/Anxiety Reporting Behaviors Following the Assembly Task

Effects of personality type on reporting behaviors were limited to females. Overall post-task average discomfort (MDSavg) was significantly higher for Type B females than Type A females, by more than 400%. Type A females reported 56% higher post-task anxiety levels than Type B females.

Psychosocially-imposed time stress also affected reporting behaviors in a limited way. Stress had no effect on any of the composite discomfort scores, except as moderated by condition order. Average discomfort scores (MDSavg) reported following the stress condition were higher when it was performed last, but lower when it was performed first. The same relationships were obtained for average back discomfort, but the stress condition only significantly impacted (increased by 51%) discomfort when the stress condition was performed last. Stress did increase anxiety scores by 8%, but there was a larger difference (19%) between condition orders.

7.4.5 General Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety

7.4.5.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects and all observations for each of the self-report musculoskeletal discomfort and anxiety variables are contained in Table 7-14.

The mean composite discomfort scores by survey administration (SURVEY) can be seen in Figure 7-35. From the figure, it can be seen that mean MDSavg and MDSbak scores were higher following the task trials (administrations 3N and 3S) than they were at the other times (1, 2, and 4).

The mean ANXtot scores by survey administration (SURVEY) can be seen in Figure 7-36. From the figure, it appears that the mean scores are relatively constant across administrations 1, 2, 3N, and 3S, but lower for the final administration. The means were 20.71, 20.96, 19.25, and 20.88 for administrations 1, 2, 3N, and 3S, respectively. The mean for administration 4 was 17.42.

Table 7-14. Summary statistics for self-report musculoskeletal discomfort and anxiety variables for all survey administrations (120 observations).

Dependent Variable	units	N	Mean	Standard Deviation	Minimum	Maximum
MDSh	centimeters	120	0.105	0.532	0.000	3.800
MDSnsL	centimeters	120	0.483	1.192	0.000	5.200
MDSnsR	centimeters	120	0.544	1.455	0.000	6.300
MDSaeL	centimeters	120	0.013	0.146	0.000	1.600
MDSaeR	centimeters	120	0.015	0.164	0.000	1.800
MDShwL	centimeters	120	0.000	0.000	0.000	0.000
MDShwR	centimeters	120	0.000	0.000	0.000	0.000
MDSubL	centimeters	120	0.188	0.832	0.000	7.300
MDSubR	centimeters	120	0.103	0.485	0.000	4.200
MDSlbL	centimeters	120	0.594	1.153	0.000	4.700
MDSlbR	centimeters	120	0.631	1.348	0.000	6.500
MDSlfL	centimeters	120	0.243	0.850	0.000	5.600
MDSlfR	centimeters	120	0.373	1.056	0.000	5.300
MDSavg	centimeters	120	0.253	0.403	0.000	1.946
MDSupx	centimeters	120	0.176	0.424	0.000	1.917
MDSbak	centimeters	120	0.379	0.655	0.000	2.625
ANXtot		120	19.84	4.20	15	32

Possible MDS visual analogue scale scores ranged from 0 to 10 centimeters. Possible ANXtot score ranged from 15 to 60. Actual dependent variables are MDSavg, MDSupx, and MDSbak. Others provided for reference.

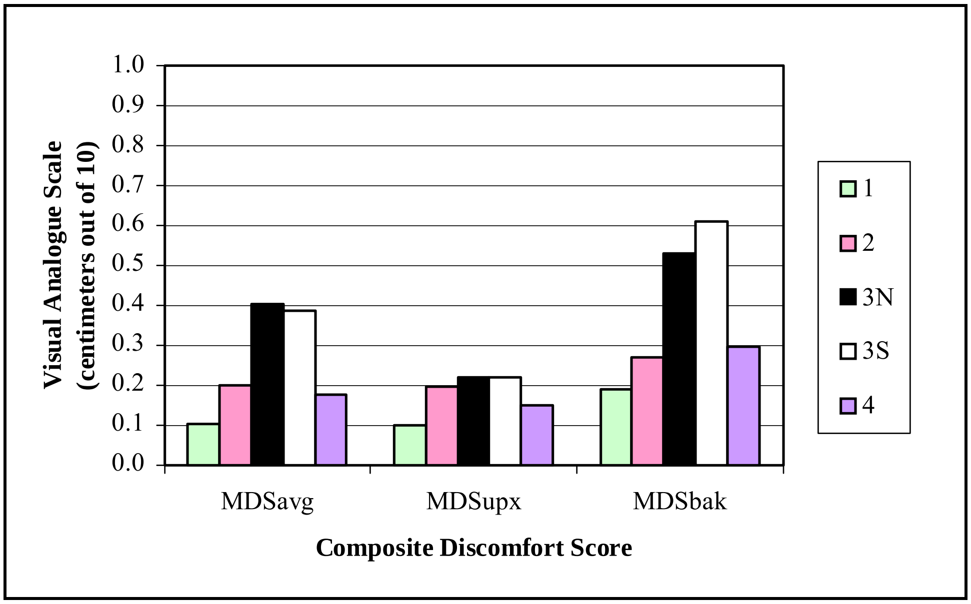


Figure 7-35. Mean composite discomfort scores by survey administration (SURVEY).

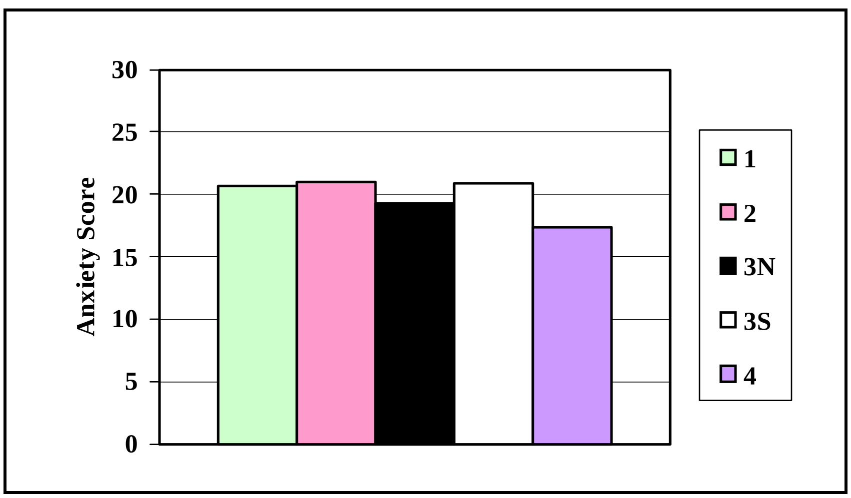


Figure 7-36. Mean state anxiety score by survey administration (SURVEY).

7.4.5.2 Correlations among Self-reported Discomfort Scores

Pearson correlation coefficients were generated for each of the composite MDS variables across the five survey administrations (SURVEY = 1, 2, 3N, 3S, and 4). This resulted in ten (10) unique correlations for each of the MDSavg, MDSupx, and MDSbak groups. All thirty (30) resulting correlations were highly significant. Results for each composite discomfort MDS variable are provided separately in Table 7-15, Table 7-16, and Table 7-17.

7.4.5.3 Correlations among Self-reported State Anxiety Scores

Pearson correlation coefficients were generated for each of the anxiety scores (ANXtot) across the five survey administrations (SURVEY = 1, 2, 3N, 3S, and 4). This resulted in ten (10) unique correlations between ANXtot scores, which are provided in Table 7-18. Seven correlations were significant. The three non-significant correlations involved ANXtot scores from the first administration.

7.4.5.4 Correlations between Self-reported Discomfort and Anxiety Scores

The relationship between self-reported measures of discomfort and state anxiety were evaluated with Pearson correlation coefficients. For each survey administration (SURVEY), correlations were computed between the anxiety score for that administration (e.g., ANXtot1) and the corresponding composite MDS scores (e.g., MDSavg1, MDSupx1, MDSbak1). This resulted in fifteen (15) unique correlations. None of these correlations were significant.

Table 7-15. Correlations among MDSavg discomfort scores across administrations (N = 24).

	MDSavg1	MDSavg2	MDSavg3N	MDSavg3S
MDSavg2	**0.8385**			
	<0.0001			
MDSavg3N	**0.6331**	**0.6674**		
	0.0009	*0.0004*		
MDSavg3S	**0.7750**	**0.7718**	**0.8303**	
	<0.0001	*<0.0001*	*<0.0001*	
MDSavg4	**0.9203**	**0.8181**	**0.8240**	**0.8412**
	<0.0001	*<0.0001*	*<0.0001*	*<0.0001*

p-values shown in italics. Significant correlations shown in bold.

Table 7-16. Correlations among MDSupx discomfort scores across administrations (N = 24).

	MDSupx1	MDSupx2	MDSupx3N	MDSupx3S
MDSupx2	**0.631**			
	0.0009			
MDSupx3N	**0.698**	**0.745**		
	0.0002	*<0.0001*		
MDSupx3S	**0.679**	**0.726**	**0.973**	
	0.0003	*<0.0001*	*<0.0001*	
MDSupx4	**0.887**	**0.624**	**0.892**	**0.882**
	<0.0001	*0.0011*	*<0.0001*	*<0.0001*

p-values shown in italics. Significant correlations shown in bold.

Table 7-17. Correlations among MDSbak discomfort scores across administrations (N = 24).

	MDSbak1	MDSbak2	MDSbak3N	MDSbak3S
MDSbak2	**0.941**			
	<0.0001			
MDSbak3N	**0.678**	**0.746**		
	0.0003	*<0.0001*		
MDSbak3S	**0.639**	**0.676**	**0.816**	
	0.0008	*0.0003*	*<0.0001*	
MDSbak4	**0.759**	**0.691**	**0.830**	**0.775**
	<0.0001	*0.0002*	*<0.0001*	*<0.0001*

p-values shown in italics. Significant correlations shown in bold.

Table 7-18. Correlations among state anxiety scores (ANXtot) across administrations (N = 24).

	ANXtot1	ANXtot2	ANXtot3N	ANXtot3S
ANXtot2	0.293			
	0.1647			
ANXtot3N	0.291	**0.715**		
	0.1673	*<0.0001*		
ANXtot3S	0.127	**0.819**	**0.796**	
	0.5531	*<0.0001*	*<0.0001*	
ANXtot4	**0.511**	**0.633**	**0.785**	**0.688**
	0.0107	*0.0009*	*<0.0001*	*0.0002*

p-values shown in italics. Significant correlations shown in bold.

7.4.5.5 *Summary of Findings for General Discomfort/Anxiety Reporting Behaviors for the Phase II Laboratory Study of an Assembly Task*

The evaluation of general reporting behaviors revealed that discomfort scores were significantly correlated (30 significant of 30 total) across administrations. Anxiety scores were also correlated (7 significant of 10 total), except for between the first administration and three of the other scores. There were no significant correlations between discomfort and anxiety scores obtained during each administration.

7.4.6 Sensitivity of Results to Excluding Higher Order Interactions

7.4.6.1 *General Statistical Analysis and Results*

Each of the statistical analyses previously discussed was rerun with higher order (3-way and 4-way) interactions removed from the models to evaluate the sensitivity of the results. This resulted in five changes in significance status, with either the p-value increasing from $p<0.05$ to $p\geq0.05$ and thus becoming not statistically significant or with the p-value decreasing from $p\geq0.05$ to $p<0.05$ and thus becoming statistically significant. These changes are provided in Table 7-19 and Table 7-20.

Table 7-19. Between-subjects significance changes and resulting p-values for reduced ANOVA's.

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER
Anthropometry						
Hand length			0.0547 *(0.0420)*			
Performance						
none						
Wrist Kinematics						
none						
MDS/Anxiety specific						
none						

Significant ($p < 0.05$) p-values for reduced ANOVA's shown in bold.
Previous resulting p-value italicized and in parentheses.

Table 7-20. Within-subjects significance changes and resulting p-values for reduced ANOVA's.

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS
Anthropometry				
N/A				
Performance				
none				
Wrist Kinematics				
nRFEpos	**0.0337** *(0.0535)*	**0.0462** *(0.0698)*		
aRFEacc	**0.0305** *(0.0505)*			
nromLRU			0.0678 *(0.0392)*	
MDS/Anxiety specific				
none				

Significant (p < 0.05) p-values for reduced ANOVA's shown in bold.
Previous resulting p-value italicized and in parentheses.

8. PHASE III – LABORATORY-BASED EXPERIMENT TO INVESTIGATE MUSCLE ACTIVITY, PERFORMANCE, AND DISCOMFORT REPORTING DURING UPPER EXTREMITY TASKS

8.1 SPECIFIC STUDY ABSTRACT

Psychosocial factors are becoming increasingly more prevalent in studies that explore occupational musculoskeletal injury/illness. The research presented here explores the relationships between internal (e.g., personality type) and external (e.g., time stress, frustration stress) psychosocial factors and muscle activity. Twenty-five (25) subjects participated in this laboratory study. Personality type was assessed in a pre-tested pool of introductory psychology students using a modified version of the Jenkins Activity Survey. Selected participants (12 Type A and 13 Type B) performed a pipetting task under verbally imposed “no time stress” and “time stress” conditions and a computer task under programmed “no frustration stress” and “frustration stress” conditions. Task performance order and the order of the stress conditions within each task were counterbalanced across subjects by gender and personality type. Independent measures included personality type, gender, stress condition order, and stress condition. Dependent measures included performance times, normalized integrated electromyography (NIEMG) from ten muscles, discomfort reports, and self-reported state anxiety scores. Additional analyses were included to explore discomfort and anxiety reporting behaviors across seven administrations during the experiment.

Results support the importance of including psychosocial factors in the study of performance, muscle tension/activity, and reporting behaviors. This study further demonstrates (1) the feasibility of this methodology to explore the roles that psychosocial factors may play in musculoskeletal injury and (2) the importance of including individual differences in biomechanical evaluations.

8.2 BRIEF REVISIT TO SPECIFIC INTRODUCTORY CONCEPTS

Occupational musculoskeletal injuries/illnesses are a major problem for industry. Some task-related risk factors (e.g., high force, awkward postures, excessive repetition) are well understood and accepted as targets for ergonomic interventions. Still, situations exist where individuals (1) become injured in jobs where physical risk factors are not apparent or (2) experience different injury outcomes in the same or similar jobs. One area that is receiving increased attention is the possible roles that psychosocial factors may play in the injury process.

The definition of “psychosocial” factors is broad by nature and quite varied within the literature. Studies have included a wide range of constructs that have been referred to as, or could legitimately fall into the category of, psychosocial factors. Moon and Sauter (1996) suggest that these factors can be “loosely viewed in three categories, which clearly overlap and interrelate” (p. 111). These categories are (1) “objective work environment” characteristics (e.g., job demands, time pressure), (2) “responses to inquiry” reflecting worker perceptions of workplace characteristics, and (3) “measures of pre-existing and presumably personal characteristics” (e.g., traits such as personality and coping style). This research focuses on exploration of psychosocial factors that fall into categories (1) and (3) above. For simplification, those psychosocial factors that fall into category (1) will be referred to as “external” psychosocial characteristics while those falling into category (3) will be referred to as “internal” psychosocial factors. The research presented here focuses on efforts to explore the relationships between psychosocial factors, both internal and external, and muscle tension/activity.

Muscle tension represents an individual’s level of tension (i.e., tensile force per unit area) in one or more muscles. Muscle tension is considered to be a significant factor in understanding the exposure-response relationship between work and musculoskeletal injury/illness. Muscle tension is generated by both passive elements (e.g., connective tissue) and active elements (e.g., contracting muscle fibers). Electromyography (EMG) is used to measure the electrical signal generated by the muscle as it contracts. The surface EMG signal is affected, not only by the active tension produced in the muscle(s) being measured, but by other things such as muscle type/size, muscle conditioning, body tissue (e.g., skin/blood impedance), cross-talk from surrounding muscles, equipment and environmental signal noise, etc. The relationship between muscle force/tension and surface EMG may be approximately linear, quasi-linear, or curvilinear. However the correlation is generally positive, such that an increase in muscle tension produces an increase in the EMG signal. Though muscle tension and electromyographic activity are not equivalent, many studies have employed surface electromyography techniques to (1) describe the characteristics of muscle activity associated with particular types of work (e.g., lifting, sustained static work, light repetitive work); (2) investigate the potential link between muscle activity and discomfort, pain, or injury; and (3) model the loads imposed on the body’s joints using EMG-driven biomechanical models. Many factors (e.g., stress, movement, attention/arousal) may cause changes in muscle tension and "little is known regarding the level and temporal pattern of muscle tension due to such influences" (Westgaard & Bjorklund, 1987, p. 911). The exact relationship(s) that exist between muscle tension and injury remains ambiguous, but it is generally believed that muscle tension is a significant component of musculoskeletal illness.

Theoretical and empirical evidence support the study of psychosocial traits and muscle tension. One such psychosocial trait is Type A personality. Though Type A behavior is generally characterized by attributes of competitiveness, impatience, multitasking, and irritability, descriptions have specifically included terms such as "tense" (Sparacino, 1979), "general appearance of tension" (Jamal, 1985), and "tenseness of facial musculature" (Rowland & Sokol, 1977). Salminen et al., 1991 (1991) looked at Type A personality and tenderness/pain in the neck and shoulders in metal industry workers. They found that those reporting tenderness "more often had type A behavior than those without tenderness (p=0.10)" and postulated that Type A personality might be "associated with increased muscle activity in the neck and shoulders leading to muscular fatigue and tenderness" (p. 344). Glasscock et al. (1999) looked at Type A personality and muscle activity in a controlled laboratory study and found that Type A subjects exhibited significantly higher levels of antagonist muscle activity during controlled elbow flexion tasks.

Empirical evidence also offers support for inclusion of "external" characteristics (e.g., stress) in studies of psychosocial factors and muscle tension. Marras et al. (2000) explored the role of psychosocial stress and personality on lumbar spinal loading during sagittally symmetric lifts in the laboratory. They found that psychosocial stress increased the estimated spine loading in subjects with certain personality types (as defined by the Myers-Briggs Type Indicator) due to increased muscle coactivation levels. Though no direct relationship to injury or reporting of injury can be drawn from these laboratory studies, they did explore a direct link between psychosocial factors (internal traits and external states) and biomechanical measures (increased muscle activity and/or estimated spinal load) believed to be important factors in the injury process.

The purpose of the present study was to explore the relationships between internal and external psychosocial factors and muscle tension, as well as performance aspects of workstyle and discomfort reporting behaviors. Specifically, this study investigated the effect of personality type and psychosocially-imposed stress on muscle activity, performance time, and discomfort reports during laboratory-simulated pipetting and computer entry tasks. Psychosocially-imposed stress conditions included imposition of verbally scripted time stress and frustration stress. This study also explored effects of other characteristics of the subjects including gender, order of exposure to stress conditions, and order of task performance.

8.3 METHOD

8.3.1 Experimental Design

8.3.1.1 Design

This experiment was conducted using a mixed design containing both between-subjects independent variables and within-subjects independent variables. The design and methodology were as described for the previous study in Section 7, except where specifically noted and described here. Each subject performed both a pipetting task and a computer task.

8.3.1.2 Independent variables

The between-subjects independent variables in this study were the individual's personality type (TYPE: levels A and B), gender (GENDER: levels Female and Male), and stress condition order (ORDER: levels 1 and 2), each as described previously. ORDER was randomly assigned to TYPE x GENDER combinations such that equal numbers of subjects performed each of the two orders, with the exception that one additional subject (Male Type B) performed order 1 of each task. The within-subjects independent variable described the psychosocially-imposed stress condition (STRESS: levels N and S).

For the pipetting task, the stress condition involved imposition of time stress. The no-stress (N) condition was invoked by administering the following verbal script to the subject prior to beginning the task: "During this task you will be using the pipette instrument to fill the cells in these plastic trays, just as you practiced. For each tray, fill the cells according to the map provided on the instruction card. When you have finished the first tray, let me know by saying 'done.' Then start on the next tray. Assume that you are performing this task in a hospital lab on a routine day. Perform the task at a pace that you would feel comfortable if you had to perform the task for 8 hours. Continue to perform the task until I tell you to stop." Likewise, the time stress (S) condition was invoked with the following change in script spoken to convey urgency: "… Assume that you are performing this task in a hospital lab on a *very busy day full of emergencies*. Perform the task *as quickly as you can to meet today's high demands*. Continue to perform the task *as quickly as you can* until I tell you to stop." Each subject performed each of the stress conditions for 10 minutes for the pipetting task. For order 1, individuals completed the no-stress condition first and then the stress condition.

For the computer task, the stress condition involved imposition of frustration stress. During both the no-stress (N) and stress (S) conditions, the following script was verbally provided to the participant prior to beginning the task: "During this task you will be entering this list of part numbers into the computer, just as we practiced. The characters that you enter will be displayed to you on the screen as the * character. The computer will alert you if you have entered the part number incorrectly and you must enter it again. However, you do not have to worry about case. Perform the task as quickly and as accurately as possible. Continue to perform the task until I tell you to stop." Once the subject entered the part number and pressed "Enter," the computer compared the entered string sequence to a pre-programmed sequence to determine if the sequence was entered correctly. Computer feedback was then provided according to the specific stress condition currently being performed by the participant. During both conditions, the program provided accurate feedback if nothing was entered or if the wrong part number was entered. During the no-stress (N) condition, this was the only feedback that was provided. If the number was entered correctly, then the computer presented the screen for the next part number. Otherwise, it provided accurate feedback regarding the error that was made. During the stress (S) condition, the computer provided accurate feedback regarding incorrect entry of the part number in addition to sometimes providing "false" negative feedback when the number was entered correctly. For a pre-defined set of part numbers, this false feedback condition presented a message "Sorry, P/N not found!! Re-enter the P/N" even if the correct part number was entered. For some of the part numbers, the computer presented this feedback only once and then provided accurate feedback for the next entry. For a few cases, the computer presented this feedback several times for the same part numbers. Each subject performed each of the stress conditions for 5 minutes for the computer task. For order 1, individuals completed the no-stress condition first and then the stress condition.

This study also included an independent variable, SURVEY, representing the specific point in time of administration for the discomfort and anxiety surveys. These surveys were administered seven separate times during the experimental session. The levels of survey administration (SURVEY) were as follows:

1 – first time, directly following consent form signing

2 – second time, directly following training

3pN – third, fourth, fifth, or sixth time depending on task order, directly following “no-stress” condition of pipetting task

3pS – third, fourth, fifth, or sixth time depending on task order, directly following “stress” condition of pipetting task

3cN – third, fourth, fifth, or sixth time depending on task order, directly following “no-stress” condition of computer task

3cS – third, fourth, fifth, or sixth time depending on task order, directly following “stress” condition of computer task

4 – seventh time, end of experiment but prior to debriefing

8.3.1.3 Dependent variables

The dependent variables in this study included measures for evaluating the constructs of (1) workstyle, (2) muscle tension/activity, (3) discomfort and anxiety reporting behaviors, and (4) subject physical traits.

Workstyle was represented by per-unit task performance times. Performance was measured by average time per cell filled (avgPIPtpc) for the pipetting task and average time per part number entered (avgCOMtpp) for the computer entry task.

Muscle activity was represented by mean values of normalized integrated EMG (NIEMG) for each of ten muscles. The NIEMG dependent variables included the dominant and non-dominant side forearm flexor digitorum/carpi groups (dFLEX and nFLEX), extensor digitorum/carpi groups (dEXT and nEXT), upper (descending) portions of the trapezius (dTRAP and nTRAP), rhomboid-trapezius-erector spinae regions (dRHOM and nRHOM), and paraspinalis muscles at the level of T10 (dPARA and nPARA).

Reporting behaviors were represented by measures of self-reported state anxiety and musculoskeletal discomfort. State anxiety was measured as a single score (ANXtot). Discomfort measures included composite scores representing average overall discomfort (MDSavg), average upper extremity discomfort (MDSupx), and average back discomfort (MDSbak).

Physical traits included 18 measurements of anthropometry. The specific variables can be found in the Results section.

8.3.1.4 Specific Hypotheses

Several governing hypotheses were formulated for this specific study as described in Section **5.6**. The following specific hypotheses relating to personality TYPE were formulated for this experiment:

- **H1**: It was hypothesized that Type A individuals would demonstrate faster workstyles than Type B individuals as represented by task performance times.
- **H3**: It was hypothesized that Type A individuals would demonstrate higher muscle activity levels than Type B individuals.
- **H4**: It was hypothesized that Type A individuals would report lower levels of self-reported discomfort than Type B individuals.
- **H5**: It was hypothesized that Type A individuals would report lower levels of self-reported state anxiety than Type B individuals.

The following specific hypotheses related to psychosocial STRESS were formulated for this experiment:

- **H6**: It was hypothesized that performance times would be faster under conditions where time stress was imposed (H6a) and slower when psychosocially-imposed stress was imposed (H6b).
- **H8**: It was hypothesized that muscle activity would increase for both the time (H8a) and frustration (H8b) stress conditions.
- **H9**: It was hypothesized that self-reported discomfort would increase for both the time (H9a) and frustration (H9b) stress conditions.
- **H10**: It was hypothesized that self-reported state anxiety would increase for both the time (H10a) and frustration (H10b) stress conditions.

The following specific TYPE x STRESS hypotheses were formulated for this study.

- **H11**: It was hypothesized that muscle activity would increase during the time stress (H11a) and the frustration stress (H11b) conditions more so for Type A subjects than for Type B subjects.

8.3.2 Participants

Subjects participating in this experiment were recruited from the same pre-tested pool (N=92) of students described for the previous laboratory study. Additional pre-testing (N=10) was conducted during the following semester to complete the study. Using scores from the modified Jenkins Activity Survey, subjects were categorized as having either Type A or B personalities. Subjects were categorized, screened, and recruited as in the previous study. This resulted in 12 Type A and 13 Type B who were randomly assigned to experimental condition orders and task orders in a counterbalanced fashion. The personality type was unknown to the experimenter and the participants. Subjects ranged in age from 18.4 to 20.8 years (mean 19.3 (0.62) years).

8.3.3 Tasks

8.3.3.1 Pipetting task

The task required subjects to dispense colored liquids into plastic assay plates using a pipettor instrument (see Figure 8-1 and Figure 8-2). Subjects were standing at a height-adjustable workstation. The work surface was adjusted such that the top surface of the foam assay plate holder was positioned 10 centimeters below the subject's standing elbow height, as measured by the distance from the floor to the subject's dominant side lateral epicondyle height. Subjects dispensed the colored water into the cells according to a fixed color grid placed in front of the subject. Each subject performed both stress conditions of the pipetting task for 10 minutes each. Prior to performing the actual task conditions, the subjects practiced the task for 5 to 10 minutes, filling an average of 51.2 (ranging from 27 to 85) cells.

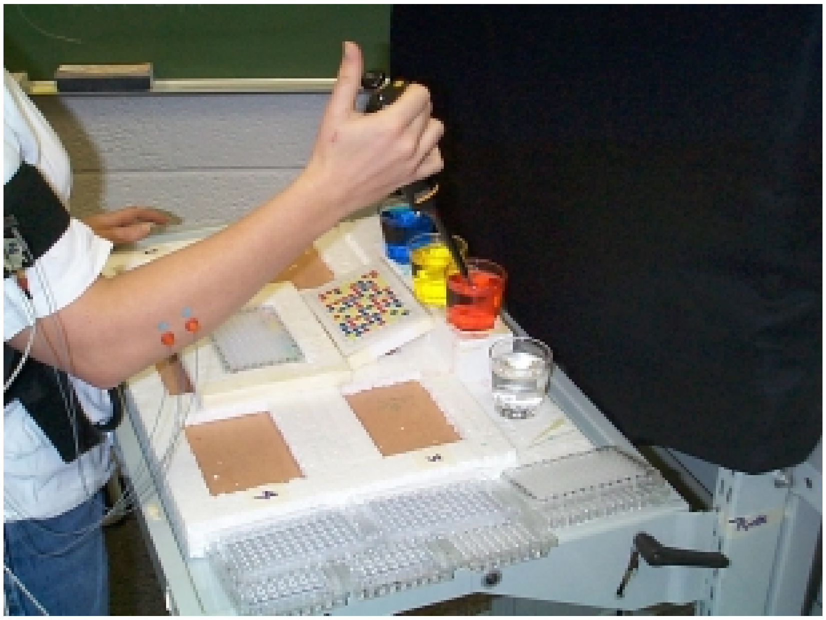


Figure 8-1. Standing pipetting task.

Figure 8-2. Close-up view of pipettor, assay plates, and pipetting station.

8.3.3.2 Computer task

The computer task required subjects to enter part numbers into a desktop computer (see Figure 8-3 and Figure 8-4). Subjects were standing at a height-adjustable workstation. The work surface was adjusted such that the top surface of the "H" key on the keyboard was positioned 2 centimeters below the subject's standing elbow height, as measured by the distance from the floor to the subject's dominant side lateral epicondyle height. Subjects entered "part numbers" that contained a sequence of letters and numbers. Each part number consisted of equal numbers of letter and number characters from the left and right side of the keyboard (See Appendix 13.6). The part numbers were displayed on a clipboard placed in front of the subject. The subject entered the part numbers into a PC compatible computer running a uniquely developed Windows-based Visual Basic program. The subject followed each part number by pressing the "Enter" key. The program would then provide feedback according to the previously described criteria associated with the specific stress condition being performed. Each subject performed both stress conditions of the computer task for 5 minutes each. Prior to performing the actual task conditions, the subjects practiced the task under the no-stress condition for an average of 2.9 (ranging from 1.1 to 4.9) minutes, entering an average of 12.8 (ranging from 7 to 22) part numbers.

Figure 8-3. Standing computer task.

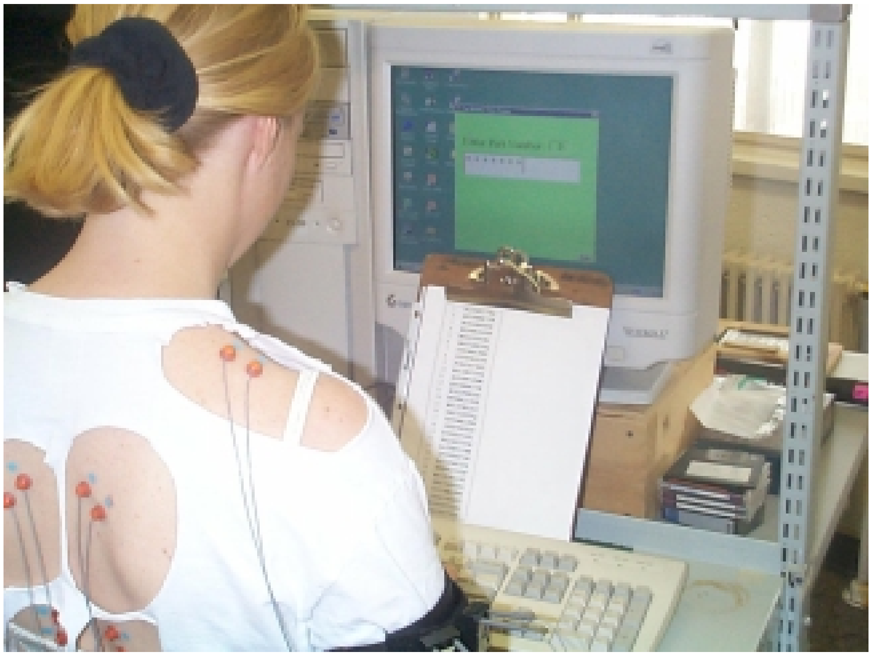


Figure 8-4. Windows-based application and part number list for computer task.

8.3.4 Apparatus

8.3.4.1 Bioinstrumentation

8.3.4.1.1 Electromyography

Muscle activity was measured from 10 muscles using surface electromyography (EMG). EMG was collected using Ag-Ag/Cl bipolar surface electrodes (Model E22x, 4mm sensor diameter, InVivo Metric, Healdsburg, CA). Twenty-one electrodes were placed on the skin to measure the EMG signal produced by the sampled muscles (see Figure 8-5). Specific electrode placement descriptions are provided in Table 8-1. Electrode wires were plugged into pre-amplifiers (1000x) affixed to Velcro straps worn by the subject (see Figure 8-5). The pre-amplified EMG signal was carried via shielded cables to the EMG system (Data Design, Inc., Columbus, Ohio) where it was amplified according to individual channel gains set for each subject (see Procedure section), notch filtered to remove signals at 60 Hz, and low-pass filtered to remove signals greater than 1000 Hz.

The EMG signal was collected at 1024 Hz, converted from analog to digital form using software running on personal computer, and saved to the computer for further analysis.

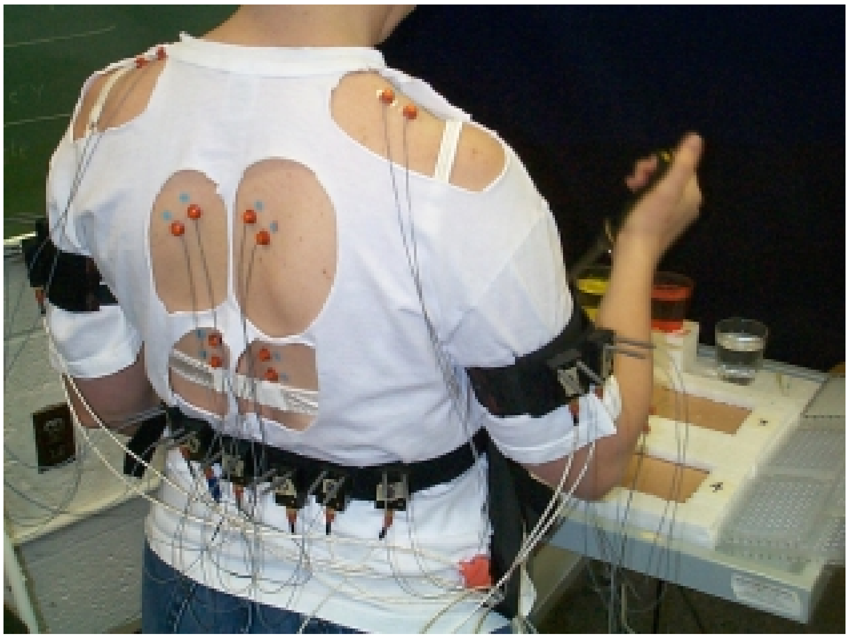


Figure 8-5. Electromyography (EMG) electrodes, preamplifiers, and cabling affixed to subject.

8.3.4.1.2 Pipettor

The pipetting task was accomplished using a Corning Costar Onepette single-channel pipettor. The pipettor has a micrometer volume control that is adjustable between 10 and 100µL. The pipettor was locked at a volume setting of 60 µL to allow a fixed button stroke distance. Colored water was dispensed into standard 8x12 plastic assay plates according to a fixed color grid. The pipettor and pipetting station can be seen in Figure 8-1 and Figure 8-2.

8.3.4.1.3 Blood Pressure/Pulse Monitor and Anthropometer

Blood pressure and pulse were measured as described for the previous study. Anthropometry measurements were obtained as described for the previous study.

8.3.4.2 Survey Instruments

The following instruments were administered in paper form as described for the previous study:

Revised NEO Personality Inventory

Modified Life Events Stress Checklist

Musculoskeletal Discomfort Survey

Modified State Anxiety Survey

Proxy Measure of Personality Type and Emotional Expressiveness

8.3.5 Procedure

Each subject participated in the experiment in a single individual session. Upon arrival in the laboratory, the subject was provided with a brief explanation of the experiment and then asked to read and sign a written consent form. While the subject completed the form, electrodes were filled with conductive electrode gel. Upon completion of the consent form, the subject was seated while baseline blood pressure and pulse measurements were recorded. The subject then completed baseline anxiety and discomfort surveys. A second blood pressure and pulse reading was recorded. Next, a variety of anthropometric dimensions were measured and recorded.

Electrodes were applied to the skin at ten locations as described in Table 8-1. Once the locations were determined, the subject's skin at each location was prepared by shaving the site and rubbing the skin vigorously with an alcohol-soaked cotton pad until the skin was slightly pink. Once dry, a small amount of conductive electrode gel was applied to the skin at the site over which the electrode sensor was to be positioned. The electrodes were affixed to the skin using standard electrode collars. Once all electrodes were affixed to the skin, resistances of each pair were checked and verified. Electrodes were replaced as required, including additional preparation of the skin, for those pairs whose resistance values were unacceptable. The subject remained seated during application of the electrodes.

Once the electrode application was completed, the subject was positioned standing in front of the EMG collection system. All electrodes were connected to pre-amplifiers that were affixed to Velcro straps worn by the subject. The EMG signal was then verified for each muscle. The hardware gains were set for each individual muscle to ensure acceptable resolution of the signal. The subject then performed two repetitions each of a series of maximum voluntary contractions (MVC's) in a standard fixed order with a minimum of one minute of rest between contractions. Each of these contractions was a few seconds in duration. The order and description of how the MVC's were obtained from the subject are contained in Table 8-2. The subject then performed four low-level test contractions. A 5-second resting value was also recorded while the subject stood quietly at rest with both arms in a relaxed position by his/her sides.

Immediately upon completion of the standing "rest" trial, the subject was seated while blood pressure and pulse were recorded. The subject also completed discomfort and anxiety surveys. The following introductory script was verbally provided to the subject prior to beginning the first task: "Today, you will be asked to perform a variety of tasks that are similar to those seen throughout industry. It is important that you approach each task as you would if you were actually asked to perform the task in the workplace. You will be given specific instructions prior to beginning each task. You will be performing each task twice." The subject was then positioned standing at the height-adjusted workstation for the first task, as dictated by the task order assigned to this subject.

The subject was then introduced to the task and allowed to practice. The subject then performed each stress condition of that task. The subject was then positioned at the height-adjusted work station for the second task and allowed to practice before performing both stress conditions. The subject was seated while physiological readings and surveys were completed following completion of each task condition.

At the end of the experiment, the electrodes were removed and the subject completed the NEO-FFI and modified SRRS-R surveys. The subject was then informed about the proxy survey and asked whether he/she was willing to participate by providing this survey to someone else to complete. The subject documented his response on a separate consent form. A final blood pressure and pulse measure was recorded. The subject also completed a final anxiety and discomfort survey. Prior to leaving the laboratory, the subject was provided with the proxy survey, given a t-shirt, allowed to ask questions, and then debriefed about the deception involved in the computer task. The experiment was recorded on videotape. The entire session lasted approximately 3 hours.

Table 8-1. Description of EMG locations and labels for sampled muscle groups.

EMG Channel	Muscle Group	Label	Electrode Location
1 & 2	left & right flexor digitorum/carpi group	LFLEX RFLEX	Have subject hold elbows at 90 degrees with upper arms close to body, palms facing up, and apply resistance while subject attempts to flex wrist. Palpate ~5cm distal to elbow. Place electrodes over muscle mass in direction of muscle fibers (approximately along imaginary line between medial epicondyle and thumb). 3cm ctr-ctr distance.
3 & 4	left & right extensor digitorum/carpi group	LEXT REXT	Have subject hold elbows at 90 degrees with upper arms close to body, palms facing down, while mimicking typing motion. Palpate ~5cm distal to elbow. Place electrodes over muscle mass in direction of muscle fibers (slightly superior to imaginary line between lateral epicondyle and styloid process of ulna). 3cm ctr-ctr distance.
5 & 6	left & right upper descending portions of trapezius	LTRAP RTRAP	Locate C7. Locate acromion process of scapula. Draw a line between these points. Locate center of line. Draw a mark 2cm lateral to center. Place electrodes 1cm on either side of mark. 2cm ctr-ctr distance.
7 & 8	left & right rhomboids-trapezius-erector spinae regions	LRHOM RRHOM	Count down from C7 to locate T4/T5. Locate medial border of scapula. Place electrodes @ 45 to 55 deg angle relative to vertebral column and with center half-way between vertebral column and medial border of scapula. 2.5cm ctr-ctr distance.
9 & 10	left & right paraspinalis	LPARA RPARA	Locate iliac crests. Extend imaginary plane through iliac crests and L4/L5. Count vertebrae upwards to T10. Verify by counting down from T4. Place electrodes 2cm lateral to spine. 3cm ctr-ctr distance.

Table 8-2. Description of maximum voluntary contractions (MVC's) for sampled muscle groups.

Standard Collection Order	Muscle Group	Maximum Voluntary Contraction
left – 1st & 5th right – 3rd & 7th	LFLEX RFLEX	Have subject hold elbow at approximately 90 degrees with upper arm close to body, palm facing up with finger tips folded into palm. Have subject place opposite hand against closed fingers and resist movement while trying to flex wrist as hard as he/she can.
left – 2nd & 6th right – 4th & 8th	LEXT REXT	Have subject hold elbow at approximately 90 degrees with upper arm close to body, palm facing up with hand/fingers stretched almost flat. Have subject place opposite hand underneath fingers and resist while trying to extend the wrist and fingers as hard as he/she can.
left – 9th & 11th right – 10th & 12th	LTRAP RTRAP	Have subject abduct shoulder to 90 degrees with elbow bent at 90 degrees. Apply resistance proximal to the elbow while the subject attempts to further abduct the shoulder as hard as he/she can.
left & right – 13th & 14th	LRHOM RRHOM	Have the subject simultaneously retract both scapulas (i.e., "squeeze the shoulder blades together") as hard as he/she can.
left & right – 15th & 16th	LPARA RPARA	Have subject lay prone on flat, padded surface (of Kin-Com dynamometer). Affix a resistive strap across the upper back beneath shoulder level. Have the subject extend upward against the strap as hard as he/she can.

8.3.6 Data Reduction

8.3.6.1 Generating Dependent Variables

Data was processed and analyzed using customized files and codes created for this experiment to generate specific dependent variables. The analyses are described here for generating the dependent variables that represented each construct evaluated in this study.

8.3.6.1.1 Physical traits - Anthropometry

Anthropometry variables were used as recorded, with the exception of body weight which was converted from pounds to kilograms. The specific variables are provided in the Results section.

8.3.6.1.2 Workstyle - Performance

Workstyle-related performance variables were calculated for each participant for each task condition by determining an average per-unit performance time achieved by the subject for the specific task condition. For the pipetting task, the total number of cells for a given condition was divided by the total time the subject performed the task during that condition. Times required for the experimenter to replace completed assay plates with empty ones were removed from the performance times prior to computing the average per unit performance time. For the computer time, the total number of part numbers entered for a given condition was divided by the total time the subject was entering part numbers. The performance time was computed only based on completely entered part numbers. Therefore, the performance time was computed based on the cumulative time expired for the last part number entered prior to the ending of the 5-minute task time. If the subject completed the list of 30 part numbers and started a new list, the performance time was computed based only on the first list of 30 completed. This resulted in the following dependent variables:

avgPIPtpc: average time per cell filled (in seconds)

avgCOMtpp: average time per part number entered (in seconds)

8.3.6.1.3 Physiological Response – Muscle Tension/Activity

Ten (10) normalized integrated electromyography (NIEMG) variables were computed to describe muscle activity in ten (five bilateral) muscle regions for each task condition. Data were processed and analyzed using customized code created for this experiment. Data were inspected visually during collection and during subsequent analysis. If any anomalies (e.g., recurring spikes, loss of signal, etc.) were noted during the display of the data during the experiment, these files were inspected further and (1) mechanical equipment was tested/repaired as required, (2) portions of the data file or the data file in its entirety were eliminated as required from the valid data set, and (3) data was recollected if of short duration (e.g., resting file, maximum file). During subsequent analysis, all data was inspected. Each EMG channel of each data file for each subject was plotted graphically to detect for signal anomalies. This resulted in minimal elimination of data.

The NIEMG values for each muscle were computed from the collected EMG via a series of processing steps. The stored binary data was (1) filtered to eliminate environmental noise and motion artifacts, (2) converted to voltages, (3) smoothed to aid in further processing, (4) rectified, (5) processed to remove the heart rate signal from those channels where it was present, (6) averaged across the entire task trial, and (7) normalized to the maximum processed EMG collected during the maximum voluntary contractions (MVC's) for each muscle. Filtering was accomplished using code modified from a previously developed algorithm (Joines, 2002; Lawrence, 2002). The data was filtered to remove the following frequency intervals: 0 – 10 Hz, 59 – 61 Hz, 119 – 121 Hz, 179 – 181 Hz, and 239 – 241 Hz. All other steps were accomplished with uniquely developed code for this study. The algorithm for removing heart rate from the signal is described in more detail in the following section.

Data obtained during the MVC trials were processed through steps (1), (2), (4), and (6) above. Due to the magnitude of the signal (such that heart rate would have negligible impact) and the method (of averaging over windows of substantial length) selected for computing the maximum from this data, smoothing and removal of heart rate were not required. Each 5-second trial was then processed further to generate forty 1/8 second duration averages for that trial (Kelaher, 1996). The maximum value for that trial was obtained by taking the maximum 1/8 duration average. The maximum for the specific muscle was then obtained by taking the maximum of both maximum trials. This maximum was used to normalize the task-generated EMG values. This resulted in mean left and right NIEMG variables for each of the five muscle regions. Dependent variables were created from these variables by setting the left NIEMG variables to non-dominant variables and the right NIEMG variables to dominant ones for right-handed subjects. The opposite was done for left-handed subjects. This resulted in the dependent variables (e.g., nFLEX, dFLEX, nEXT, etc.) used in the remaining analyses.

8.3.6.1.3.1 Algorithm to Remove Heart Rate

The algorithm for removing heart rate from the signal was generated based on detailed inspection of characteristics of the heart rate signal in the various files and channels across subjects. The algorithm was not employed for either of the four forearm EMG locations. For each subject, a determination was made regarding the EMG channel that provided the strongest heart rate signal by (1) graphically displaying and inspecting original, smoothed, and extra smoothed data for each channel of the resting file and (2) computing and evaluating quantitative measures of effective heart rate obtained during task trials using various algorithms. In some subjects, the heart rate could easily be seen in the filtered but unsmoothed data (see Figure 8-6). For some subjects, the heart rate signal only became apparent when the data was smoothed (i.e., over 3 points), or extra smoothed (i.e., over 31 points) as shown in Figure 8-7. In two subjects, the heart rate was not apparent in either signal. The channel where the heart rate was most apparent (i.e., HR trigger channel) was used for detecting heart rate across all files for this subject. The HR trigger channel used for most subjects was EMG channel 7 (i.e., left rhomboid region). For some subjects, EMG channel 9 (i.e., left paraspinalis region) provided a better HR trigger channel.

The extra smoothed signal was used to detect heart rate in the removal algorithm. Once the HR trigger channel was determined for a subject, the algorithm computed the maximum amplitude of the signal occurring in this channel for the resting file that was collected. The algorithm then used this amplitude (i.e., detects when the signal reaches 50% of this value) and the HR trigger channel for that subject to locate heart rate in the task trial files. The algorithm also accounted for duration between heart rate signals found. For each heart rate that was found in the HR trigger channel, the heart rate was removed in all channels where the heart rate appeared for this subject. Removal of the heart rate was accomplished by computing the two mean EMG values for 100 data points just prior to and following the heart rate signal. These two means were averaged together and the EMG data spanning the heart rate signal was replaced with the overall mean value (see Figure 8-8 and Figure 8-9). Each of the task trial data files was processed using this method to locate and remove heart rate from the channels where it was present. The algorithm is contained in Appendix 13.7.

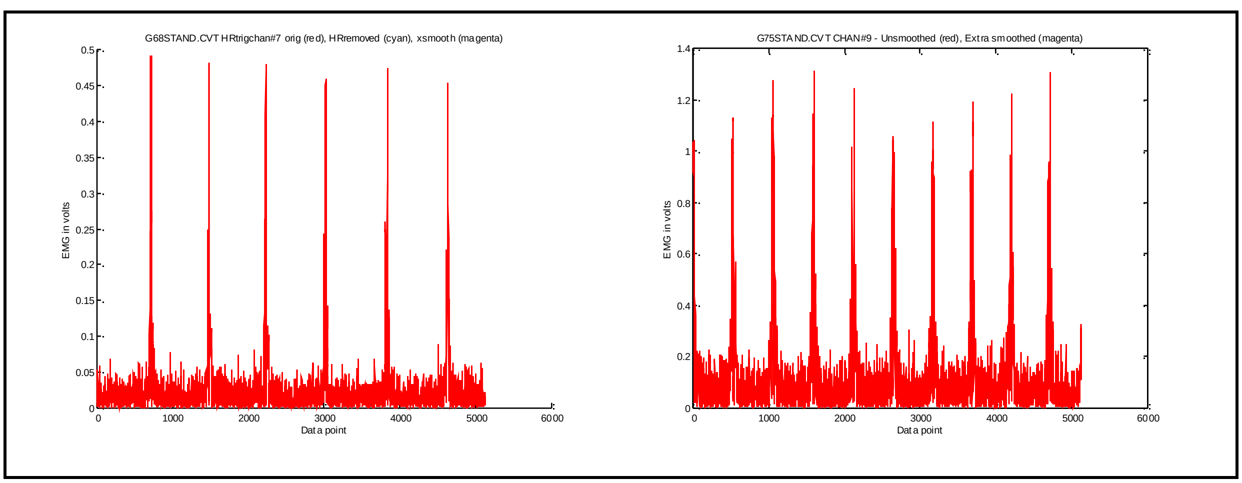


Figure 8-6. Visible heart rate in unsmoothed EMG signal for left rhomboid region (left) and left paraspinalis region (right) obtained during resting file for two different subjects.

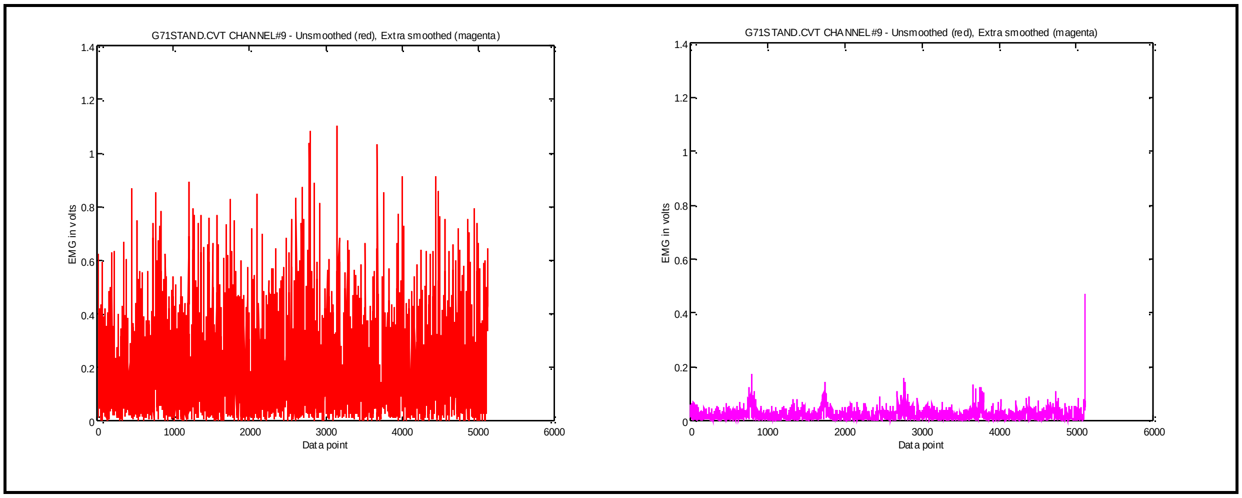


Figure 8-7. Unsmoothed (left) and extra smoothed (right) EMG signal for left paraspinalis region during resting file (with heart rate only visible in extra smoothed signal).

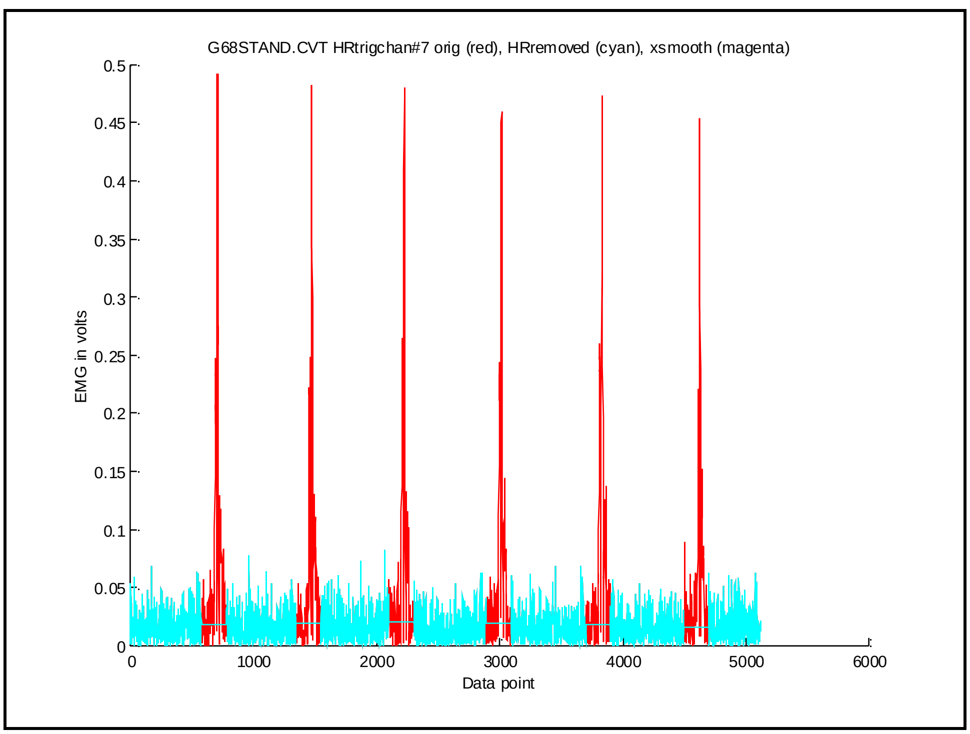


Figure 8-8. Smoothed signal with heart rate unremoved shown with overlay of signal with heart rate removed for left rhomboid region obtained from one subject's resting file.

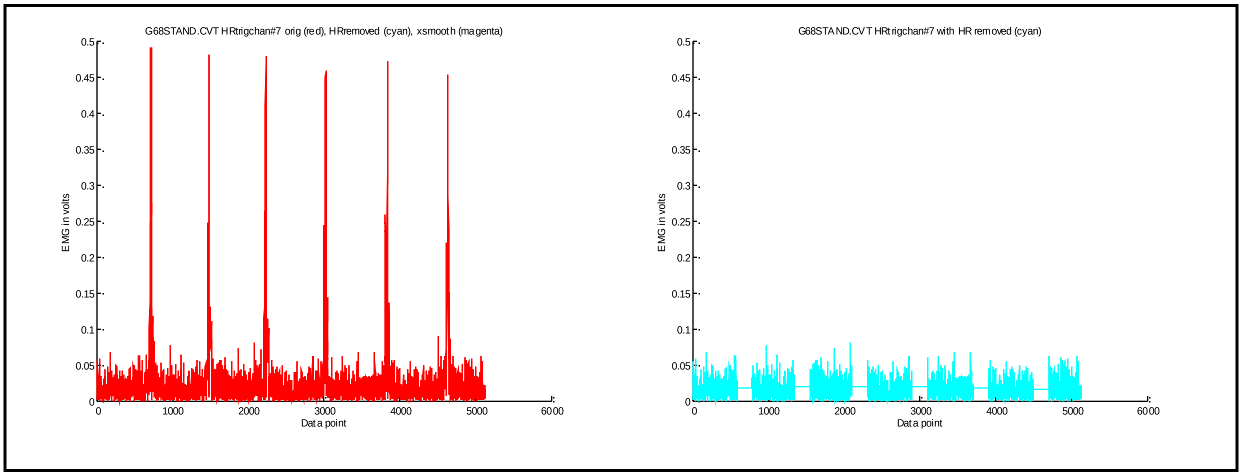


Figure 8-9. Signals from Figure 8-8 shown separately as smoothed signal with heart rate unremoved (left) and after heart rate removed (right).

8.3.6.1.3.2 Verification of Heart Rate Algorithm

The algorithm was verified through qualitative visual inspection and with quantitative evaluations of the algorithm's success at removing heart rate signals. Three measures were calculated. First, for those channels where heart rate was removed from the signal, a measure was calculated indicating the number of successful removals of the discrete heart rate signals present in the signal. This was done by generating random-number based 5-second display intervals and visually inspecting the displayed signal to determine the success of the algorithm for that interval. This was done for each channel in the resting file, one computer task trial, and one pipetting task trial for each subject. The computer trial and pipetting trial were selected randomly within the inspection code using random-number generation. Based on this evaluation, the algorithm resulted in successful elimination of 96.6 percent (6217 of 6435 visible) of the heart rate signals in those channels where the heart rate was visually apparent in the signal.

A second quantitative evaluation was simultaneously performed. For the same display intervals, the number of non-heart rate intervals that were removed by the algorithm (i.e., "false-positives") was recorded. This resulted in 5.3 percent (346 of 6563) "false-positive" removals.

A third quantitative evaluation was performed to determine the "risk" of (1) removing signal durations that were not heart rate and/or (2) not removing heart rate that may have been present but was difficult to detect. This sometimes occurred consistently within subjects, within certain channels (e.g., right trapezius), and/or within portions of signals. In order to perform this evaluation, the mean NIEMG value was calculated both prior to removing the heart rate (i.e., with heart rate unremoved) and subsequent to processing the signal to remove the heart rate (i.e., with heart rate removed). The difference was calculated between each of these mean values. This difference was then normalized to the mean value with the heart rate unremoved to generate a ratio of the algorithm's impact on the mean NIEMG value for the signal. This was done for each channel for each file for each subject. During the random interval displays for the previously described evaluations, the specific instances were noted where the heart rate was not visibly obvious. Those instances were used in conjunction with the values for two subjects in which the heart rate was not removed to compute an average impact ratio of the algorithm. The value obtained from this evaluation was 1.4 percent.

8.3.6.1.4 Reporting Behaviors - Musculoskeletal Discomfort and State Anxiety

Discomfort and anxiety surveys were administered seven separate times during the experimental session. Scores were generated as described for the previous study resulting in the following dependent variables

MDSavg – the average response score (in centimeters) across all 13 individual body regions

MDSupx – the average response score (in centimeters) across the 6 upper extremity body regions (MDSnsL MDSnsR MDSaeL MDSaeR MDShwL MDShwR)

MDSbak – the average response score (in centimeters) across the 4 back body regions (MDSubL MDSubR MDSlbL MDSlbR)

ANXtot – the state anxiety survey score

8.3.6.2 Statistical Analysis

Analysis of variance (ANOVA) procedures were used to detect significant effects of the independent variables and their interactions on the dependent measures. Two different ANOVA models were used as described previously in Section **5.5** and as outlined for this specific study in Table 8-3. One of these models was specifically used to evaluate the experimental hypotheses.

Model #1 was employed to evaluate the effect of the between-subjects independent variables (TYPE, GENDER, and ORDER) and the within-subjects STRESS variable on performance, wrist motion kinematics, and discomfort/anxiety reporting behaviors. A second model, Model #2, was employed to evaluate the effect of the between-subjects independent variables (TYPE, GENDER, and ORDER) on subject anthropometry variables. This was done to evaluate the chance that random assignment may have produced groups that differed significantly in one or more of the anthropometry variables that could have confounded the results obtained in the analyses to test the hypotheses. The detailed linear models and specific error terms for testing the effects were described previously in Section **5.5**. Pearson correlation coefficients were also computed among and between the composite discomfort scores and the state anxiety scores.

Table 8-3. Summary of specific analyses and statistical models utilized in Phase III experiment.

Statistical Model	Between-subjects Independent Variables	Within-subjects Independent Variables	Dependent Variables
#1	TYPE GENDER ORDER	STRESS	*workstyle* **performance time** (avgPIPtpc, avgCOMtpp)
#1	TYPE GENDER ORDER	STRESS	*physiological response* **muscle tension** (nFLEX, dFLEX, nEXT, dEXT nTRAP, dTRAP, nRHOM, dRHOM, nPARA, dPARA)
#1	TYPE GENDER ORDER	STRESS	*specific reporting behaviors* **musculoskeletal discomfort** (MDSavg, MDSupx, MDSbak)
#1	TYPE GENDER ORDER	STRESS	*specific reporting behaviors* **state anxiety** (ANXtot)
#2	TYPE GENDER ORDER		*physical traits* **anthropometry**
In the "Dependent Variables" column, the overall construct is shown in italics, the specific construct is shown in bold, and the dependent variables are listed in parentheses.			

8.4 RESULTS

8.4.1 Physical Traits – Anthropometry

8.4.1.1 Overall Descriptive Statistics

The mean values across all subjects for each of the 18 anthropometry variables are provided in Table 8-4.

Table 8-4. Subject anthropometry.

Anthropometric Measurement	Label	Mean	Standard Deviation	Minimum	Maximum
Wrist circumference (cm)	WC	16.6	1.3	13.6	19.0
Forearm circumference (cm)	FC	25.9	2.7	20.0	30.3
Hand span (cm)	HS	20.5	1.7	18.3	25.4
Hand breadth (cm)	HB	7.9	0.6	6.8	9.0
Wrist width (cm)	WW	5.7	0.5	4.8	6.6
Hand length (cm)	HL	18.3	1.4	16.5	21.4
Forearm length (cm)	FL	44.5	3.8	38.7	50.8
Shoulder width (cm)	SW	39.4	3.0	34.8	43.9
Arm length (cm)	AL	75.0	6.5	60.9	85.4
Floor to finger tip height (cm)	FFT	68.1	4.4	61.4	76.5
Floor to iliac crest (cm)	FIC	107.2	8.5	93.9	126.9
Floor to elbow height (cm)	FE	112.0	7.1	101.2	125.6
Floor to shoulder height (cm)	FS	143.4	9.4	130.0	161.5
Standing eye height (cm)	SEH	164.9	11.2	147.6	187.2
Pipetting work surface height (cm)	PipWS	102.0	7.1	91.2	115.6
Computer work surface height (cm)	ComWS	110.0	7.1	99.2	123.6
Stature (cm) - *measured*	ST	175.8	11.2	159.8	199.7
Weight (kg) - *calculated*	WT	68.2	10.9	48.1	90.7
Stature (in) - *calculated*		69.2	4.4	62.9	78.6
Stature (ft) - *calculated*		5.8	0.4	5.2	6.6
Weight (lb) - *measured*		150.5	24.1	106.0	200.0

Units of measurement shown in parentheses (cm=centimeters, kg=kilograms, in=inches, ft=feet, lb=pounds).
All measurements taken from the dominant hand side.

8.4.1.2 General Statistical Analysis and Results

Anthropometry variables were evaluated using Analysis of Variance (ANOVA) with Model #2 as described in Section 5.5.3 to check for potential confounding. The purpose of this analysis was to evaluate the chance that random assignment may have resulted in groups of subjects that differed significantly in anthropometry. Since anthropometry plays a critical role in biomechanical findings, this analysis was considered necessary to assess the possibility that one or more anthropometry differences may have confounded the results obtained in the analyses to test the primary hypotheses. Separate models were required to evaluate the success of randomization for the pipetting task and the computer task. Each model included TYPE, GENDER, and ORDER (representing either pipetting stress condition order or computer task stress condition order) as between-subjects independent variables. The models also included all possible interactions. All between-subjects main effects and interactive effects were tested using the model error term and Type III sums of squares (due to unequal cell sizes). There was one observation of each of the dependent variables for each subject resulting in 25 total observations with 18 variables in each observation for this analysis. Results of the pipetting task individual ANOVA's for the physical traits variables are summarized in Table 8-5. These results are described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.8.

8.4.1.3 Between-subjects Effects for Pipetting Task

Eighteen (18) anthropometry variables were analyzed using a between-subjects ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER (using the stress condition order for the pipetting task). Results of the analyses were summarized in Table 8-5.

A significant main effect of GENDER was observed for all 18 variables. The means by GENDER for the anthropometric variables are provided in Table 8-6. As expected, mean values for males were consistently higher than mean values for females. The analysis revealed no other significant main or interactive effects.

8.4.1.4 Between-subjects Effects for Computer Task

The same eighteen (18) anthropometry variables were analyzed using a between-subjects ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER (using the stress condition order for computer task). Results of the analyses were similar to those presented in Table 8-5 for the pipetting task. However, a significant effect of GENDER x ORDER ($F\{1,17\}$ =

7.18, p=0.0159) was observed for one variable, Hand Span (HS). The nature of this interaction can be seen in Figure 8-10. As expected and found in the previous analysis using the pipetting ORDER, a significant main effect of GENDER was observed for all 18 variables. The means by GENDER for the anthropometric variables are provided in Table 8-6. The analysis revealed no other significant main or interactive effects.

Table 8-5. Model #2 resulting p-values of individual ANOVA's for subject anthropometry variables using pipetting stress condition ORDER (25 observations).

Anthropometric Measurement	**TYPE**	**GENDER**	**ORDER**	**TYPE X GENDER**	**TYPE X ORDER**	**GENDER X ORDER**	**TYPE X GENDER X ORDER**
WC	0.0774	**<0.0001**	ns	ns	ns	ns	ns
FC	ns	**<0.0001**	ns	ns	ns	0.0731	ns
HS	ns	**0.0003**	ns	ns	ns	ns	ns
HB	0.0809	**<0.0001**	ns	ns	ns	ns	ns
WW	ns	**<0.0001**	0.0925	ns	ns	ns	ns
HL	ns	**<0.0001**	ns	ns	ns	ns	ns
FL	ns	**<0.0001**	ns	ns	ns	ns	ns
SW	0.0885	**<0.0001**	ns	ns	ns	ns	ns
AL	ns	**<0.0001**	ns	ns	ns	0.0986	ns
FFT	ns	**0.0025**	ns	ns	ns	ns	ns
FIC	ns	**<0.0001**	ns	ns	ns	ns	ns
FE, PipWS, ComWS	ns	**<0.0001**	ns	ns	ns	ns	ns
FS	ns	**<0.0001**	ns	ns	ns	ns	ns
SEH	ns	**<0.0001**	ns	ns	ns	ns	0.0967
ST	ns	**<0.0001**	ns	ns	ns	ns	0.0650
WT	ns	**0.0002**	ns	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 8-6. Subject anthropometry by gender.

Anthropometric Measurement	**Abbreviation**	**Female (N=12)**		**Male (N=13)**	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Wrist circumference (cm)	WC	15.4	0.8	17.6	0.5
Forearm circumference (cm)	FC	23.8	1.9	27.7	1.6
Hand span (cm)	HS	19.3	1.0	21.6	1.6
Hand breadth (cm)	HB	7.4	0.3	8.4	0.4
Wrist width (cm)	WW	5.3	0.3	6.1	0.3
Hand length (cm)	HL	17.0	0.5	19.4	0.9
Forearm length (cm)	FL	41.2	1.6	47.6	2.3
Shoulder Width (cm)	SW	37.0	1.4	41.7	2.2
Arm length (cm)	AL	69.4	3.7	80.2	3.5
Floor to finger tip height (cm)	FFT	65.4	3.3	70.6	3.8
Floor to iliac crest (cm)	FIC	100.1	3.5	113.8	5.8
Floor to elbow height (cm)	FE	106.1	3.6	117.5	4.7
Floor to shoulder height (cm)	FS	135.1	4.0	151.1	5.5
Standing eye height (cm)	SEH	154.9	5.0	174.0	6.4
Pipetting work surface height (cm)	PipWS	96.1	3.6	107.5	4.7
Pipetting work surface height (cm)	ComWS	104.1	3.6	115.5	4.7
Stature (cm) - *measured*	ST	165.8	4.4	185.0	6.3
Weight (kg) - *calculated*	WT	60.6	9.2	75.3	7.1
Stature (in) - *calculated*		65.3	1.7	72.8	2.5
Stature (ft) - *calculated*		5.4	0.1	6.1	0.2
Weight (lb) - *measured*		133.7	20.3	165.9	15.6

Units of measurement shown in parentheses (cm=centimeters, kg=kilograms, in=inches, ft=feet, lb=pounds).
All measurements taken from the dominant hand side.

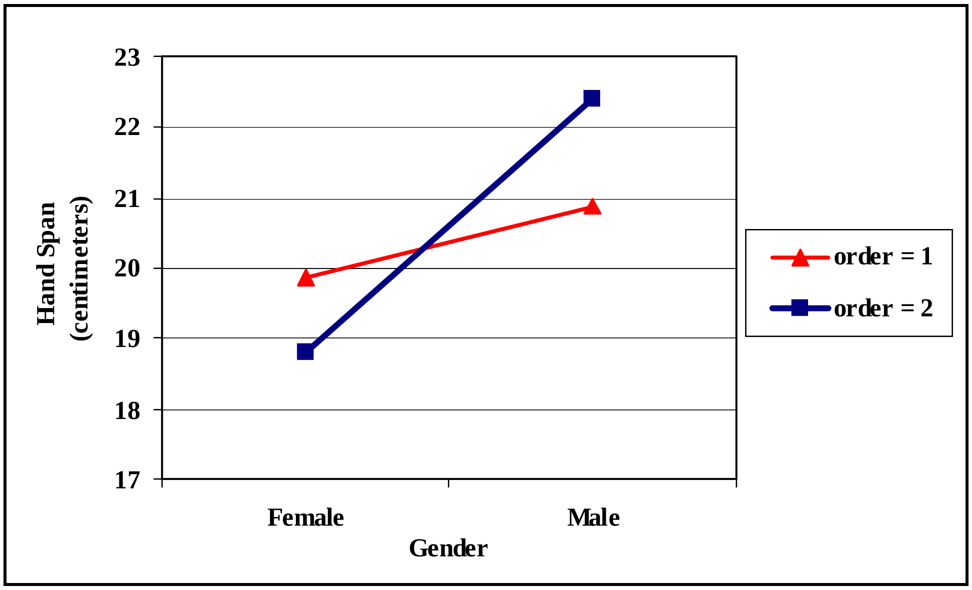


Figure 8-10. Significant interaction effect (p=0.0170) of gender (GENDER) and computer task stress condition order (ORDER) for Hand Span.

8.4.1.5 Summary of Findings for Physical Traits

The possibility of anthropometric differences between TYPE x GENDER x ORDER groups was evaluated for both the pipetting task and the computer task. The only difference between the models used to evaluate this was the order variables, which represented the stress condition order for the specific task. As expected for both analyses, gender significantly impacted physical traits as measured by anthropometry. Females were smaller across all measures. An interactive effect of gender and condition order was unexpectedly obtained for hand span for the computer task.

8.4.2 Workstyle – Performance

8.4.2.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for the pipetting and computer task performance variables are contained in Table 8-7.

Table 8-7. Summary statistics for pipetting and computer task performance variables.

Performance Variable	units	N	Mean	Standard Deviation	Minimum	Maximum
avgPIPtpc	seconds	50	3.67	1.03	2.27	6.38
avgCOMtpp	seconds	50	10.21	2.18	6.00	14.58

avgPIPtpc = average time per pipetting cell filled (in seconds).
avgCOMtpp = average time per part number entered (in seconds).

8.4.2.2 General Statistical Analysis and Results

The effects of the independent variables on task performance time (avgPIPtpc and avgCOMtpp) were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. Separate analyses were required for the pipetting task and the computer task since the stress condition ORDER variable was specific to each task. Each model included a single performance variable (avgPIPtpc or avgCOMtpp) for each stress condition for each subject resulting in 50 observations for each ANOVA. The results of the analyses are summarized in Table 8-8 and Table 8-9 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.8.

8.4.2.2.1 Verification of the ANOVA Assumptions

The performance data (avgPIPtpc and avgCOMtpp variables) were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Appendix 13.9. All plots and computed statistics indicate that the data meet the assumptions that the residuals are normally and independently distributed with mean zero and constant variance.

Table 8-8. Model #1 resulting between-subjects p-values of separate task performance ANOVA's.

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
avgPIPtpc	ns	ns	ns	ns	ns	ns	ns
avgCOMtpp	ns	ns	ns	ns	ns	ns	ns
Significant ($p < 0.05$) p-values shown in bold. Almost significant ($0.05 \leq p \leq 0.1$) p-values provided. ns – not significant and $p > 0.1$.							

Table 8-9. Model #1 resulting within-subjects p-values of separate task performance ANOVA's.

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
avgPIPtpc	**0.0021**	ns	ns	**0.0016**	ns	ns	ns	ns
avgCOMtpp	**<0.0001**	ns	ns	**0.0124**	ns	ns	ns	ns
Significant ($p < 0.05$) p-values shown in bold. Almost significant ($0.05 \leq p \leq 0.1$) p-values provided. ns – not significant and $p > 0.1$.								

8.4.2.3 Between-subjects Effects

Task performance times (avgPIPtpc and avgCOMtpp) were analyzed using separate mixed ANOVA analyses as previously described to determine the effects of TYPE, GENDER, and stress condition ORDER. There were no significant between-subject main or interaction effects for avgPIPtpc or avgCOMtpp. Though not statistically significant, the mean values by TYPE, GENDER, and ORDER are provided in Table 8-10.

Table 8-10. Performance time means by personality type, gender, and stress condition order.

	Type A	Type B	Female	Male	Order 1	Order 2
avgPIPtpc						
mean	3.85	3.51	3.38	3.94	3.53	3.83
standard deviation	1.03	1.03	0.78	1.18	0.87	1.19
avgCOMtpp						
mean	10.47	9.98	10.26	10.17	9.95	10.50
standard deviation	2.28	2.11	1.74	2.56	1.85	2.50

8.4.2.4 Within-subjects Effects

Task performance times (avgPIPtpc and avgCOMtpp) were analyzed using separate mixed ANOVA analyses as previously described to determine the effects of STRESS. The ANOVA analysis for the pipetting task revealed a significant main effect of STRESS for avgPIPtpc ($F\{1,17\} = 13.19$, $p=0.0021$). The ANOVA analysis for the computer task revealed a significant main effect of STRESS for avgCOMtpp ($F\{1,17\} = 25.85$, $p<0.0001$).

The mean scores by STRESS condition can be seen in Figure 8-11. From the figure, it can be seen that the mean pipetting task performance time for the time stress condition was lower, and therefore faster, than for the no-stress condition. The mean avgPIPtpc value for the stress condition was 88.2% of the mean value for the no-stress condition. From the figure it can also be seen that the mean computer task performance time for the "frustration" stress condition was higher, and thus slower, than for the no-stress condition. The mean avgCOMtpp value for the stress condition was 107.9% of the mean value for the no-stress condition.

The analysis for avgPIPtpc revealed a significant 2-way interaction effect of ORDER x STRESS ($F\{1,17\} = 14.08$, $p=0.0016$). The mean avgPIPtpc performance times for each ORDER x STRESS combination can be seen in Figure 8-12. Subsequent analyses demonstrated that there was a simple effect of time stress on avgPIPtpc for order 1 but not for order 2, indicating that the main effect obtained for STRESS held only for order 1. For those performing the no-stress condition first, the mean per-cell pipetting time (avgPIPtpc) was 77.4% of the no-stress time, or 23% faster. There were no differences between orders for either of the stress conditions.

The analysis for avgCOMtpp revealed a significant 2-way interaction effect of ORDER x STRESS ($F\{1,17\} = 7.81$, $p=0.0124$). The mean avgCOMtpp performance times for each ORDER x STRESS combination can be seen in Figure 8-13. Subsequent analyses demonstrated that there was a simple effect of frustration stress on avgCOMtpp for order 2 but not for order 1, indicating that the main effect obtained for STRESS held only for order 2. For those performing the stress condition first, the mean per-entry computer time (avgCOMtpp) was 112.7% of the no-stress time, or 13% slower. There were no differences between orders for either of the stress conditions.

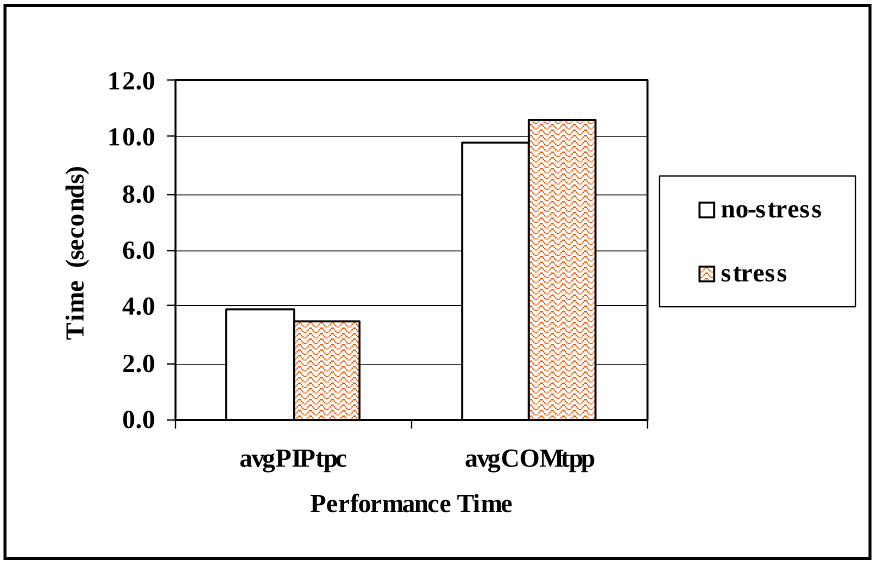


Figure 8-11. Significant effects of stress condition (STRESS) on task performance times.

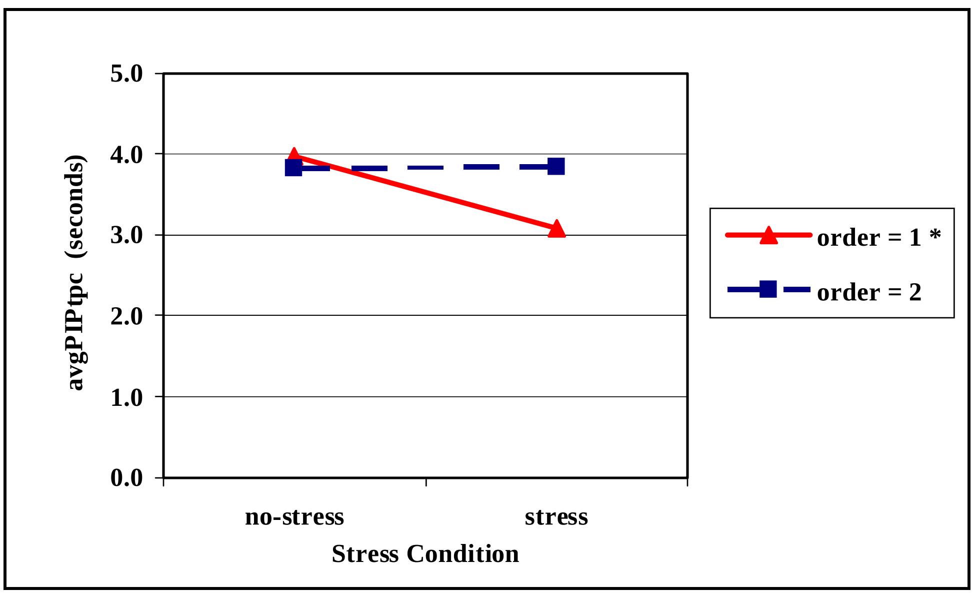


Figure 8-12. Significant interaction effect (p=0.0016) of stress condition order (ORDER) and stress condition (STRESS) on average pipetting task performance time (avgPIPtpc). (* indicates simple effect within this level of independent variable.)

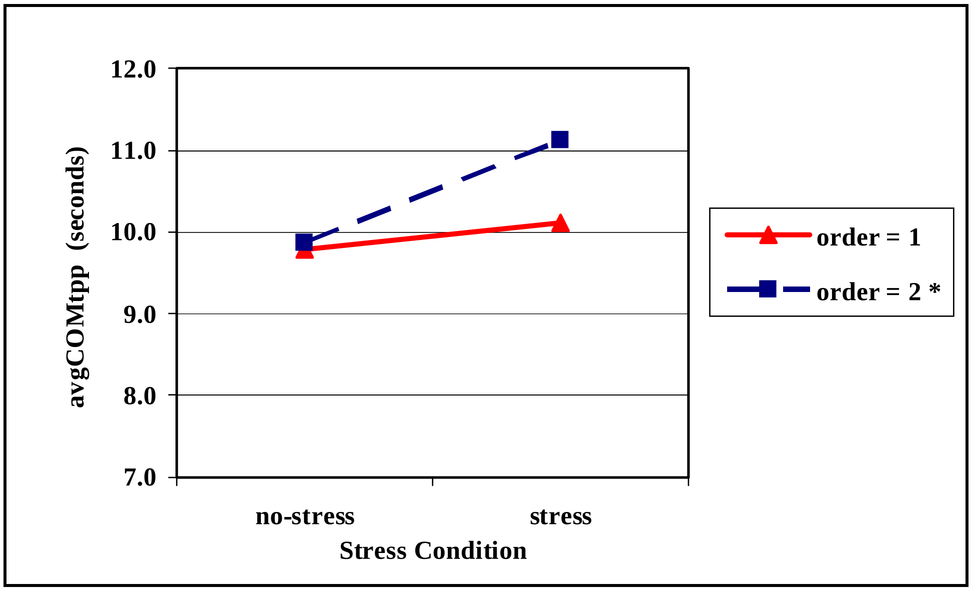


Figure 8-13. Significant interaction effect (p=0.0124) of stress condition order (ORDER) and stress condition (STRESS) on average computer task performance time (avgCOMtpp). (* indicates simple effect within this level of independent variable.)

8.4.2.5 Summary of Findings for Workstyle-related Performance

Personality type did not impact workstyle-related performance for either the pipetting or the computer task. The effects of psychosocially-imposed stress were limited by moderating effects of condition order. Psychosocially-imposed time stress decreased per-cell pipetting times by 23% for those who performed the no-stress condition first. Psychosocially-imposed frustration stress increased per-entry computer times by 13% for those who performed the stress condition first.

8.4.3 Physiological Response – Muscle Tension/Activity during Pipetting

8.4.3.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for each of the normalized integrated electromyography (NIEMG) dependent variables are contained in Table 8-11.

Table 8-11. Summary statistics for normalized integrated electromyographic (NIEMG) variables obtained during both conditions of the pipetting task.

NIEMG variable	units	N	Mean	Standard Deviation	Minimum	Maximum
nFLEX	% of max	50	1.00	0.80	0.30	3.96
nEXT	% of max	50	1.84	1.62	0.27	6.47
nTRAP	% of max	50	2.94	2.14	0.19	7.27
nRHOM	% of max	50	3.76	2.93	1.19	16.24
nPARA	% of max	50	6.25	2.99	2.23	15.42
dFLEX	% of max	50	2.99	1.83	0.94	9.29
dEXT	% of max	50	5.80	2.46	2.37	13.09
dTRAP	% of max	50	6.31	3.94	1.05	18.14
dRHOM	% of max	50	8.56	6.16	1.23	31.32
dPARA	% of max	50	5.82	2.28	1.16	10.39

NIEMG are non-dominant (e.g., nFLEX) and dominant (e.g., dFLEX) side measures.

8.4.3.2 General Statistical Analysis and Results

The effects of the independent variables on the ten pipetting NIEMG variables were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and stress condition ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The NIEMG data included 10 variables (5 non-dominant and 5 dominant side) for each condition for each subject resulting in 50 observations for each ANOVA. Each of these variables and the results of the analyses are summarized in Table 8-12 and Table 8-13 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.8.

Table 8-12. Model #1 resulting between-subjects p-values of pipetting task NIEMG ANOVA's.

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
nFLEX	ns	ns	0.0675	ns	ns	ns	**0.0419**
nEXT	ns	**0.0482**	ns	ns	ns	ns	ns
nTRAP	ns	ns	ns	0.0761	ns	ns	**0.0466**
nRHOM	ns	ns	ns	ns	ns	ns	ns
nPARA	ns	ns	ns	ns	ns	ns	ns
dFLEX	ns	ns	0.0676	**0.0043**	ns	**0.0191**	ns
dEXT	ns	0.0922	ns	ns	ns	ns	ns
dTRAP	ns	ns	ns	ns	ns	ns	ns
dRHOM	ns	ns	ns	ns	ns	ns	ns
dPARA	ns	ns	ns	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 8-13. Model #1 resulting within-subjects p-values of pipetting task NIEMG ANOVA's.

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
nFLEX	ns	ns	ns	ns	ns	ns	0.0743	ns
nEXT	ns	ns	ns	ns	ns	ns	ns	0.0812
nTRAP	**0.0158**	ns	0.0768	ns	ns	ns	**0.0220**	ns
nRHOM	**0.0071**	ns	ns	ns	ns	ns	ns	ns
nPARA	ns	ns	ns	ns	ns	ns	ns	ns
dFLEX	**0.0008**	ns	**0.0030**	ns	ns	ns	**0.0015**	ns
dEXT	**0.0125**	ns	**0.0198**	ns	ns	ns	ns	ns
dTRAP	**0.0067**	ns	ns	ns	ns	ns	ns	ns
dRHOM	**0.0144**	0.0833	ns	ns	ns	ns	ns	0.0634
dPARA	ns	ns	ns	ns	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

8.4.3.2.1 Verification of the ANOVA Assumptions

The NIEMG data were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Appendix 13.9. All plots and computed statistics indicate that the data meet, or only moderately violate, the assumptions that the residuals are normally and independently distributed with mean zero and constant variance.

8.4.3.3 Between-subjects Effects

The pipetting task NIEMG variables (10 variables) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and stress condition ORDER. The results were shown in Table 8-12.

The analysis revealed no significant main effects of personality TYPE. The mean values by personality TYPE are shown in Figure 13-10 of Appendix 13.4. Though not statistically significant, Type B mean values were higher than Type A mean values for 7 of the 10 variables. Type A mean values were higher for the three upper extremity non-dominant mean values (nFLEX, nEXT, and nTRAP).

The analysis revealed a significant effect ($F\{1,17\} = 4.53$, $p=0.0482$) of GENDER for only one variable, nEXT. The mean NIEMG values by GENDER are shown in Figure 8-14. Though not statistically significant, the mean values for Females were higher than the mean Male values for eight of the ten NIEMG measures. For those eight, the mean Female values ranged from 106.5% to 196.2% of the mean Male values. Only the nPARA and dPARA mean values were lower for Females than for Males. The mean nEXT value for Females was 196.2% of the mean value for Males.

The analysis revealed no significant main effects of stress condition ORDER for any of the NIEMG variables. The mean NIEMG values by GENDER are shown in Figure 13-11 of Appendix 13.4. Though not statistically significant, the same trend appeared for the non-dominant side variables as for the dominant side variables. The upper extremity values (nFLEX, nEXT, nTRAP, dFLEX, dEXT, and dTRAP) were lower for order 1 than for order 2 while the postural values (nRHOM, nPARA, dRHOM, and dPARA) were higher for order 1 than for order 2.

The analysis revealed two significant 2-way interaction effects. The TYPE x GENDER ($F\{1,17\} = 10.87$, $p=0.0043$) and the GENDER x ORDER ($F\{1,17\} = 6.70$, $p=0.0191$) interactions were significant for dFLEX. The mean dFLEX values for each TYPE x GENDER combination are shown in Figure 8-15. Subsequent analyses demonstrated that there was a simple effect of personality type for both Males and Females, but in opposite directions. Type A female dFLEX activity was 57.4% of the Type B female activity. Type A male dFLEX activity was 187.9% of the Type B male activity. There was also a simple effect of gender for Type B's but not for Type A's.

The mean dFLEX values for each GENDER x ORDER combination are shown in Figure 8-16. Subsequent analyses demonstrated that there was a simple effect of gender for order 2 but not for order 1. There was also a simple effect of order for Females but not for Males.

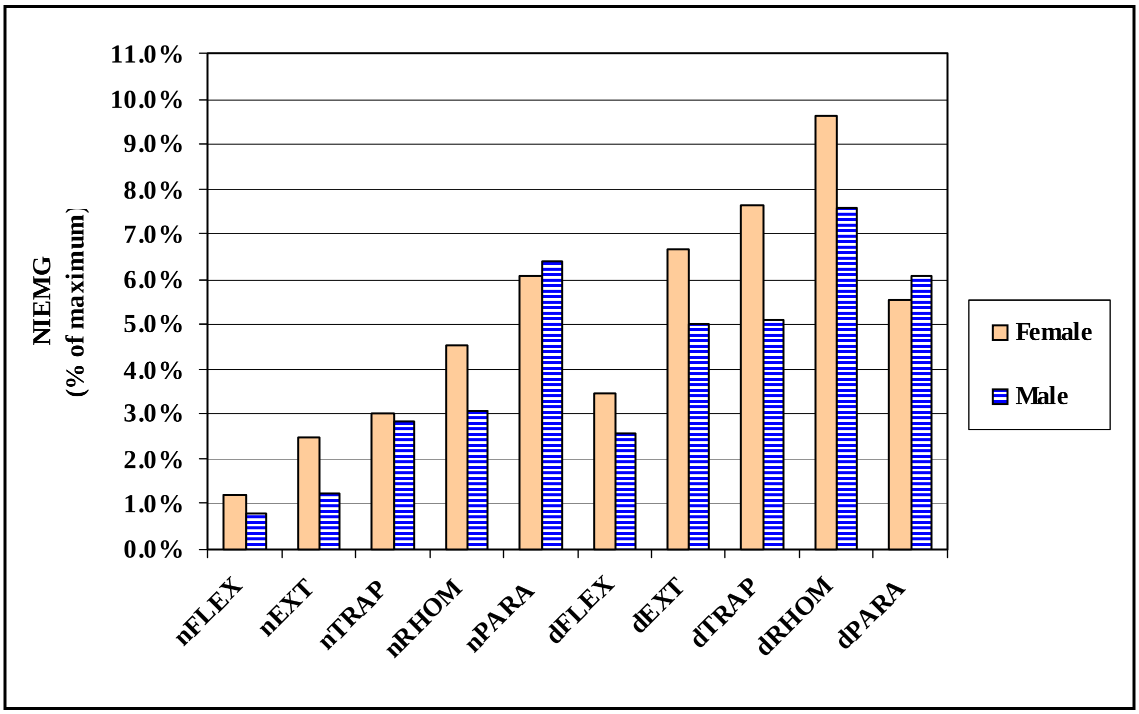


Figure 8-14. Significant (for nEXT) and nonsignificant effects (for all others) of gender (GENDER) on pipetting NIEMG mean values.

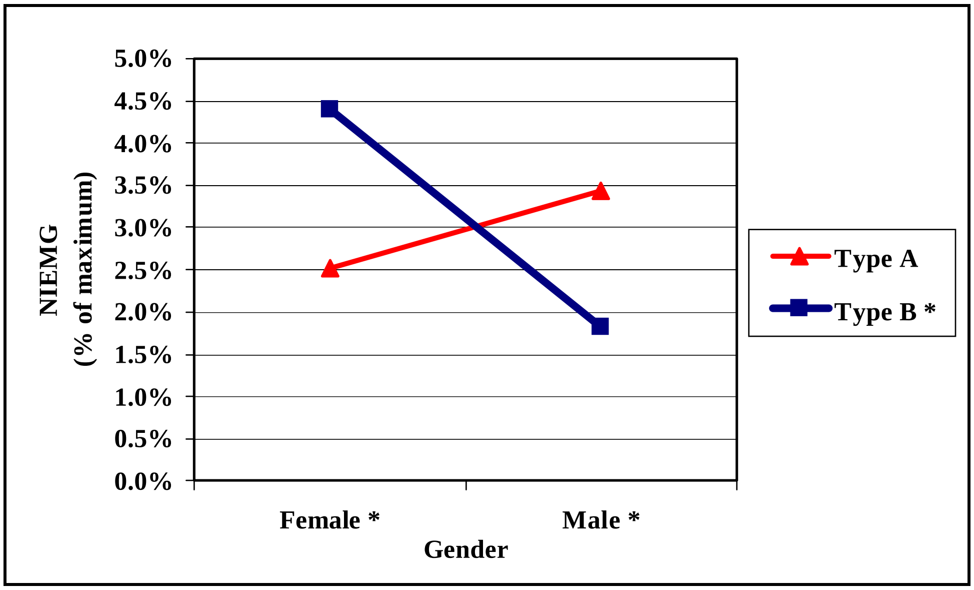


Figure 8-15. Significant interaction effect (p=0.0043) of personality type (TYPE) and gender (GENDER) for pipetting task dFLEX. (* indicates simple effect within this level of independent variable.)

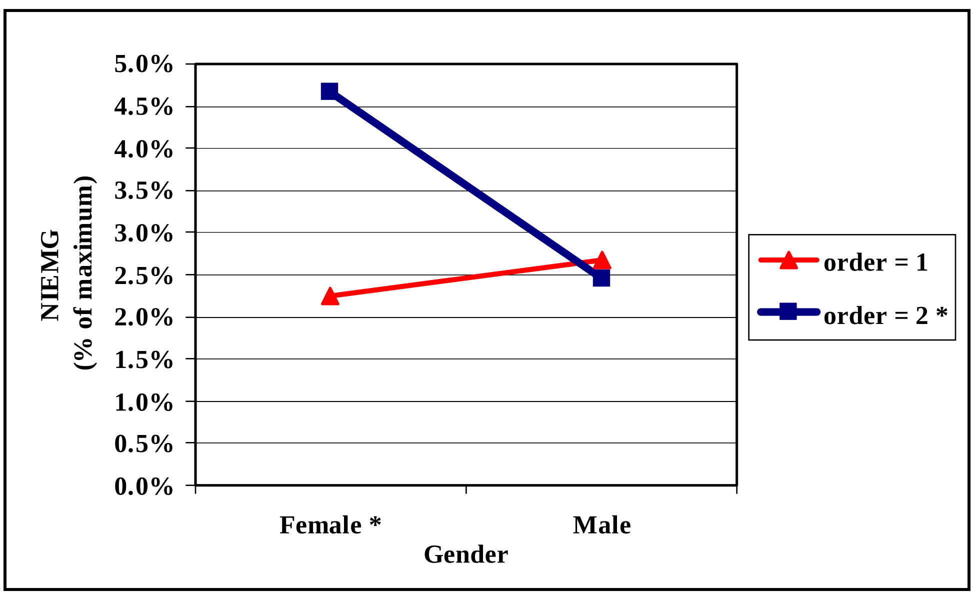


Figure 8-16. Significant interaction effect (p=0.0191) of gender (GENDER) and stress condition order (ORDER) for pipetting task dFLEX. (* indicates simple effect within this level of independent variable.)

8.4.3.4 Within-subjects Effects

The pipetting task NIEMG variables (10 variables) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed a significant main effect of STRESS for six of the variables. Some interaction effects were also obtained. These are described here.

The analysis revealed a significant main effect of STRESS for dFLEX ($F\{1,17\} = 16.53$, $p=0.0008$), dEXT ($F\{1,17\}= 7.80$, $p=0.0125$), dTRAP ($F\{1,17\} = 9.52$, $p=0.0067$), dRHOM ($F\{1,17\} = 7.43$, $p=0.0144$), nTRAP ($F\{1,17\} = 7.19$, $p=0.0158$), and nRHOM ($F\{1,17\} = 9.35$, $p=0.0071$). The mean values by STRESS condition are shown in Figure 8-17. The mean NIEMG values ranged from 1.0% to 9.0%MVC. From the figure, it can be seen that the mean NIEMG values were lower for the no-stress condition across all ten variables. The mean stress condition NIEMG values for the six NIEMG measures that were found to be significant ranged from 109.4% to 123.0% of the no-stress condition mean values. The mean stress condition values for the nonsignificant NIEMG measures were 105.4%to 115.8% of the no-stress values.

The analysis revealed a significant 2-way interaction effect of GENDER x STRESS for dFLEX ($F\{1,17\} = 11.96$, $p=0.0030$). The mean dFLEX values for each GENDER x STRESS combination can be seen in Figure 8-18. Subsequent analyses demonstrated that there was a simple effect of stress on dFLEX for Females but not for Males, indicating that the main effect obtained for STRESS held only for Females. Females had 25.4% higher dFLEX levels for the time stress condition than for the no-time stress condition. There was also a simple effect of gender for the stress condition but not for the no-stress condition.

The analysis also revealed a significant 2-way interaction effect of GENDER x STRESS for dEXT ($F\{1,17\} = 6.61$, $p=0.0198$). The mean dEXT values for each GENDER x STRESS combination can be seen in Figure 8-19. Subsequent analyses demonstrated that there was a simple effect of stress on dEXT for Females but not for Males, indicating that the main effect obtained for STRESS held only for Females. Females had 29.1% higher dEXT levels for the time stress condition than for the no-time stress condition. There was also a simple effect of gender for the stress condition but not for the no-stress condition.

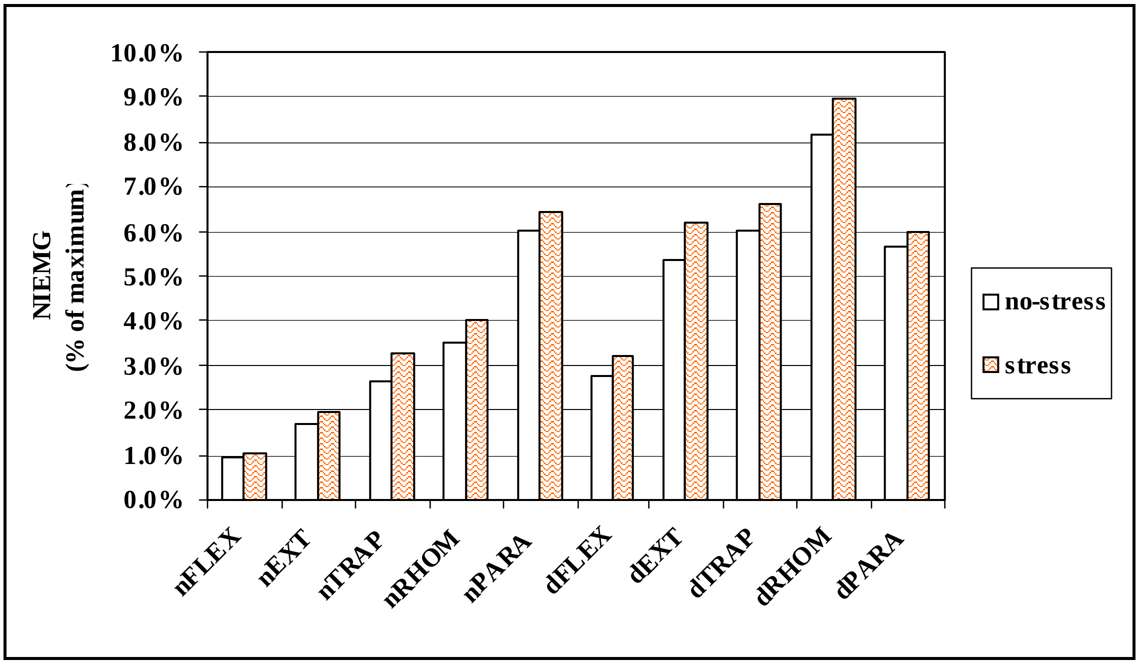


Figure 8-17. Significant (for nTRAP, nRHOM, dFLEX, dEXT, dTRAP, and dRHOM) and nonsignificant effects of stress condition (STRESS) on pipetting NIEMG mean values.

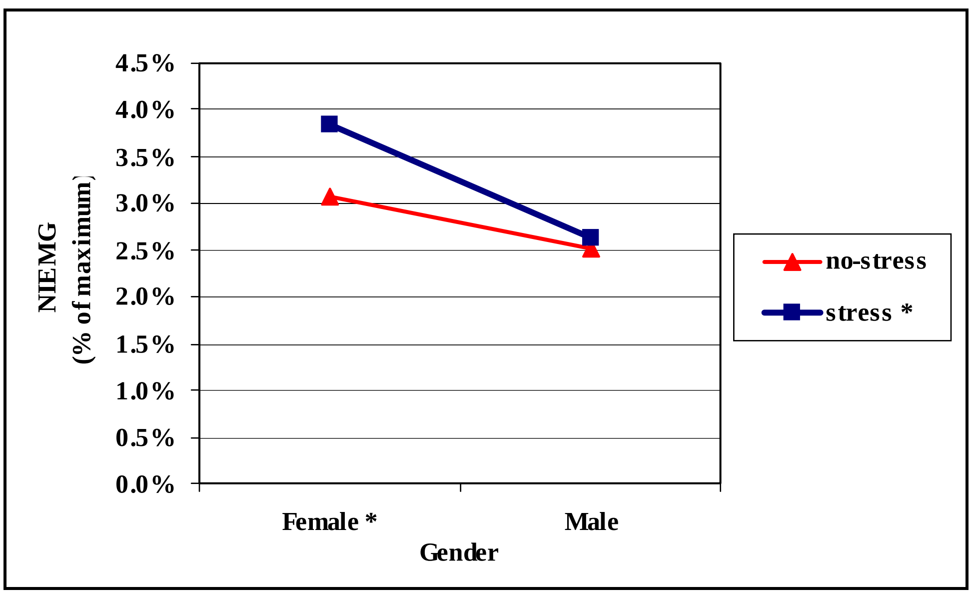


Figure 8-18. Significant interaction effect (p=0.0030) of gender (GENDER) and stress condition (STRESS) for pipetting task dFLEX. (* indicates simple effect within this level of independent variable.)

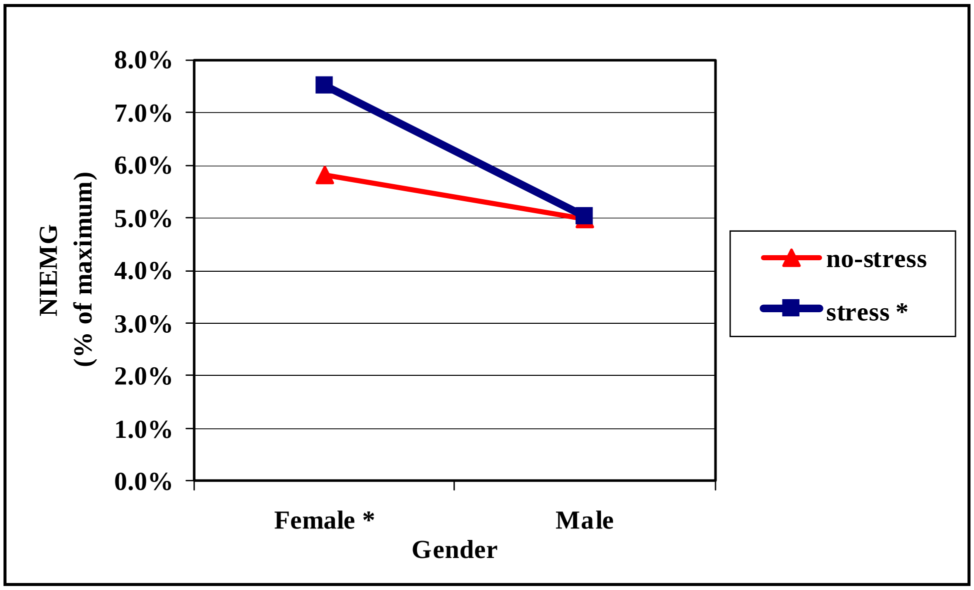


Figure 8-19. Significant interaction effect (p=0.0198) of gender (GENDER) and stress condition (STRESS) for pipetting task dEXT. (* indicates simple effect within this level of independent variable.)

8.4.3.5 Summary of Findings for Muscle Tension/Activity during Pipetting

In general, personality type did not impact muscle activity during the pipetting task. However, it did significantly impact dFLEX activity, but in opposite directions for males and females. Type A female dFLEX activity was 57% of the Type B female activity. Type A male dFLEX activity was 188% of the Type B male activity.

Psychosocially-imposed time stress had a wider impact on muscle activity, though in some cases this impact was moderated by gender. Significant increases were observed during the stress condition for six of the ten muscles used to evaluate muscle activity. These included four dominant-side and two non-dominant side muscles. Mean activity in these muscles increased by 9 to 23% during the stress condition. However, gender moderated this effect for the dominant flexor (dFLEX) and extensor (dEXT) groups which were the primary executers for the pipetting task. Time stress produced 25 to 29% increases in the activity of these muscles for females. However, no differences were obtained for males.

8.4.4 Physiological Response – Muscle Tension/Activity during Computer Entry

8.4.4.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for each of the normalized integrated electromyography (NIEMG) dependent variables are contained in Table 8-14.

Table 8-14. Summary statistics for normalized integrated electromyographic (NIEMG) variables obtained during both conditions of the computer task.

NIEMG variable	units	N	Mean	Standard Deviation	Minimum	Maximum
nFLEX	% of max	50	2.0	1.1	0.5	4.9
nEXT	% of max	50	10.4	5.1	4.3	28.6
nTRAP	% of max	50	4.1	3.1	0.6	13.9
nRHOM	% of max	50	3.2	1.8	1.3	11.2
nPARA	% of max	50	4.2	2.9	1.2	16.0
dFLEX	% of max	50	1.9	1.2	0.7	6.8
dEXT	% of max	50	9.8	5.1	1.4	31.3
dTRAP	% of max	50	4.3	2.9	0.6	10.8
dRHOM	% of max	50	5.0	3.7	0.7	18.3
dPARA	% of max	50	4.5	2.1	1.0	9.5

NIEMG are non-dominant (e.g., nFLEX) and dominant (e.g., dFLEX) side measures.

8.4.4.2 General Statistical Analysis and Results

The effects of the independent variables on the ten computer NIEMG variables were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and stress condition ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The NIEMG data included 10 variables (5 non-dominant and 5 dominant side) for each condition for each subject resulting in 50 observations for each ANOVA. Each of these variables and the results of the analyses are summarized in Table 8-15 and Table 8-16 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.8.

8.4.4.2.1 Verification of the ANOVA Assumptions

The NIEMG data were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Appendix 13.9. All plots and computed statistics indicate that the data meet, or only moderately violate, the assumptions that the residuals are normally and independently distributed with mean zero and constant variance.

Table 8-15. Model #1 resulting between-subjects p-values of computer task NIEMG ANOVA's.

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
nFLEX	ns	ns	ns	ns	ns	ns	ns
nEXT	ns	ns	ns	ns	ns	ns	ns
nTRAP	ns	ns	**0.0459**	ns	ns	ns	ns
nRHOM	ns	ns	ns	ns	ns	ns	ns
nPARA	ns	ns	ns	ns	ns	ns	ns
dFLEX	ns	ns	ns	ns	ns	ns	ns
dEXT	ns	ns	ns	ns	ns	ns	ns
dTRAP	ns	ns	ns	ns	ns	ns	ns
dRHOM	ns	ns	ns	ns	ns	ns	ns
dPARA	ns	ns	ns	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 8-16. Model #1 resulting within-subjects p-values of computer task NIEMG ANOVA's.

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
nFLEX	ns	ns	ns	**0.0329**	ns	0.0935	ns	ns
nEXT	ns	ns	ns	ns	ns	ns	ns	ns
nTRAP	ns	ns	ns	ns	ns	ns	ns	ns
nRHOM	ns	ns	ns	**0.0142**	ns	ns	ns	ns
nPARA	ns	ns	ns	ns	0.0538	ns	ns	ns
dFLEX	ns	ns	ns	ns	ns	ns	ns	ns
dEXT	ns	ns	ns	ns	ns	ns	ns	ns
dTRAP	ns	ns	ns	ns	ns	ns	ns	ns
dRHOM	ns	ns	ns	ns	ns	**0.0035**	ns	ns
dPARA	ns	ns	ns	ns	ns	0.0622	ns	0.0785

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

8.4.4.3 Between-subjects Effects

The computer task NIEMG variables (10 variables) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and stress condition ORDER. The results were shown in Table 8-15.

The analysis revealed no significant main effects of personality TYPE. The mean values by personality TYPE are shown in Figure 13-12 of Appendix 13.4. Though not statistically significant, Type B mean values were higher than Type A mean values for 8 of the 10 variables. Type A mean values were only higher for the nFLEX and nTRAP.

The analysis revealed no significant effects of GENDER. The mean NIEMG values by GENDER are shown in Figure 13-13 of Appendix 13.4. Though not statistically significant, the mean values for Females were higher than the mean Male values for six of the ten NIEMG measures.

For those six, the mean Female values ranged from 113.3% to 161.5% of the mean Male values. The nEXT, dEXT, nPARA, and dPARA mean values were lower for Females than for Males. For those four, the mean Female values ranged from 71.0% to 91.6% of the mean Male values. The same trend appeared for the non-dominant side variables as for the dominant side variables.

The analysis revealed a significant main effect ($F\{1,17\} = 4.61$, $p=0.0459$) of stress condition ORDER for nTRAP. The mean NIEMG values by ORDER are shown in Figure 8-20 for all of the NIEMG variables. The mean nTRAP value for order 1 was 2.8% of maximum, which was significantly lower than the mean value of 5.5% of maximum that was obtained for order 2. Though not statistically significant, the mean values for order 1 were higher for seven of the ten variables. With the exception of nEXT and dEXT, the same trend appeared for the non-dominant side variables as for the dominant side variables.

The analysis revealed no significant 2-way or 3-way interaction effects for the between-subjects variables.

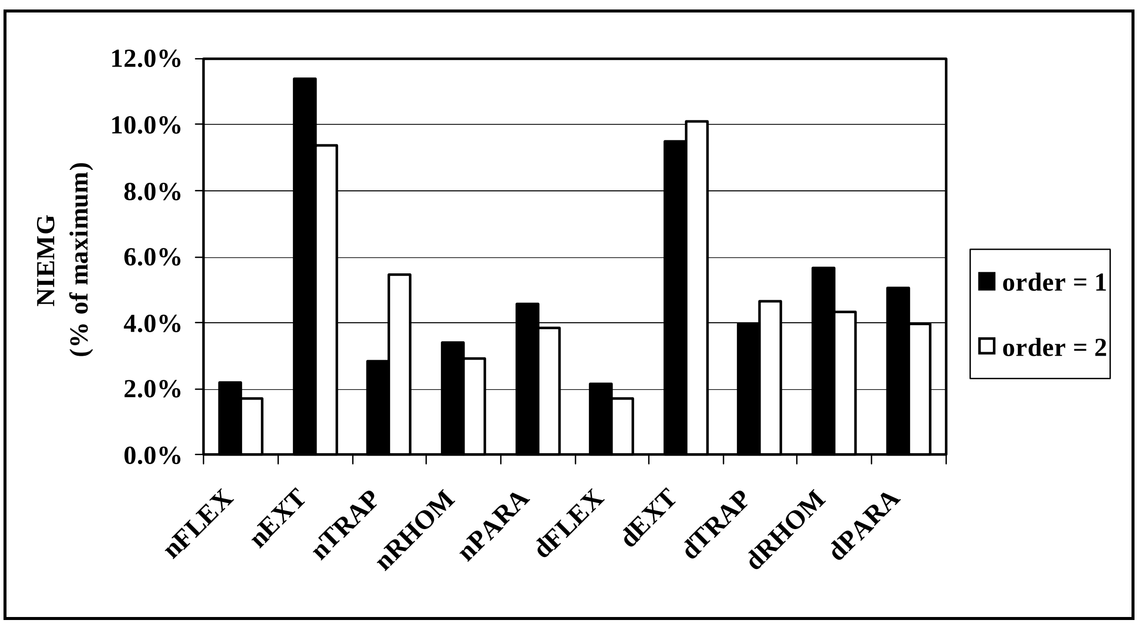


Figure 8-20. Significant (for nTRAP) and nonsignificant (for all others) effects of stress condition order (ORDER) on computer NIEMG mean values.

8.4.4.4 Within-subjects Effects

The computer task NIEMG variables (10 variables) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed no significant main effects of STRESS for any of the variables. The mean values by STRESS condition are shown in Figure 13-14 of Appendix 13.4. The mean values obtained from the stress condition ranged from 92.3% to 108.4% of the mean values obtained from the no-stress condition.

The analysis revealed a significant 2-way interaction effect of ORDER x STRESS for nFLEX ($F\{1,17\} = 5.39$, $p=0.0329$). The mean nFLEX values for each ORDER x STRESS combination can be seen in Figure 8-21. Subsequent analyses demonstrated that there was a simple effect of stress for order 1 but not for order 2. There was a 6.3% increase in nFLEX activity during the stress condition when subjects performed the no-stress condition first. However, there were no differences between orders for either of the stress conditions.

The analysis revealed a significant 2-way interaction effect of ORDER x STRESS for nRHOM ($F\{1,17\} = 7.46$, $p=0.0142$). The mean nRHOM values for each ORDER x STRESS combination can be seen in Figure 8-22. Subsequent analyses demonstrated that there was a simple effect of stress for order 1 but not for order 2. There was a 26.1% decrease in nRHOM activity during the stress condition when subjects performed the no-stress condition first. There were no differences between orders for either of the stress conditions.

Figure 8-21. Significant interaction effect (p=0.0329) of stress condition order (ORDER) and stress condition (STRESS) for computer task nFLEX. (* indicates simple effect within this level of independent variable.)

Figure 8-22. Significant interaction effect (p=0.0142) of stress condition order (ORDER) and stress condition (STRESS) for computer task nRHOM. (* indicates simple effect within this level of independent variable.)

8.4.4.5 Summary of Findings for Muscle Tension/Activity during Computer Entry

In general, neither personality type nor psychosocially-imposed frustration stress impacted the physiological response of muscle activity during computer entry. However, two non-dominant side muscles (nFLEX, nRHOM) showed responses to stress that were moderated by stress condition order, but the effects were in opposite directions. Stress produced a decrease (by 26.1%) in nRHOM activity but an increase (by 6.3%) in nFLEX activity when subjects performed the no-stress condition first. Order also significantly impacted the non-dominant trapezius (nTRAP) activity.

8.4.5 Specific Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety – Following Pipetting Task Conditions

8.4.6 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for the pipetting post-task survey administrations for each of the self-report musculoskeletal discomfort and anxiety variables are contained in Table 8-17.

8.4.6.1 General Statistical Analysis and Results

The effects of the independent variables on self-reported musculoskeletal discomfort and state anxiety were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The discomfort scores (MDSavg, MDSupx, and MDSbak) and the state anxiety scores (ANXtot) obtained from the two post-task administrations (3pN and 3pS) were evaluated with individual ANOVA's. The results of the analyses for those 50 observations are summarized in Table 8-18 and Table 8-19 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.8.

Table 8-17. Summary statistics for self-report musculoskeletal discomfort and anxiety variables for pipetting post-task survey administrations (50 observations).

Discomfort Measure	units	N	Mean	Standard Deviation	Minimum	Maximum
MDSh	centimeters	50	0.11	0.38	0	1.8
MDSnsL	centimeters	50	0.83	1.46	0	6.4
MDSnsR	centimeters	50	0.81	1.52	0	6.4
MDSaeL	centimeters	50	0.23	0.64	0	2.9
MDSaeR	centimeters	50	0.17	0.62	0	2.9
MDShwL	centimeters	50	0.00	0.00	0	0.0
MDShwR	centimeters	50	0.26	0.75	0	3.7
MDSubL	centimeters	50	0.43	0.94	0	4.0
MDSubR	centimeters	50	0.44	0.96	0	4.0
MDSlbL	centimeters	50	0.38	0.78	0	3.2
MDSlbR	centimeters	50	0.35	0.78	0	3.3
MDSlfL	centimeters	50	0.61	1.60	0	6.9
MDSlfR	centimeters	50	0.67	1.57	0	6.5
MDSavg	centimeters	50	0.41	0.51	0	2.03
MDSupx	centimeters	50	0.38	0.60	0	2.78
MDSbak	centimeters	50	0.40	0.71	0	2.75
ANXtot		50	23.74	5.89	14	37

Possible MDS visual analogue scale scores ranged from 0 to 10 centimeters. Possible ANXtot score ranged from 15 to 60. Actual dependent variables are MDSavg, MDSupx, and MDSbak. Others provided for reference.

Table 8-18. Model #1 resulting between-subjects p-values of individual discomfort and anxiety ANOVA's for pipetting post-task administrations only (50 observations).

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
MDSavg	ns	ns	ns	ns	ns	ns	ns
MDSupx	ns	ns	ns	ns	ns	ns	ns
MDSbak	ns	ns	ns	**0.0130**	0.0616	0.0975	ns
ANXtot	ns	ns	0.0847	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

Table 8-19. Model #1 resulting within-subjects p-values of individual discomfort and anxiety ANOVA's for pipetting post-task administrations only (50 observations).

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
MDSavg	ns	ns	0.0530	ns	ns	ns	ns	ns
MDSupx	ns	ns	ns	ns	ns	ns	ns	ns
MDSbak	ns	ns	ns	0.0753	ns	ns	ns	ns
ANXtot	ns	ns	ns	ns	ns	ns	ns	ns

Significant ($p < 0.05$) p-values shown in bold.
Almost significant ($0.05 \leq p \leq 0.1$) p-values provided.
ns – not significant and $p > 0.1$.

8.4.6.2 Self-reported Musculoskeletal Discomfort

8.4.6.2.1 Between-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. There were no significant main effects for the between-subjects variables for any of the three composite discomfort scores.

The means for the composite discomfort scores by personality TYPE are shown in Figure 13-15 of Appendix 13.4. Though statistically nonsignificant, all three mean composite discomfort scores were substantially lower for Type B individuals than Type A individuals. The mean Type B MDSavg score was 41.9% of the mean Type A score. The mean Type B MDSupx score was 52.0% of the mean Type A score. The mean MDSbak score was 60.1% of the mean Type A score.

The means for the composite discomfort scores by GENDER are shown in Figure 13-16 of Appendix 13.4. Though statistically nonsignificant, the mean composite discomfort scores differed substantially between genders. The mean MDSavg and MDSupx scores were lower for males than for females. The mean MDSavg for males was 80.5% of the mean score for females. The mean

MDSupx score was 47.5% of the mean score for females. However, the mean MDSbak score for males was 195.4% of the mean score for females.

The ANOVA analysis also revealed a significant interaction effect of TYPE x GENDER ($F\{1,17\} = 7.69$, $p=0.0130$) for MDSbak. The mean scores for each TYPE x GENDER combination can be seen in Figure 8-23. Subsequent analyses demonstrated that there was a simple effect of personality type for Males but not for Females. There was also a simple effect of gender for Type A's but not for Type B's.

The ANOVA analysis revealed no other significant 2-way or 3-way interaction effects for the between-subjects variables.

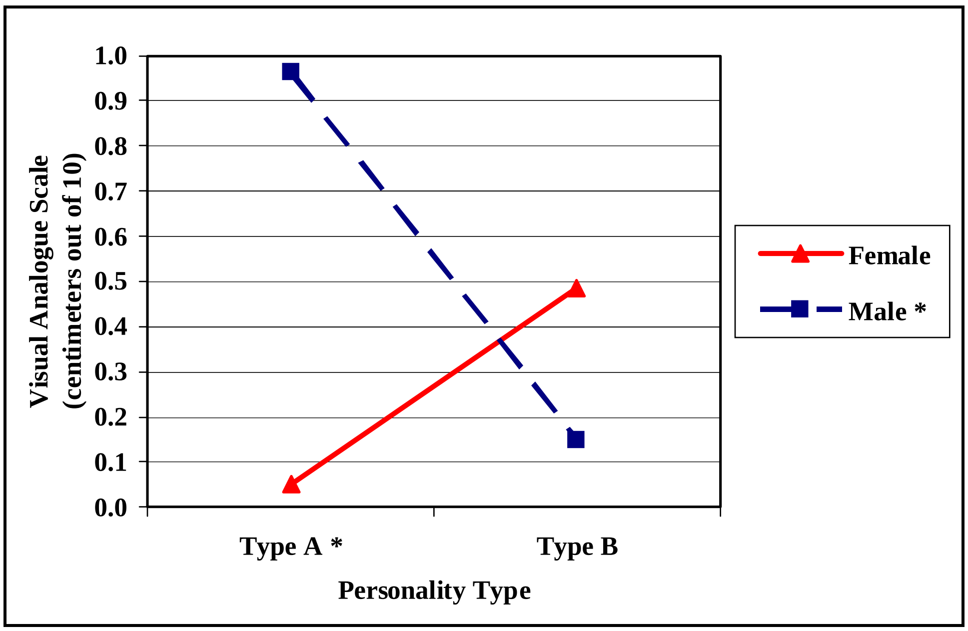


Figure 8-23. Significant interaction effect (p=0.0130) of personality type (TYPE) and gender (GENDER) on MDSbak discomfort scores for pipetting post-task administrations only (50 observations). (* indicates simple effect within this level of independent variable.)

8.4.6.2.2 Within-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed no significant main or interactive effects of STRESS for any of the three composite discomfort variables. Though statistically nonsignificant, all three mean scores for the stress condition were higher than for the no-stress condition. The mean MDSavg, MDSupx, and MDSbak scores for the stress condition were 117.0%, 147.1%, and 111.6%, respectively, of the means for the no-stress condition.

8.4.6.3 Self-reported State Anxiety

8.4.6.3.1 Between-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. This analysis revealed no significant main or interactive effects of the between-subjects variables.

8.4.6.3.2 Within-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. This analysis revealed no significant main or interactive effects of STRESS.

8.4.6.4 Summary of Findings for Specific Discomfort/Anxiety Reporting Behaviors Following the Pipetting Task

Effects of personality type on discomfort reports following the pipetting trial were limited to average back discomfort (MDSbak) reported by males. Type A males reported average back discomfort that was more than 6 times the level reported by Type B males, though the magnitudes of these values were small (< 1.0). Personality type had no effect on levels of anxiety that were reported. Psychosocially-imposed time stress had no effects on discomfort or anxiety reports following the pipetting task conditions.

8.4.7 Specific Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety – Following Computer Task Conditions

8.4.7.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects for the computer post-task survey administrations for each of the self-report musculoskeletal discomfort and anxiety variables are contained in Table 8-20.

Table 8-20. Summary statistics for self-report musculoskeletal discomfort and anxiety variables for computer post-task survey administrations (50 observations).

Discomfort Measure	units	N	Mean	Standard Deviation	Minimum	Maximum
MDSh	centimeters	50	0.06	0.31	0	1.7
MDSnsL	centimeters	50	0.68	1.35	0	5.7
MDSnsR	centimeters	50	0.68	1.39	0	5.7
MDSaeL	centimeters	50	0.16	0.52	0	2.5
MDSaeR	centimeters	50	0.19	0.56	0	2.4
MDShwL	centimeters	50	0.07	0.29	0	1.7
MDShwR	centimeters	50	0.09	0.33	0	1.7
MDSubL	centimeters	50	0.75	1.71	0	7.4
MDSubR	centimeters	50	0.77	1.76	0	7.6
MDSlbL	centimeters	50	0.28	0.68	0	3.0
MDSlbR	centimeters	50	0.26	0.67	0	3.0
MDSlfL	centimeters	50	0.37	1.40	0	7.8
MDSlfR	centimeters	50	0.47	1.45	0	7.7
MDSavg	centimeters	50	0.37	0.68	0	3.08
MDSupx	centimeters	50	0.31	0.54	0	1.90
MDSbak	centimeters	50	0.52	1.00	0	3.75
ANXtot		50	23.98	7.13	15	45

Possible MDS visual analogue scale scores ranged from 0 to 10 centimeters. Possible ANXtot score ranged from 15 to 60. Actual dependent variables are MDSavg, MDSupx, and MDSbak. Others provided for reference.

8.4.7.2 General Statistical Analysis and Results

The effects of the independent variables on self-reported musculoskeletal discomfort and state anxiety were evaluated using Analysis of Variance (ANOVA) with Model #1 as described in Section 5.5.2. The model included TYPE, GENDER, and ORDER as between-subjects independent variables and STRESS as the within-subjects independent variable. The model also included all possible interactions. The discomfort scores (MDSavg, MDSupx, and MDSbak) and the state anxiety scores (ANXtot) obtained from the two post-task administrations (3cN and 3cS) were evaluated with individual ANOVA's. The results of the analyses for those 50 observations are summarized in Table 8-21 and Table 8-22 and described in more detail in the sections following the tables. The discussion is limited to main effects and 2-way interaction effects of the independent variables. Higher order interactions were not interpreted due to the small numbers of subjects that created these values. However, any that were found to be significant are provided in Appendix 13.8.

Table 8-21. Model #1 resulting between-subjects p-values of individual discomfort and anxiety ANOVA's for computer post-task administrations only (50 observations).

	TYPE	GENDER	ORDER	TYPE x GENDER	TYPE x ORDER	GENDER x ORDER	TYPE x GENDER x ORDER
MDSavg	ns	ns	**0.0260**	ns	ns	0.0888	ns
MDSupx	ns	ns	**0.0149**	ns	ns	0.0773	ns
MDSbak	ns	ns	0.0729	ns	ns	ns	ns
ANXtot	ns	0.0710	ns	ns	ns	ns	ns
Significant ($p < 0.05$) p-values shown in bold. Almost significant ($0.05 \leq p \leq 0.1$) p-values provided. ns – not significant and $p > 0.1$.							

Table 8-22. Model #1 resulting within-subjects p-values of individual discomfort and anxiety ANOVA's for computer post-task administrations only (50 observations).

	STRESS	TYPE x STRESS	GENDER x STRESS	ORDER x STRESS	TYPE x GENDER x STRESS	TYPE x ORDER x STRESS	GENDER x ORDER x STRESS	TYPE x GENDER x ORDER x STRESS
MDSavg	ns	ns	ns	ns	ns	ns	ns	ns
MDSupx	ns	ns	ns	ns	ns	ns	ns	ns
MDSbak	ns	ns	ns	ns	ns	ns	ns	ns
ANXtot	**0.0042**	ns	ns	ns	0.0892	ns	ns	**0.0021**
Significant ($p < 0.05$) p-values shown in bold. Almost significant ($0.05 \leq p \leq 0.1$) p-values provided. ns – not significant and $p > 0.1$.								

8.4.7.3 Self-reported Musculoskeletal Discomfort

8.4.7.3.1 Between-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. There were no significant main effects for TYPE or GENDER for any of the three composite discomfort scores.

The means for the composite discomfort scores by personality TYPE are shown in Figure 13-17 of Appendix 13.4. Though statistically nonsignificant, all three mean composite discomfort scores were substantially lower for Type B individuals than Type A individuals. The mean Type B MDSavg score was 40.6% of the mean Type A score. The mean Type B MDSupx score was 53.1% of the mean Type A score. The mean MDSbak score was 39.1% of the mean Type A score.

The means for the composite discomfort scores by GENDER are shown in Figure 13-18 of Appendix 13.4. Though statistically nonsignificant, all three mean composite discomfort scores were substantially lower for Males than for Females. The mean MDSavg for males was 43.3% of the mean score for females. The mean MDSupx score was 39.9% of the mean score for females. The mean MDSbak score was 59.1% of the mean score for females.

The ANOVA analysis did reveal a significant main effect of ORDER for MDSavg ($F\{1,17\} = 5.95$, $p=0.0260$) and MDSupx ($F\{1,17\} = 7.33$, $p=0.0149$). The mean scores by ORDER can be seen in Figure 8-24. The mean scores for those subjects performing the stress condition first (order = 2) were significantly higher than the means for those subjects performing the no-stress condition first (order = 1). The mean MDSavg, MDSupx, and MDSbak scores for order 2 were 747.3%, 787.2%, and 603.8% of the order 2 means, respectively.

The ANOVA analysis revealed no significant 2-way or 3-way interaction effects for the between-subjects variables.

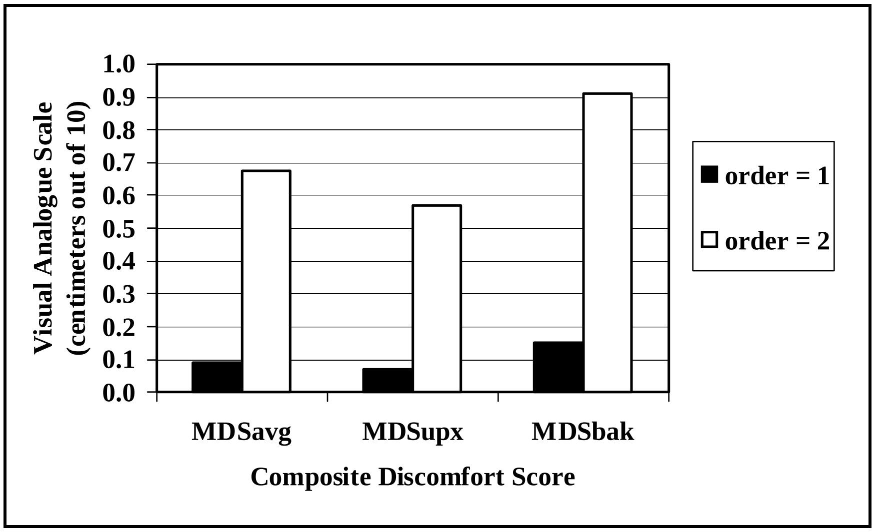


Figure 8-24. Significant (for MDSavg and MDSupx) and nonsignificant (for MDSbak) effects of stress condition order (ORDER) on composite discomfort scores for computer post-task administrations only (50 observations).

8.4.7.3.2 Within-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. The ANOVA analysis revealed no significant main or interactive effects of STRESS for any of the three composite discomfort variables. The mean scores by STRESS condition can be seen in Figure 13-19 of Appendix 13.4. Though statistically nonsignificant, all three mean scores for the stress condition were slightly lower than for the no-stress condition. The mean MDSavg, MDSupx, and MDSbak scores for the stress condition were 95.6%, 97.9%, and 87.0%, respectively, of the means for the no-stress condition.

8.4.7.4 Self-reported State Anxiety

8.4.7.4.1 Between-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER. This analysis revealed no significant main or interactive effects of the between-subjects variables.

8.4.7.4.2 Within-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA as previously described to determine the effects of STRESS. This analysis revealed a significant ($F\{1,17\} = 10.89$, $p=0.0042$) main effect of STRESS. The no-stress mean ANXtot value was 23.3. The stress condition mean value was 24.7, which was 106.0% of the no-stress value.

8.4.7.5 Summary of Findings for Specific Discomfort/Anxiety Reporting Behaviors Following the Computer Task

There were no effects of personality type for specific discomfort or anxiety reports obtained after the computer task conditions. Psychosocially-imposed frustration stress also had no effect on discomfort reports. However it did significantly increase reported anxiety by 6%. Order affected overall discomfort and upper extremity discomfort. The mean scores for those subjects performing the stress condition first (order = 2) were significantly higher (by more than 600%) than the means for those subjects performing the no-stress condition first (order = 1). However, the magnitudes of the mean values and the differences between them were small (< 1.0).

8.4.8 General Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety

8.4.8.1 Overall Descriptive Statistics

The means, standard deviations, and ranges across all subjects and all observations for each of the self-report musculoskeletal discomfort and anxiety variables are contained in Table 8-23.

The mean composite discomfort scores by survey administration (SURVEY) can be seen in Figure 8-25. From the figure, it is can be seen that all three mean composite scores show a similar trend. The scores from administrations following the task trials (administrations 3pN, 3pS, 3cN, and 3cS) were higher than they were at the other times (1, 2, and 4). For each discomfort score, the initial administration (SURVEY=1) was the lowest in magnitude, followed by the second administration, followed by the last administration (SURVEY=4), and then by the task trials.

The mean anxiety scores by survey administration (SURVEY) can be seen in Figure 8-26. From the figure, it appears that the mean scores are relatively constant across administrations 1, 2, 3cN, 3cS, 3pN, and 3pS but lower for the final administration.

Table 8-23. Summary statistics for self-report musculoskeletal discomfort and anxiety variables for all survey administrations (175 observations).

Dependent Variable	units	N	Mean	Standard Deviation	Minimum	Maximum
MDSh	centimeters	175	0.100	0.483	0	4.700
MDSnsL	centimeters	175	0.564	1.209	0	6.400
MDSnsR	centimeters	175	0.531	1.202	0	6.400
MDSaeL	centimeters	175	0.172	0.542	0	2.900
MDSaeR	centimeters	175	0.165	0.551	0	2.900
MDShwL	centimeters	175	0.026	0.167	0	1.700
MDShwR	centimeters	175	0.105	0.451	0	3.700
MDSubL	centimeters	175	0.425	1.205	0	7.400
MDSubR	centimeters	175	0.440	1.232	0	7.600
MDSlbL	centimeters	175	0.238	0.628	0	3.200
MDSlbR	centimeters	175	0.220	0.629	0	3.300
MDSlfL	centimeters	175	0.289	1.162	0	7.800
MDSlfR	centimeters	175	0.369	1.195	0	7.700
MDSavg	centimeters	175	0.280	0.502	0	3.077
MDSupx	centimeters	175	0.260	0.487	0	2.783
MDSbak	centimeters	175	0.331	0.746	0	3.750
ANXtot		175	22.760	6.094	14	45

Possible MDS visual analogue scale scores ranged from 0 to 10 centimeters. Possible ANXtot score ranged from 15 to 60. Actual dependent variables are MDSavg, MDSupx, and MDSbak. Others provided for reference.

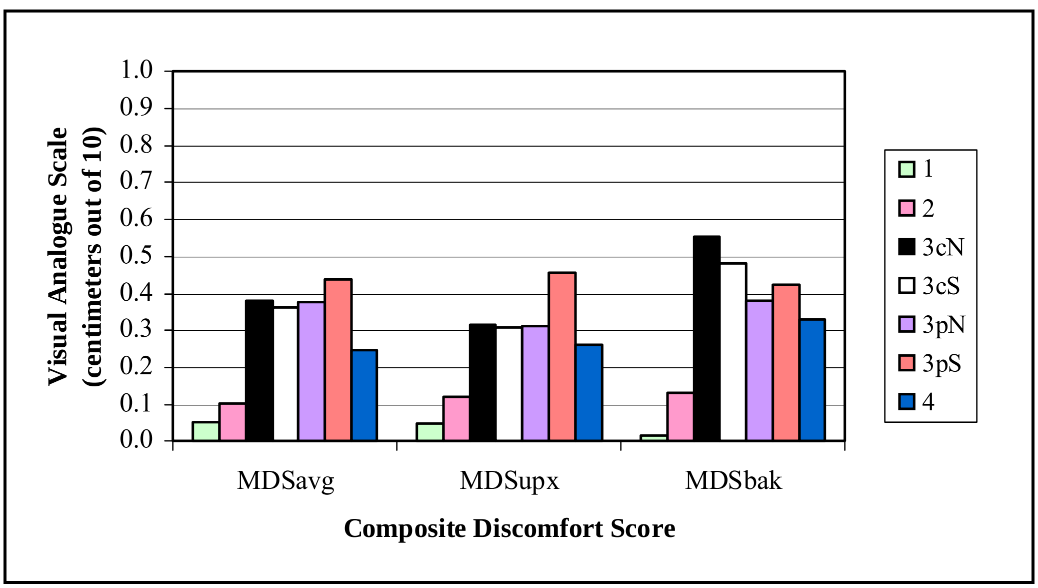


Figure 8-25. Mean composite discomfort scores by survey administration (SURVEY).

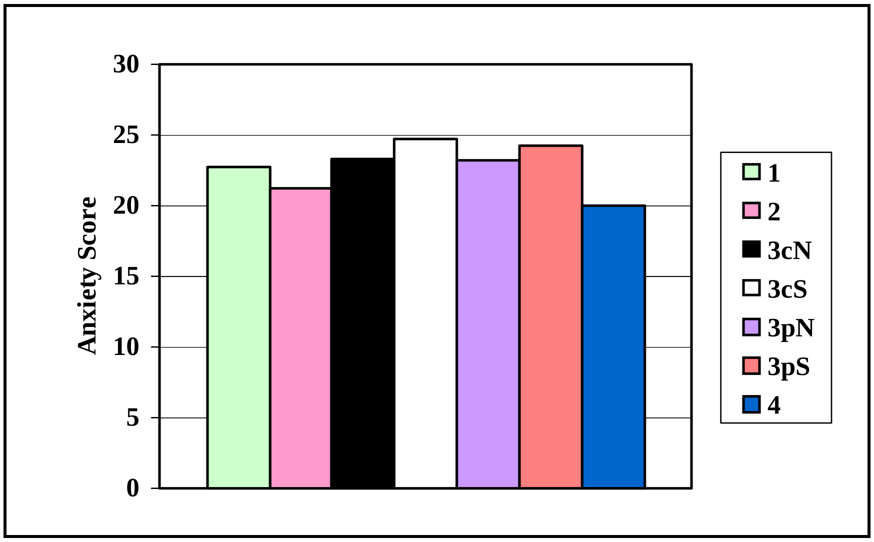


Figure 8-26. Mean state anxiety score (ANXtot) by survey administration (SURVEY).

8.4.8.2 Correlations among Self-reported Discomfort Scores

Pearson correlation coefficients were generated for each of the composite MDS variables across the seven survey administrations (SURVEY = 1, 2, 3cN, 3cS, 3pN, 3pS, and 4). This resulted in 21 unique correlations for each of the MDSavg, MDSupx, and MDSbak groups. Results for each composite discomfort MDS variable are provided separately in Table 8-24, Table 8-25, and Table 8-26.

Table 8-24. Correlations among MDSavg discomfort scores across administrations (N = 25).

	MDSavg1	MDSavg2	MDSavg3pN	MDSavg3pS	MDSavg3cN	MDSavg3cS
MDSavg2	**0.432**					
	0.0310					
MDSavg3pN	0.050	0.288				
	0.8130	*0.1634*				
MDSavg3pS	0.117	**0.481**	**0.805**			
	0.5772	*0.0148*	*<0.0001*			
MDSavg3cN	0.008	0.310	**0.711**	**0.939**		
	0.9710	*0.1312*	*<0.0001*	*<0.0001*		
MDSavg3cS	0.079	0.327	**0.650**	**0.908**	**0.976**	
	0.7071	*0.1104*	*0.0004*	*<0.0001*	*<0.0001*	
MDSavg4	0.073	0.323	**0.657**	**0.885**	**0.946**	**0.945**
	0.7278	*0.1148*	*0.0004*	*<0.0001*	*<0.0001*	*<0.0001*

p-values shown in italics. Significant correlations shown in bold.

Table 8-25. Correlations among MDSupx discomfort scores across administrations (N = 25).

	MDSupx1	MDSupx2	MDSupx3pN	MDSupx3pS	MDSupx3cN	MDSupx3cS
MDSupx2	**0.804**					
	<0.0001					
MDSupx3pN	**0.494**	**0.574**				
	0.0120	*0.0027*				
MDSupx3pS	**0.609**	**0.699**	**0.617**			
	0.0012	*<0.0001*	*0.0010*			
MDSupx3cN	0.393	**0.518**	**0.396**	**0.897**		
	0.0520	*0.0079*	*0.0500*	*<0.0001*		
MDSupx3cS	**0.509**	**0.702**	**0.476**	**0.933**	**0.947**	
	0.0093	*<0.0001*	*0.0161*	*<0.0001*	*<0.0001*	
MDSupx4	**0.469**	**0.480**	**0.529**	**0.724**	**0.694**	**0.666**
	0.0179	*0.0152*	*0.0066*	*<0.0001*	*0.0001*	*0.0003*

p-values shown in italics. Significant correlations shown in bold.

Table 8-26. Correlations among MDSbak discomfort scores across administrations (N = 25).

	MDSbak1	MDSbak2	MDSbak3pN	MDSbak3pS	MDSbak3cN	MDSbak3cS
MDSbak2	0.106					
	0.6142					
MDSbak3pN	-0.009	**0.514**				
	0.9662	*0.0086*				
MDSbak3pS	0.029	**0.661**	**0.726**			
	0.8915	*0.0003*	*<0.0001*			
MDSbak3cN	-0.104	0.321	**0.598**	**0.574**		
	0.6221	*0.1175*	*0.0016*	*0.0027*		
MDSbak3cS	-0.001	0.351	**0.572**	**0.518**	**0.969**	
	0.9956	*0.0852*	*0.0028*	*0.0079*	*<0.0001*	
MDSbak4	0.024	0.389	0.319	0.319	**0.843**	**0.896**
	0.9089	*0.0543*	*0.1202*	*0.1200*	*<0.0001*	*<0.0001*

p-values shown in italics. Significant correlations shown in bold.

8.4.8.3 Correlations among Self-reported State Anxiety Scores

Pearson correlation coefficients were generated for each of the anxiety scores (ANXtot) across the seven survey administrations (SURVEY = 1, 2, 3cN, 3cS, 3pN, 3pS, and 4). This resulted in 21 unique correlations between ANXtot scores. All correlations were significant. Results are provided in Table 8-27.

Table 8-27. Correlations among state anxiety scores (ANXtot) across administrations (N = 25).

	ANXtot1	ANXtot2	ANXtot3pN	ANXtot3pS	ANXtot3cN	ANXtot3cS
ANXtot2	**0.709**					
	<0.0001					
ANXtot3pN	**0.716**	**0.713**				
	<0.0001	*<0.0001*				
ANXtot3pS	**0.707**	**0.637**	**0.790**			
	<0.0001	*0.0006*	*<0.0001*			
ANXtot3cN	**0.634**	**0.714**	**0.844**	**0.788**		
	0.0007	*<0.0001*	*<0.0001*	*<0.0001*		
ANXtot3cS	**0.679**	**0.690**	**0.799**	**0.842**	**0.932**	
	0.0002	*0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	
ANXtot4	**0.461**	**0.582**	**0.724**	**0.637**	**0.874**	**0.766**
	0.0204	*0.0023*	*<0.0001*	*0.0006*	*<0.0001*	*<0.0001*

p-values shown in italics. Significant correlations shown in bold.

8.4.8.4 Correlations between Self-reported Discomfort and Anxiety Scores

The relationship between self-reported measures of discomfort and state anxiety were evaluated with Pearson correlation coefficients. For each survey administration (SURVEY), correlations were computed between the anxiety score for that administration (e.g., ANXtot1) and the corresponding composite MDS scores (e.g., MDSavg1, MDSupx1, MDSbak1). This resulted in twenty-one (21) unique correlations. Only two correlations, both from administration 1, were significant. The correlation between MDSavg1 and ANXtot1 was 0.451 (p=0.0237). The correlation between MDSbak1 and ANXtot1 was 0.404 (p=0.0449).

8.4.8.5 Summary of Findings for General Discomfort/Anxiety Reporting Behaviors for the Phase III Laboratory Study of Pipetting and Computer Tasks

The evaluation of general reporting behaviors revealed that upper extremity discomfort (MDSupx) scores were significantly correlated (20 significant of 21 total) across administrations, while overall discomfort and back discomfort were only somewhat correlated. However, overall discomfort scores (MDSavg) were significantly correlated for all administrations that occurred after the second administration. Anxiety scores were significantly correlated (21 significant of 21 total) across all administrations. In general, discomfort and anxiety scores obtained during each administration were not correlated (2 significant of 21 total).

8.4.9 Sensitivity of Results to Excluding Higher Order Interactions

8.4.9.1 General Statistical Analysis and Results

Each of the statistical analyses previously discussed was rerun with higher order (3-way and 4-way) interactions removed from the models to evaluate the sensitivity of the results. This resulted in only one change in significance status. The GENDER x STRESS p-value obtained for MDSavg for the pipetting post-task administrations changed from 0.0530 to **0.0336**.

9. OVERALL SUMMARY OF RESULTS

Results of the two laboratory studies yielded significant findings for between-subjects and within-subjects variables. These findings are summarized in Table 9-1 and Table 9-2 and discussed in the following section.

Table 9-1. Summary of statistically significant findings for between-subject variables.

		T	G	O	T x G	T x O	G x O	T x G x O
Assembly task	**anthropometry**		ALL	Hand length Forearm length Arm length				AL
	performance	avgDIStpu avgASSYtpu						
	wrist motion	nRRUpos		aRRUvel aRFEvel aRRUacc aRFEacc nromRFE			romLRU nromLRU	
	discomfort				MDSavg		MDSupx	
	anxiety			ANXtot	ANXtot			ANXtot
Pipetting task	**anthropometry**		ALL					
	performance							
	NIEMG		nEXT		dFLEX		dFLEX	nFLEX nTRAP
	discomfort				MDSbak			
	anxiety							
Computer task	**anthropometry**		ALL				HS	
	performance							
	NIEMG			nTRAP				
	discomfort			MDSavg MDSupx				
	anxiety							
Significant ($p < 0.05$) p-values shown. T – personality type, G – gender, O – condition order.								

Table 9-2. Summary of statistically significant findings for within-subject variables.

		S	T x S	G x S	O x S	T x G x S	T x O x S	G x O x S	T x G x O x S
Assembly task	**performance**	avgDIStpu avgASSYtpu			DIS				
	wrist motion	pos all vel all acc romLRU nromLRU		aLRUvel aLRUacc romLRU nromLRU	romLRU nromLRU			aLRUvel aLRUacc romLRU nromLRU	romRFE nromRFE
	discomfort				MDSavg MDSbak		MDSavg	MDSavg	
	anxiety	ANXtot						ANXtot	
Pipetting task	**performance**	avgPIPtpc			avgPIPtpc				
	NIEMG	dFLEX dEXT dTRAP dRHOM nTRAP nRHOM		dFLEX dEXT				dFLEX nTRAP	
	discomfort								
	anxiety								
Computer task	**performance**	avgCOMtpp			avgCOMtpp				
	NIEMG				nFLEX nRHOM		dRHOM		
	discomfort								
	anxiety	ANXtot							ANXtot

Significant ($p < 0.05$) results shown. T – personality type, G – gender, O – condition order, S – stress condition.

10. DISCUSSION

A number of primary hypotheses were formulated for this specific study. The results obtained and presented in the previous chapters offer varied levels of support for these hypotheses. Significant results related to each of these hypotheses are discussed here. Several nonsignificant findings will also be reviewed. These nonsignificant findings are related to trends and/or large differences that were observed for mean values but not found to be statistically significant. It is possible that these findings (1) are not meaningful, simply exist with this sample, and/or would disappear or reverse with another sample; or (2) represent meaningful trends and could potentially emerge as statistically significant findings if more subjects were included in an expanded protocol. Some results were also described for additional evaluations beyond those hypotheses that were specifically stated. These results and their implications will also be discussed. Finally, there have been some important methodological lessons learned in this study that will also be presented.

Though different subjects participated in the first and second laboratory studies, many evaluations were performed within each study. This resulted in the same people being used for multiple statistical analyses. A standard significance criterion ($p < 0.05$) was used in these analyses. It is possible that a more conservative level should have been used to compensate for the multiple analyses. However, recent similar studies (Marras et al., 2000; Van Galen, Muller, Meulenbroek, & Van Gemmert, 2002) employed a less conservative ($p < 0.1$) significance criteria for some results, and this has been suggested as a possibility with small-sized experiments (Steel, Torrie, & Dickey, 1997,p. 94). These things should be considered when interpreting the results.

10.1 SUPPORT FOR PRIMARY HYPOTHESES

10.1.1 Hypotheses related to personality type (TYPE)

10.1.1.1 Workstyle – Performance time

It was hypothesized (H1) that Type A individuals would demonstrate faster workstyles than Type B individuals and this would be reflected in lower task performance times. Results provided mixed support for this hypothesis. Performance times obtained in the first laboratory study of an assembly task supported this hypothesis with Type A subjects showing significantly faster per-unit completion times than Type B subjects. Type B disassembly and assembly times were 117% and 114% of the Type A times. This finding was not confirmed in the second study. There were no significant differences between Type A and Type B mean pipetting or computer task performance times. Type B mean values were 91% and 95% of the Type A values, respectively.

In formulating this original hypothesis, it seemed reasonable to assume that Type A's would perform faster than Type B's based on the widely described "time urgency" characteristic of the Type A personality. This was illustrated with the assembly task, but not with the pipetting task or the computer task. It is possible that performance differences were not found during the pipetting task or the computer task simply because these tasks do not offer much possibility for developing a faster strategy. However, the assembly task did allow for variance in the strategy employed and may be the source of the faster completion times. Since the performance differences that were obtained during the assembly task could not be explained by faster hand/wrist motions (to be discussed in the following section), it is possible that Type A's employed different strategies to achieve the faster performance times. Another possibility also exists. The only metrics of successful performance provided to them were provided through the verbal scripts that included terminology such as "perform the task at a pace" and "perform the task as quickly." It is possible that performance time would have been affected differently if other metrics (e.g., accuracy) of success had been presented to the subjects for performing this task.

10.1.1.1.1 Comparison to Other Studies

The variability in the effect of personality type on performance found in the current study is consistent with the results of previous work. A recent study (Sudhakaran, 2003) showed no increase in speed of completion for Type A subjects while performing a simple overhead assembly task. The author hypothesized that the simplicity of the task did not allow the subjects of either personality type to develop strategies that could significantly and consistently improve performance. Jamal (1985) reported that findings from other studies indicate that Type A's outperform Type B's on "simple tasks" and in "situations calling for persistence and endurance" and that Type A's "set higher initial goals for their task performance" (p. 61). Since Jamal also states that "Type B's outperform Type A's on tasks that require slow, careful responses and broad focus of attention," it seems apparent that performance (and thus "outperforming") includes more than speed of performance. Still, it seems from the finding reported for the current study of faster performance for Type A's for the assembly task that Type A's did set and/or achieve higher performance goals. A recent study (Gregg et al., 2002) reported both supporting and contradicting evidence for faster performance times among Type A's. A 9-month prospective study of Army soldiers found a significant relationship between the Type A behavior pattern (using a 21-item abbreviated version of the Jenkins Activity Survey Form C) and the number of sit-ups completed in 2 minutes. However the study reported no relationship for number of push-ups completed in 2 minutes or for two-mile run time. Based on these observations, it seems possible that Type A's are generally believed to perform faster, but realization of this in measured results might be affected by other factors including (1) the limiting nature of the task for developing faster strategies, (2) implications of externally-presented metrics of success, and (3) limitations (e.g., physical limitations or lack of training on the task) outside of their intrinsic inclination to perform faster.

10.1.1.2 Workstyle – Wrist Motion Kinematics

It was hypothesized (H2) that Type A individuals would demonstrate faster workstyles than Type B individuals as represented by faster, more accelerated, and more deviated motions. There were no statistically significant findings for any of the wrist motion variables to offer support for this hypothesis. Some statistically non-significant findings, however, deserve some discussion because a consistent trend has occurred across dependent measures. Though only statistically significant for nRRUpos, Type B mean position variables were greater (i.e., higher absolute value with negative value indicating direction) for three of the four position variables. An inspection of extreme observations ruled out the possibility that these means were elevated by a single Type B subject. Type A mean left hand velocity and acceleration values were greater than Type B values. An inspection of extreme observations ruled out the possibility that these means were elevated by a single Type A subject. If these trends had been shown to be statistically significant, the increased velocities and accelerations for Type A's would have supported aspects of the original hypothesis (i.e., faster, more accelerated movements) while not supporting other aspects (i.e., more deviated postures). This again may be related to strategies that were used to perform the task.

At least three possible explanations exist for the absence of faster wrist motions for Type A's even though they displayed significantly faster performance times during the assembly task. First, it is possible that faster joint/segment motions are indeed experienced, but somewhere other than the hand/wrist. Second, Type A's may have employed one or more strategies that did not increase joint/segment motion. Subjects were not restricted to using a specific strategy. They could use one hand and/or both hands. They could pick up parts individually and/or pick several up simultaneously. Further evaluation of these possibilities could provide useful information for future exploration and development of the construct of workstyle and the methods employed to operationalize the construct. Third, even though task orders were randomly assigned to TYPE x GENDER groups, randomization may have failed to prevent possible confounding of the results due to anthropometric differences. Significant effects were obtained for ORDER for three important anthropometry variables – hand length, forearm length, and arm length (see Figure 7-7). Additionally, though not interpreted, significant or nearly significant TYPE x GENDER x ORDER effects were obtained for these same three variables. These results make it difficult to ascertain what results emerged based on the between-subjects variables and what results were due to differences in anthropometry. It may be possible that different statistical analysis methods (e.g., analysis of covariance) would allow these effects to be evaluated.

10.1.1.2.1 Comparison to Other Studies

Though no direct comparisons can be made regarding results that were obtained related to personality type, comparisons can be made to studies on general wrist motion kinematics and the magnitudes of these measures collected in the current work are consistent with previous studies. Marras and Schoenmarklin (1993) compared wrist motion parameters between high and low CTD risk jobs for 40 subjects in eight industrial plants. They presented mean, minimum, maximum, and difference between minimum and maximum values for angular position, velocity, and acceleration in each of three planes of movement. The results obtained in the current study are comparable to the values presented by Marras and Schoenmarklin. Specific comparisons of the means obtained in the current study are presented in Table 10-1. Each comparison provides the number of standard deviations from the mean presented in their study required to capture the mean obtained in the current study. A few notes of caution should be mentioned. Though Marras and Schoenmarklin measured wrist motion values for both hands, the values they presented were not hand-specific. Those values were based on hand selection criteria that involved job risk and/or hand dominance (Schoenmarklin, 1991). Additionally, some descriptive statistics for the motion parameters could not be compared. Though the mean velocity and acceleration values they presented were based on absolute values of the data, the minimum and maximum values were not. Therefore, these values are not comparable to the current study. The range of motion values obtained in the current study were compared to the position difference (between minimum and maximum) values presented in that study. No difference values for velocity and acceleration were calculated for the current study.

Though the comparison values are presented by risk level, it is not intended for the current study's results to imply direct inferences regarding injury risk. The current study may provide some insight into pathways to injury, but it must be remembered that these subjects were college students and only performed these wrist motions for very short durations.

Table 10-1. Comparison of wrist motion parameters to industry-based high- and low-risk group parameters.

	Current study	**Comparative study High-risk group**			**Comparative study Low-risk group**		
	Mean	**Mean**	**Standard deviation**	**Current mean within …**	**Mean**	**Standard deviation**	**Current mean within …**
nLRUpos	-6.78	-6.73	4.66	1 SD	-7.62	4.42	1 SD
nLFEpos	-3.64	-12.02	7.16	2 SD	-10.09	11.88	1 SD
nRRUpos	-9.10	-6.73	4.66	1 SD	-7.62	4.42	1 SD
nRFEpos	-8.90	-12.02	7.16	1 SD	-10.09	11.88	1 SD
aLRUvel	10.7	25.9	6.7	3 SD	17.0	6.7	1 SD
aLFEvel	13.8	42.2	11.7	3 SD	28.7	7.6	2 SD
aRRUvel	14.7	25.9	6.7	2 SD	17.0	6.7	1 SD
aRFEvel	20.6	42.2	11.7	2 SD	28.7	7.6	2 SD
aLRUacc	181	494	142	3 SD	301	125	1 SD
aLFEacc	250	824	268	3 SD	494	156	2 SD
aRRUacc	252	494	142	2 SD	301	125	1 SD
aRFEacc	382	824	268	2 SD	494	156	1 SD
romLRU	36.13	23.65	6.71	2 SD	17.64	7.53	3 SD
romLFE	50.33	35.63	11.53	2 SD	27.95	9.92	3 SD
romRRU	39.78	23.65	6.71	3 SD	17.64	7.53	3 SD
romRFE	55.74	35.63	11.53	2 SD	27.95	9.92	3 SD

Comparative values obtained from Marras and Schoenmarklin (1993).
SD – standard deviation(s)

10.1.1.3 Muscle Tension/Activity

It was hypothesized (H3) that Type A individuals would demonstrate higher muscle activity levels than Type B individuals. This was explored in the second laboratory study for both the pipetting task and the computer entry task. There were no statistically significant main effects to support the hypothesis. However, a significant interaction of TYPE x GENDER was obtained for the pipetting dFLEX variable that may explain the absence of a main effect for this one NIEMG measure. When the nature of this interaction was evaluated, the results revealed that personality type had a significant effect for both males and females for dFLEX, but in opposite directions. For males, Type A's did exhibit significantly higher muscle activity values than Type B's. However, for females, Type A's exhibited significantly lower dFLEX values than Type B's. Therefore the original hypothesis was supported for this single case for males, but not for females. The results also revealed that female Type B's exhibited significantly higher dFLEX activity than Male Type B's, while there were no differences between Type A males and females. Since the dominant flexor group muscles were the primary executers of this task, this finding seems important even though it provides the only significant result involving personality type.

No effects involving personality type were found for the remaining nine NIEMG measures. Even though it is possible that no differences do indeed exist between Type A and Type B muscle activity for these values, another possibility seems plausible. The EMG signal obtained from a muscle during an activity of interest (e.g., task-specific activity) must be normalized to a specific value obtained for that muscle within that subject. This is typically the signal obtained from a muscle-specific maximum voluntary contraction (MVC). If one of these values is thought to be affected by a subject characteristic (e.g., personality type), then it may be possible that both are affected by this characteristic. It seems possible that the muscle activity of interest (e.g., task-specific EMG) might be being normalized to a value (e.g., MVC EMG) that is being affected by the same variable that is affecting task-specific EMG. If so, then significant differences for normalized EMG values would be difficult to obtain between groups that differ on the variable (e.g., personality type) whose effect is being evaluated.

Some statistically nonsignificant findings deserve some discussion because a consistent trend has occurred across dependent measures. Though there were no statistically significant effects of personality type for any of the NIEMG variables, Type B mean values were higher than Type A mean values for seven of the ten NIEMG variables for the pipetting task and for eight of the ten NIEMG variables for the computer task. For the pipetting task, Type A mean values were higher for the three non-dominant upper extremity values (nFLEX, nEXT, and nTRAP). Since this task was predominantly performed with only the dominant hand, these muscles were not directly required for performing the task. For the computer task, Type A mean values were higher for two of the same three (nFLEX and nTRAP). The computer task did required both hands, and thus directly required nFLEX and nEXT. Though not evaluated, it is possible that the nonsignificant differences in the presence of these trends may be a problem with variability and adequate statistical power. However, since a previous study (Glasscock et al., 1999) showed both trends and statistical results to support higher antagonist muscle activity during a controlled elbow exertion, these trends may deserve further exploration with more subjects and/or a more controlled task.

10.1.1.3.1 Comparison to Other Studies

The NIEMG levels found for the pipetting and computer tasks in this study appear to follow expected trends. In the pipetting task where only the dominant hand was actively working, the dominant side mean values were higher than the non-dominant side. In the computer task where both hands were actively working, values were similar on both the non-dominant and dominant sides.

No studies were found for direct comparison of muscle activity in the sampled muscles as a function of Type A personality. However, the overall mean NIEMG values obtained in this study appear to be comparable to levels that might be expected for these tasks. The results for the pipetting task were compared to a previous study conducted in this laboratory for an industry standard configuration of a standing power screwdriver task (Lutz, Starr, Smith, Stewart, Monroe, Joines, & Mirka, 2001). This study reported mean left and right trapezius NIEMG values to be approximately 3% MVC. The mean trapezius values found in the current study were 2.9% and 6.3%. The same study reported left and right thoracic muscle NIEMG levels of 10% and 6%. The mean values for the paraspinalis (at the level of T10) muscles in the current study were 6.2% and 5.8%. An additional study of simulated bank cashier work (Takala & Viikari-Juntura, 1991) reported trapezius activities of 4.1% to 6.2%. and rhomboideus/erector spinae activities of 10.1% to 12.6%.

The results for the computer task were compared to a previous study conducted in this laboratory to explore trapezius muscle activity during typing (Leyman, Mirka, Kaber, & Sommerich, 2001). Mean levels were reported to be 1% to 2% MVC for the left and right trapezius, respectively. The current study found these values to be 4.1% and 4.3%. Differences may be attributed to (1) the seated posture utilized in that study vs. the standing posture for the current study and (2) the requirement to continuously look down at the part number list in the current study.

10.1.1.4 Reporting Behaviors – Musculoskeletal Discomfort

It was hypothesized (H4) that Type A individuals would report lower levels of self-reported discomfort than Type B individuals. Though no main effects of personality type were obtained to support this hypothesis in either of the laboratory studies, some significant interactions with gender were found in both studies and may offer some insight. For reported overall average discomfort (MDSavg) in the study of the assembly task, there was significant support for this hypothesis but only for females. The mean Type B discomfort score for females was 535% of the mean Type A female discomfort score. There was no significant difference between Male Type A's and B's, even though the mean Type A score for males was 151% of the mean Type B score for males. For reported average back discomfort (MDSbak) following the pipetting trials in the second study, there was significant contradiction of the original prediction, but only for Males. The mean Type A score for males was 642% of the mean Type B score for males. Here, there were no significant differences between Type A and B females, even though the mean Type B discomfort score was 932% of the mean Type A score. However, though these significant and nonsignificant findings reflect large percent differences, it should be noted that the absolute magnitudes of the differences were small (less than 1 centimeter).

These results may offer some possible explanations for inconsistent findings across studies that compare prevalence of injury and/or discomfort between males and females. Some studies show that gender plays a significant role in prevalence of disorders/discomfort (Andersen, Kaergaard, Frost, Thomsen, Bonde, Fallentin, Borg, & Mikkelsen, 2002; Bigos et al., 1986; Punnett, 1998; Vingard, Alfredsson, Hagberg, Kilbom, Theorell, Waldenstrom, Hjelm, Wiktorin, & Hogstedt, 2000) while some show no differences (Andersson, 1981; Finsen, Christensen, & Bakke, 1997). This might indicate that some moderating factors (e.g., personality type, task characteristics) were not considered in those studies. Some studies report gender differences in discomfort/disorder prevalence for certain body regions while not for others (Bergqvist, Wolgast, Nilsson, & Voss, 1995; Magnavita, Bevilacqua, Mirk, Fileni, & Castellino, 1999). It certainly seems possible that an evaluation of each individual body region discomfort score would provide more insight than trying to measure "overall" discomfort. However, it is also critical to remember that discomfort and prevalence of diagnosed disorders, which some of these studies refer to, are not the same. Even if self-reported discomfort was compared, it is unlikely that discomfort reports obtained in the laboratory are comparable to discomfort reports in the workplace. Still, it seems likely that discomfort reporting is affected in a complex way by individual characteristics (e.g., personality and gender), task characteristics, and possibly other factors that were not considered.

Some statistically nonsignificant findings deserve some discussion because a consistent trend has occurred across dependent measures. In the first laboratory study of the assembly task, mean Type B discomfort scores were greater in magnitude (with ratios of 119%, 107%, and 213% for MDSavg, MDSupx, and MDSbak) than the mean Type A scores. Since MDSavg and MDSbak had the largest increases of the three, they were examined further. The significant 2-way interaction of personality type and gender for MDSavg may partially explain the absence of a main effect for this score, but there were not any 2-way interactions to explain the finding for MDSbak. An inspection of extreme observations ruled out the possibility that these means were elevated by a single Type B subject. In the second laboratory study, the trends were opposite. For the pipetting post-task administrations, mean Type B scores were substantially less in magnitude (with ratios of 42%, 52%, and 60%) than the mean Type A scores. The significant 2-way interaction of personality type and gender for MDSbak may partially explain the absence of a significant main effect for this score, but there were not any 2-way interactions to explain the finding for MDSavg or MDSupx. For the computer post-task administrations, mean Type B scores were also substantially less in magnitude (with ratios of 41%, 53%, and 39%) than the mean Type A scores. There were no interactions that would offer insight into the absence of a significant main effect for any of these three scores. An inspection of extreme observations ruled out the possibility that the Type A means were elevated by a single Type A subject for either the pipetting or the computer administrations. However, all of the discomfort scores for both the Type A and B groups had a substantially large number of zero's. It is possible that no statistically significant differences emerged because one group's distribution was completely or almost completely encapsulated within the other group's distribution. Variability could also be an issue, but no immediately obvious problems were found. Even if these trends had resulted in statistically significant findings, the interpretation would still be limited. The trends obtained in the first study for the assembly task would have supported the original predictions that Type A's would report less discomfort. However, the trends in the second study would have contradicted the original prediction.

10.1.1.4.1 Comparison to Other Studies

Some studies have shown a positive relationship between Type A personality and pain/injury (Flodmark & Aase, 1992; Salminen et al., 1991; Wickström et al., 1989) and these studies actually offered empirical support for this study. Results from these studies might lead one to hypothesize that Type A's would report more discomfort that Type B's. However, the original contradictory hypothesis seemed reasonable for several reasons. First, the findings from these studies resulted from evaluations of actual workers in real working environments. These are notably different populations than the population utilized in the current study. One critical difference is age. The findings from those studies may reflect that the presence of injury has occurred over time, and possibly after years of ignoring, and possibly not reporting, discomfort. In fact, Type A's were described in one of these studies as "significantly more likely to ignore fatigue and other symptoms" and "more likely to work when suffering from disabilities" (Flodmark & Aase, 1992, p. 686). They are "thought to ignore symptoms in order to minimise their potential effect on work capacity and they tend to ignore anything that might interfere with their performance" (p. 686). The same authors also stated that "in non-challenging circumstances no A/B differences typically appear" (p.686). This statement might suggest a hypothesis that no differences would exist, but inferences about what is meant by "challenging circumstances" make it difficult to make a direct comparison.

In addition to these reasons, the time urgency characteristic associated with the Type A personality construct provided additional support for generating the original hypothesis for this study. Type A's have often been described as hard-driving and achievement-oriented and are notable for their constant sense of time urgency. The discomfort survey was designed such that it requires no time to complete if there is no discomfort to document. This is different from a survey that requires that a response be chosen from a list of response choices (e.g., as was employed in the initial phase of this study to measure discomfort).

10.1.1.5 Reporting Behaviors – State Anxiety

It was hypothesized (H5) that Type A individuals would report lower levels of self-reported state anxiety than Type B individuals. No main effects of personality type were found to support this hypothesis in either of the laboratory studies. However, a significant interaction with gender was revealed for the assembly task survey administrations, showing that the effect of personality type was limited to females. Type A females reported 56% higher state anxiety scores than Type B females. No differences were obtained for males. For Type A's, females reported significantly higher scores than males. No differences were obtained for Type B's. No significant findings were obtained for either of the pipetting task or computer task scores.

10.1.1.5.1 Comparison to Other Studies

The effect of personality type on post-task anxiety scores in this study was limited to a single finding for females during the assembly task and this result was actually opposite to the original prediction that Type A's would report less anxiety. The original hypothesis seemed reasonable for similar reasons that supported formulation of the hypothesis that Type A's would report lower discomfort. First, the Type A raw scores (JAS A scale) obtained in Phase I of this study were not significantly correlated with trait anxiety (BMAS scores). Second, Type A's are "thought to ignore symptoms in order to minimise their potential effect on work capacity and they tend to ignore anything that might interfere with their performance" (Flodmark & Aase, 1992, p. 686). The state anxiety measure used in this study had five questions that dealt directly with physical sensations (e.g., "My heart is beating faster). However, there was also support for formulating the null hypothesis in this case. At least two studies have shown only moderate correlations between the Jenkins Activity Survey score and state anxiety (Chesney, Black, Chadwick, & Rosenman, 1981; Wadden, Anderson, Foster, & Love, 1983). The results obtained in the current study illustrate that self-reported state anxiety is likely to be influenced by a combination of factors that are related to personality, gender, and environment.

10.1.2 Hypotheses related to time stress (STRESS)

10.1.2.1 Workstyle – Performance time

It was hypothesized (H6a) that individuals would demonstrate faster per unit performance times during the time stress condition than during the no-stress condition. This hypothesis was supported by results obtained from both laboratory studies. For the assembly task, mean performance times during the time stress condition were approximately 80 to 90% of the mean times during the no-stress condition. For the pipetting task, mean performance times during the time stress condition were 88% of the mean scores for the no-stress condition. These findings consistently demonstrated that time stress, as imposed by simple verbal scripts, did impact workstyle-related performance time. These faster performance times may have resulted from strategy changes and/or faster hand/wrist motions (to be discussed in the following section). Although some might argue that laboratory subjects cannot be motivated to perform faster without the presence of a tangible reward (e.g., monetary compensation), this study demonstrated that subjects can be motivated to perform faster via simple verbal scripting. It is not clear whether this finding would be generalizable to real world situations. In the real world, the implications (e.g., loss of money or job) of not performing at a certain speed may be much more powerful motivators than any verbal instruction to do so. However, the ability to motivate subjects to perform faster via simple verbal script was demonstrated in this study. This may be useful for conducting similar laboratory studies where faster performance times are desired, but the real world motivations are not present to achieve that.

There were significant interactions with stress and condition order that should be mentioned. For the assembly task, a significant ORDER x STRESS interaction was observed for mean per unit disassembly times but not for per unit assembly times. While the interaction effect was found to be significant subjects always had faster disassembly times under the stress condition. However, for the pipetting task, subjects only performed faster during the stress condition for order 1, when the no-stress condition was performed first. No performance differences were found when the subjects performed the stress condition first. It is unclear why this occurred. This may be a training issue since there was no difference between no-stress and stress performance times that were performed first. However, there was also no difference between these times and the no-stress time that was performed second. This may also be related to expectations that were formed by the subjects. It is possible that when the time stress was imposed first, it created other consequences (e.g., increased anxiety from lack of familiarity) that interfered with performance. However, subjects had been somewhat exposed to the time stress during training by instructions such as "now I want you to practice going as fast as you can." So it seems that the time stress condition being first would not have presented any surprises. Even if the reasons for this finding are unclear, it may have implications for task scheduling in real workplace environments. If this were shown to be true with real subjects doing familiar tasks, then performance gains may only be achieved during times when time stress is imposed if the time stress follows a period of time where individuals have been performing the task at their natural pace. However, caution must be exercised in interpreting these results since these subjects performed this task for very short durations.

10.1.2.1.1 Comparison to Other Studies

The most relevant aspect of what has been revealed in other studies regarding time stress is the potential role it may play in musculoskeletal injury. It is therefore important to explore these potential roles of time stress in biomechanical evaluations. Many studies have reported theoretical support or empirical findings that indicate that time pressure, high work pace, and/or high quantitative job demands at work or in the laboratory may be positively related to musculoskeletal injury (Ariens et al., 2001; Bongers et al., 1993; Houtman, Bongers, Smulders, & Kompier, 1994) or specific biomechanical indicators (Davis et al., 2002). These results may provide insight into pathways to injury, but it must be remembered that these subjects only performed at these rates for very short durations and direct generalizability to workplaces with real workers is limited.

10.1.2.2 Workstyle – Wrist Motion Kinematics

It was hypothesized (H7a) that individuals would demonstrate faster workstyles, as represented by faster, more accelerated, and more deviated wrist motions, during the time stress condition than during the no-stress condition. This hypothesis was supported by results obtained from the first laboratory study of an assembly task. Stress condition emerged as statistically significant for three position variables (nRRUpos, romLRU, and nromLRU), all four velocity measures, and three (all but aRFEacc) of the four acceleration measures. It should also be noted that when non-interpreted 3-way and 4-way interactions were removed from the statistical models and additional analyses were performed, two additional variables (nRFEpos and aRFEacc) became statistically significant. Right-hand position mean values during the stress condition were 107% and 112% of the no-stress means. The four velocity means during the stress condition ranged from 108% to 122% of the no-stress condition means. The four acceleration means during the stress condition ranged from 113% to 126% of the no-stress values. With this result, it can be stated that time stress significantly increased (1) hand/wrist velocities and accelerations in the flexion/extension and radial/ulnar directions for both hands and (2) hand/wrist deviations in the flexion/extension and radial/ulnar directions for the right hand. Faster performance times obtained during the time stress condition seemed to at least be partially attributable to increased hand/wrist motions.

The only 2-way interaction effects involved the left radial/ulnar measures. Significant main effects of stress and GENDER x STRESS interactions were obtained for aLRUvel, aLRUacc, romLRU, and nromLRU. Significant interactions with order were obtained for romLRU and nromLRU. One possible explanation could be that these measures were driven by a single subject who fell into a single gender and a single order level. An inspection of extreme observations ruled out the possibility that these means were elevated by a single subject of either category of gender and/or order. Results revealed that the main effect of stress held for both genders for all four variables, with both males and females experiencing higher values during the stress condition. However, results also revealed that even though the stress condition range of motion values were larger in magnitude for both orders, they were only significantly higher for order 2 when the stress condition was performed first. Since Marras and Schoenmarklin (1993) found that the only hand/wrist position variable that differentiated between high and low CTD risk levels was radial/ulnar range of motion, these results may have some implications to potential pathways to injury. However, as previously mentioned, the results in the current study were obtained with young subjects who performed the task for a short duration. Thus direct inferences regarding risk of injury for real workers in real work environments should not be made.

10.1.2.3 Muscle Tension/Activity

It was hypothesized (H8a) that individuals would demonstrate higher muscle activity levels under the time stress condition. This hypothesis was explored in the second laboratory study for the pipetting task. A significant main effect of time stress was obtained for six of the ten NIEMG measures. Significant increases during the stress condition were obtained for dFLEX, dEXT, dTRAP, dRHOM, nTRAP, and nRHOM. The stress-condition mean values for these six muscles ranged from 109% to 123% of the no-stress values. However, there were two significant interactions of stress with gender for dFLEX and dEXT that were found to limit the interpretation of the main effect for these two measures. For both of these NIEMG values, only females experienced higher levels during the stress condition. Females experienced a 25% increase in mean dFLEX activity and a 29% increase in mean dEXT activity during the stress condition. Males only demonstrated 3.5% and 1% increases. This finding may provide insight into (1) reports of higher prevalence of cumulative trauma disorders in females and (2) findings of relationships between musculoskeletal injury and work pace. It also supports the importance of considering gender in biomechanical evaluations of muscle tension/activity.

10.1.2.3.1 Comparison to Other Studies

The results found here are somewhat comparable to a recent similar study that explored the effects of psychosocial stress in the form of increased task pacing during lifting on the ten major muscles of the trunk (Davis et al., 2002). Results from this study showed that fast pacing produced statistically significant increases (1-5% MVC) in muscle activity for nine of the ten muscles. No moderating roles of gender were evaluated. However, the study did report differences in muscle activities between simple and complex simultaneous mental processing conditions as a function of gender. Results showed that females experienced 2 – 16% greater increases in muscle activity than males. There are at least two major differences between that study and the current study. First, the nature of the tasks being performed and the muscles sampled are much different between studies. Second, the fast pacing condition in that study consisted of a fixed increase in the number of lifts performed. The current study allowed subjects to “select” their own work pace increases. Still, both studies showed significant increases in agonist and antagonist muscle activity during faster work paces and differences in gender responses.

10.1.2.4 Reporting Behaviors – Musculoskeletal Discomfort

It was hypothesized (H9a) that individuals would report higher levels of self-reported discomfort following the time stress condition. This hypothesis was explored in the first laboratory study of the assembly task and in the second laboratory study for the pipetting task. No main effects of stress were found to support this hypothesis. However, there were significant interactions with condition order for both MDSavg and MDSbak during the assembly task. When subjects performed the no-stress condition first, overall average discomfort (MDSavg) reported after the stress condition was significantly higher than for the no-stress condition. However when subjects performed the stress condition first, overall average discomfort reported after the time stress condition was significantly lower. For average back discomfort (MDSbak), there was a significant increase in discomfort reported after the stress condition but only when it was performed second. These findings indicate that reported discomfort may have been more related to the length of time that individuals had been performing the task and not influenced by the imposition of time stress.

Composite scores were analyzed in this study to provide broader interpretability and to reduce the number of dependent variables that were evaluated. It is possible that evaluating each individual body region score (e.g., MDSnsL, MDSubR, etc) would provide better insight into the effect of the time stress.

10.1.2.4.1 Comparison to Other Studies

Many studies have reported theoretical support or empirical findings that indicate that time pressure, high work pace, and/or high quantitative job demands at work may be positively related to musculoskeletal injury (Ariens et al., 2001; Bongers et al., 1993; Houtman et al., 1994; Huang, Feuerstein, Kop, Schor, & Arroyo, 2003) or specific biomechanical indicators believed to relevant to injury risk (Davis et al., 2002). However, the current study seemed to show no influence of time stress on discomfort reports. There are several issues to consider. First, these subjects only performed these tasks under time stress for very short durations. This can not be compared to the effects that time stress might have on real workers in real working environments over long periods. Second, self-reported discomfort on a paper survey and is not equivalent to the "presence" of discomfort or "injury." The construct measured here is "reporting" of discomfort. Studies have shown response bias in self-reports, and it has already been discussed that traits of the individual do play a role in discomfort reports. However, since objective self-reports are often employed in laboratory and field evaluations, it is important to continue to explore what factors may affect them.

10.1.2.5 Reporting Behaviors – State Anxiety

It was hypothesized (H10a) that individuals would report higher levels of self-reported state anxiety following the time stress condition. This hypothesis was explored in the first laboratory study of the assembly task and in the second laboratory study for the pipetting task. A significant main effect of time stress was obtained for the pipetting task. Anxiety scores obtained following the stress condition were 8% higher than those reported after the no-stress condition.

10.1.2.5.1 Comparison to Other Studies

The current study is somewhat similar to a recent study that explored the effects of psychosocial time stress, in the form of increased task pacing, on lifting performance (Davis et al., 2002). However, they did not report any measures of anxiety.

10.1.3 Hypotheses related to main effects of frustration stress (STRESS)

10.1.3.1 Workstyle – Performance time

It was hypothesized (H6b) that individuals would demonstrate slower performance times during the frustration stress condition than during the no-stress condition. This hypothesis was supported by results obtained for the computer task. A significant main effect of stress was observed for the task performance time. The mean performance times during the time stress condition were 108% of the mean scores during the no-stress condition, indicating that subjects performed significantly slower. However, a significant interaction with stress condition order indicated that the main effect of stress only held for order 2 where subjects performed the stress condition first. For these subjects, mean performance time during the stress-condition was 113% of the mean no-stress time. The nonsignificant difference for order 1 was only 3%. This finding may indicate that the psychosocial stress imposed by the incorrect feedback had less impact when the task was more familiar to the subject. This may have important implications for aspects of real workplaces, including such things as task scheduling and training. The nature of this psychosocial stress was chosen and implemented to attempt to challenge the individual's feeling of control over his/her environment. Though these were short duration trials, it is possible that the initial removal of control from the individuals did alter their own performance expectations and/or did affect their motivation to perform, but only when the task was less familiar (e.g., prior to establishing a rhythm). It is also possible that the subjects who had performed the no-stress condition first were more likely to recognize the nature of the deception, and thus continued to perform at their established pace because they knew they had no control over the feedback.

10.1.3.2 Muscle Tension/Activity

It was hypothesized (H8b) that individuals would demonstrate higher muscle activity levels under the frustration stress condition. This hypothesis was explored in the second laboratory study for the computer task. No significant main effects were obtained to support this hypothesis. Some possible explanations for the lack of support for the primary hypothesis should be considered. As previously discussed for the computer task performance time, subjects slowed down significantly during the stress condition. Since the time stress during the pipetting trial caused significant increases in muscle activity in several muscles, then it is possible that any NIEMG increases that could have been found due to stressful nature of computer task were mitigated by the slower performance time. It is also possible that subjects figured out for themselves what was happening. Even though subjects reported significantly higher levels of anxiety following the stress condition (to be discussed later), they may not have been frustrated enough to elicit physiological changes.

10.1.3.2.1 Comparison to Other Studies

One recent study specifically looked at the effects of a similar psychosocially-imposed stress on specific biomechanical indicators of spine loading, including EMG (Marras et al., 2000). During this study, participants performed lifting tasks under a no-stressed condition and then a stress-condition. During the no-stress condition, experimenters used "positive language and actions to encourage the subject" (p.3047). During the stressed condition, "experimenters appeared distraught and used nonsupportive language and actions." The visual feedback provided to the subject while performing the task was also "manipulated to appear to fall outside the prescribed tolerance, providing a reason for the experimenters to criticize the subject's performance" (p. 3047). Muscle activity increased significantly in six of the ten muscles during the stress condition. These increases ranged from 3.5% to 6.5%. Though this study is similar, some important differences exist between it and the current study. First, the number of subjects participating in that study was almost twice the number who participated in the current study. Second, the psychosocial stress imposed in that study was much more severe and of longer duration than in the current study. The presence of increased stress was also confirmed by required increases in blood pressure and self-reported anxiety. Two subjects that did not meet those criteria were dropped from the analysis. No measures were obtained in the current study to evaluate the success of the psychosocial stress. Third, a more liberal level ($p < 0.1$) of statistical significance was obtained for two of the muscles. Last, the stressed condition in that study always followed the unstressed condition. It is likely that this approach resulted in less variability in the responses during the stressed condition than the current study in which the conditions were counterbalanced.

10.1.3.3 Reporting Behaviors – Musculoskeletal Discomfort

It was hypothesized (H9b) that individuals would report higher levels of self-reported discomfort following the frustration stress condition. This hypothesis was explored in the second laboratory study for the computer task. No findings supported this hypothesis. The analysis that yielded these results only included the discomfort administrations obtained after each of the 5-minute computer tasks. Therefore, effects were being evaluated for self-report scores that were obtained less than ten minutes apart. The hypothesis may have been supported if the subjects had performed the task longer, performed a more physically stressful task, and/or been exposed to a more severe level of frustration stress.

10.1.3.4 Reporting Behaviors – State Anxiety

It was hypothesized (H10b) that individuals would report higher levels of self-reported state anxiety following the frustration stress condition. This hypothesis was explored in the second laboratory study for the computer task. Results supported this hypothesis. Mean state anxiety scores reported after the stress condition were 106% of the mean values reported following the no-stress condition. Even though the frustration stress condition was not severe enough to produce significant physical discomfort changes (see discussion for H9b), it did produce changes in self-reported anxiety levels.

10.1.3.4.1 Comparison to Other Studies

One recent study specifically looked at the effects of a similar psychosocially-imposed stress on specific biomechanical indicators of spine loading, including EMG (Marras et al., 2000). The details, similarities, and limitations of this study were previously discussed (see discussion for H8b). Though aspects of the psychosocial stress imposed in the current study were similar to the stress imposed in that study, there were significant differences. First, the level/intensity of the stress was much more severe in that study. The stress condition included manipulated visual feedback (as in the current study) as well as "nonsupportive language and actions" (not used in the current study). Second, the psychosocial stress imposed in that study was imposed for a longer duration than in the current study. Third, while the current study evaluated the effects of the stress on state anxiety scores, the scores obtained in that study were used to confirm that the subjects responded to the stress. Two subjects that did not meet the criteria for anxiety and blood pressure increases were dropped from the analysis. Still, both studies demonstrate that psychosocial stress can be manipulated in the laboratory with measurable effects on anxiety levels.

10.1.4 Hypotheses related to interactive effects of personality type (TYPE) and stress (STRESS)

It was hypothesized that muscle activity would increase during the both the time stress condition (H11a) and the frustration stress condition (H11b) more so for Type A's than for Type B's. This hypothesis was formulated to explore the impact of challenging Type A's in control of their environments. Gastorf (1981) suggests that "Type A's and Type B's differ in their physiologic response to situational task demands" and "Type A's have more sympathetic arousal to tasks which provoke competition, time-urgency, and loss of control in the participants" (p. 16). This would suggest that the psychosocial stresses imposed in this experiment, if effective at challenging the control aspect of Type A's, would moderate the effect of personality type on the physiological response of muscle tension/activity. No results provided support for these hypotheses.

10.2 OTHER FINDINGS

10.2.1 Gender and Order

Results revealed main and interactive effects of gender and order for several measures. These were not part of the original hypotheses and have not been discussed, except where significant interactions of these variables with stress or personality type were obtained. The interactions of gender and personality type for discomfort, state anxiety, and muscle activity were already discussed. The interactions of gender and stress for wrist motions and muscle activity were also already described. There was only one main effect of gender found in this study other than the effects of gender on anthropometry. Females had significantly higher non-dominant extensor muscle activity than males during pipetting. This finding may be meaningful, but with the number of comparisons that were made, it may also be a product of chance. Interactions of gender with condition order were also found for two wrist motion parameters, one discomfort measure, and the dominant flexor activity. Since anthropometry may play a critical role, especially for such measures as performance, wrist motions, and muscle tension/activity, it is possible that gender effects on the outcome measures were wholly or partially mediated through anthropometry differences. The work station was height-adjusted to each individual, but no other individual-specific adjustments were made. These findings indicate the importance of accounting for gender differences when interpreting the results and when conducting future biomechanical evaluations.

Though order was a between-subjects variable in this study, it is a characteristic of the task/environment, not the individual. Order was found to affect wrist motions, anxiety, EMG, and discomfort. Interactive effects were also obtained. Those that were obtained for stress have already been discussed. Interactions with gender also emerged. The implications of considering order in laboratory studies and the possible implications of order on workplace factors (e.g., task scheduling) have already been discussed. Counterbalancing is a sound methodological practice and typically broadens generalizability of the results. However, it is possible that the variability introduced by the different stress condition orders limited the potential to find effects of the psychosocial factors (personality and stress) explored in this study as compared to those found in other recent studies.

10.2.2 General reporting behaviors

Another goal of this study was to evaluate general reporting behaviors. This was done by administering discomfort and anxiety surveys five times during the first experiment and seven times during the second experiment. Correlations between these measures indicated several interesting findings. Correlations between discomfort score administrations yielded different conclusions for the first experiment than the second experiment. During the first experiment, all correlations (10 each for MDSavg, MDSupx, and MDSbak) were significant. For the second experiment, only the upper extremity discomfort scores were that similar (with 20 of 21 being significant). Only about half of the scores were significantly correlated for MDSavg (12 of 21) and MDSbak (10 of 21). With one exception, the baseline scores obtained during the first administration did not correlate with the other scores. This could be due to a combination of the nature of the task and individual response bias. From results of the first experiment, one might conclude that discomfort reporting reflects a stable trait tendency, but results from the second experiment did not support that. It could also be that the assembly task in first experiment just did not create substantial increases in discomfort. In fact, even though this study was a study of hand/wrist motions, not a single hand/wrist discomfort experience was reported by any subject for any administration. The second experiment was of longer duration, required subjects to perform many maximum voluntary contractions, and contained a very repetitive dominant hand task. However, upper extremity correlations did not reveal that the pipetting task created significant changes from the baseline score.

The results of the state anxiety administrations revealed a somewhat different finding. Almost all of the correlations between anxiety scores (28 of 31 across studies) were significant. This certainly may represent a more trait-driven characteristic. Of course, it could also be that the experimental tasks created no more anxiety than the individuals “arrived” with and/or “experienced” upon arrival. One concept that was confirmed, at least for this study, is that the discomfort scores and the state anxiety scores appear to represent different constructs. This was supported by the absence of significant correlations between the discomfort and anxiety scores for each administration. Only 2 of the 36 were significant.

One interesting methodological consideration arises from these findings. If one is interesting in primarily evaluating the “trait” aspect of reporting behaviors, then this approach may be sufficient. However, an alternate approach could be chosen (e.g., analysis of covariance) if it is more important to elicit differences that emerge solely due to the experimental condition after accounting for between-subjects variations in baseline measures. With either of these approaches, previously discussed aspects of the discomfort scores might be addressed by converting them into categorical variables (e.g., “high” and “low” complainers).

10.3 METHODOLOGICAL IMPLICATIONS

Some important lessons were learned during the conduct of this research. Some of these lessons will be described here. First, the study was conducted in multiple stages. Phase I was employed to evaluate distributions among psychosocial attributes that were of interest and to evaluate relationships with discomfort reports in order to design the laboratory experiments. Results from this effort revealed that one specific construct of interest, coping style, might be difficult to explore because certain coping styles (e.g., truly low anxious) were poorly represented in the population. This initial effort demonstrated how important it is to understand the distributions and relationships among the psychosocial attributes of interest, and more specifically, the nature of these relationships within the population of interest. It is possible that the ability to evaluate a specific construct would be severely limited without this type of initial effort prior to conducting similar laboratory studies.

After the initial phase was conducted, the pre-testing phase was conducted to recruit subjects of specific attributes. The choice to pre-test subjects has both advantages and disadvantages. While it allows the selection of only the subjects who meet specific criteria, it may provide the participants some idea about what is being evaluated and alter their subsequent behaviors/responses. One way to try to address this is to administer additional, maybe even non-related, surveys along with the critical survey(s). However, psychometric properties of self-report surveys can be influenced by such things as question wording and order, and time for completing surveys may be limited. Another advantage of pre-testing is that it provides the opportunity to ensure that equal sample sizes of only the desired groups are recruited to participate. If a laboratory study is conducted without pre-testing and selection, resources might be wasted collecting data that is not used because a participant did not meet the required criteria. Also, the number of participants that fill each “level” of the independent variable (i.e., psychosocial trait) could be disproportionate resulting in unequal cell sizes. The assumptions of the analysis of variance are fairly robust if cell sizes are balanced (Montgomery, 2000). Some SAS procedures (e.g., PROC MIXED) will accommodate unbalanced cell sizes better than others when the design has both within-subjects and between-subjects variables. However, if the constraints of the study allow, equal cell sizes are suggested.

This study also demonstrated that it is important to evaluate the possibility of confounding. For example, it cannot be assumed that randomization will always create groups that are equivalent on critical measures. This was already discussed for the significant anthropometric differences obtained between groups in both of the experiments.

10.4 LIMITATIONS

There are several limitations of the current study that should be noted. First, the subjects were not real workers who have been performing familiar tasks in a real workplace. Simple tasks were chosen, but training issues as well as other issues (e.g., environment, absence of peers, age of subjects) limit direct generalizability to the real workplace. Though this does impose limitations on interpretability, this is typically the case with controlled laboratory studies. Second, the sample sizes were relatively small, especially for evaluating the higher order interactions. The true nature of some of the relationships that were explored in this study may lie in the interactions of multiple individual and task characteristics. These should be explored in future studies with adequate sample sizes, such that the results are not as sensitive to the effects of a single individual.

Though not necessarily limitations, a few additional things should be re-emphasized. The results obtained in this study are not sufficient for establishing causation regarding personality type. Relationships were evaluated using experimental research methodologies and were shown to exist. However, inferences of causation would additionally require that temporal dependency be verified and that other potential causes for the relationships be evaluated and excluded. Second, task order and stress condition order may have created variability that prevented significant findings for some relationships. Counterbalancing was selected as a method to allow broader generalization of the results. Different results may have been obtained if task/condition order had been fixed as it was in some recent similar studies (Davis et al., 2002; Marras et al., 2000).

In spite of the limitations mentioned, it is hoped that this area of research will lead to better understanding of the relationships that may exist between psychosocial factors and biomechanical indicators typically believed to be significant factors in musculoskeletal injury. With increased advancement in the knowledge of these biobehavioral mechanisms, previously unknown variability can be accounted for and better interventions can be developed and evaluated.

10.5 FUTURE WORK

The primary goal of this study was to explore potential relationships between trait/state psychosocial factors and biomechanical indicators of workstyle, physiological response, and reporting behaviors. Future work in this area should include efforts to continue to identify the biobehavioral mechanisms that may be at work between the task and the individual's response. This should include a balanced effort between (1) field studies that can identify those factors that have significant relationships with outcome measures of interest; (2) laboratory studies that investigate the potential pathways between those factors and biomechanical indicators; and (3) collaborative, multidisciplinary efforts among researchers and policy makers to guide this area of research. Efforts should continue to be made to develop a subset of theoretical models, constructs, and methodological strategies that can be used across studies so that empirical findings can be compared and utilized to form intervention strategies. The important constructs should be identified, defined, and operationalized consistently. For example, key elements of the construct of workstyle need to be identified and formulated into smaller constructs that can be employed across studies. Further efforts should be made to define the constructs of muscle tension and muscle activity, including methods for operationalizing this variable for different settings, tasks, individual characteristics, and specific hypotheses. Efforts should also be made to identify objective indicators that can be measured simultaneously with subjective (e.g., anxiety) measures of the constructs of interest. Future work should also include larger and more focused investigations of some of the findings that emerged in this exploratory effort. These efforts to identify the important pathways between psychosocial factors and illness/injury should be integrated with efforts to design individual and organizational interventions.

11. CONCLUSIONS

This study provides evidence for methodological implications and specific results for the evaluation of the relationships between individual/environment psychosocial factors and biomechanical indicators associated with injury risk. A proposed theoretical model was developed based on theoretical and empirical support. The methodology for examining specific relationships in this model was carefully developed and executed. Specific results were obtained that demonstrated that both trait psychosocial factors of the individual (i.e., personality type) and state psychosocial factors of the task (i.e., stress) impacted biomechanical indicators. Some indicators were impacted by both personality type and stress, while some were more influenced by only one of these. Gender and task order moderated some of these effects.

Personality type impacted performance during assembly but not during pipetting or computer entry. Type A assembly performance times were 12 – 14% faster than Type B's. However, personality type did not impact wrist motion kinematics. The effect of personality type on muscle activity was completely moderated by gender and only obtained for pipetting. Type A female dominant flexor activity was 57% of the Type B activity. Type A male dominant flexor activity was 188% of the Type B activity. Personality type impacted discomfort reporting, but only for females during assembly and only for males during pipetting. Female Type A's reported higher average overall discomfort than Type B's for the assembly task. However male Type B's reported higher average back discomfort during pipetting. The effect of personality type on anxiety levels was limited to females during assembly, where Type A's reported 56% higher levels than Type B's.

Psychosocial time stress impacted performance. During assembly, performance times were 11 – 18% faster during the stress condition. During pipetting, performance time was 23% faster during the time stress condition but only when this condition followed the no-stress condition. In general, time stress produced significant increases in wrist motion kinematics during assembly. Velocities and accelerations increased by 8 to 26 % when time stress was imposed. Time stress during pipetting increased muscle activity by 9 to 23% in six of the muscles sampled. However, the dominant flexor and extensor activities only increased (by 25 to 29%) for females. In general, time stress did not impact discomfort reports, but it did increase anxiety by 8% for the assembly task.

Psychosocial frustration stress impacted computer task performance but only when the stress condition followed the no-stress condition. For this case, performance time was 13% slower during the stress condition. Frustration stress did not impact muscle activity or discomfort reports, although it did increase reported anxiety by 6%.

The results of this study demonstrate that the biomechanical response of individuals is a complex phenomenon, encompassing interactions of individual characteristics (e.g., personality type, gender), task characteristics (e.g., assembly vs. pipetting), and psychosocial stress (e.g., time stress, frustration stress). Specific findings and potential implications of these findings were presented in this study. It is hoped that this effort will provide additional insight into (1) the potential biobehavioral pathways between psychosocial factors and musculoskeletal illness and (2) the methodological strategies for exploring these relationships.

12. REFERENCES

Allread GW. (2000). *An investigation of the relationship between personality and risk factors for musculoskeletal disorders.* Unpublished Doctoral dissertation, The Ohio State University, Columbus, OH.

Andersen JH, Kaergaard A, Frost P, Thomsen JF, Bonde JP, Fallentin N, et al. (2002). Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. *Spine, 27*(6), 660-667.

Andersson GBJ. (1981). Epidemiologic aspects on low-back pain in industry. *Spine, 6*(1), 53-60.

Ariens GA, van Mechelen W, Bongers PM, Bouter LM, & van der Wal G. (2001). Psychosocial risk factors for neck pain: a systematic review. *American Journal of Industrial Medicine, 39*(2), 180-193.

Armstrong TJ & Chaffin DB. (1979). Carpal tunnel syndrome and selected personal attributes. *Journal of Occupational Medicine, 21*(7), 481-486.

Armstrong TJ & Silverstein BA. (1987). Upper-extremity pain in the workplace: role of usage and causality. In N. M. Hadler (Ed.), *Clinical Concepts in Regional Musculoskeletal Illness.* Orlando: Grune & Stratton.

Bansevicius D, Westgaard RH, & Jensen C. (1997). Mental stress of long duration: EMG activity, perceived tension, fatigue, and pain development in pain-free subjects. *Headache, 37*, 499-510.

Begley TM, Lee C, & Czajka JM. (2000). The relationships of Type A behavior and optimism with job performance and blood pressure. *Journal of Business and Psychology, 15*(2), 215-227.

Bendig AW. (1956). The development of a short form of the Manifest Anxiety Scale. *Journal of Consulting Psychology, 20*(5), 384.

Bergqvist U, Wolgast E, Nilsson B, & Voss M. (1995). Musculoskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors. *Ergonomics, 38*(4), 763-776.

Bigos SJ, Spengler DM, Martin NA, Zeh J, Fisher L, & Nachemson A. (1986). Back injuries in industry: A retrospective study. III. Employee-related factors. *Spine, 11*, 252-256.

Blumenthal JA, Herman S, O'Toole LC, Haney TL, Williams RB, Jr., & Barefoot JC. (1985). Development of a brief self-report measure of the type A coronary prone behavior pattern. *Journal of Psychosomatic Research, 29*(3), 265-274.

Bongers PM, deWinter CR, Kompier MAJ, & Hildebrandt VH. (1993). Psychosocial factors at work and musculoskeletal disease. *Scandinavian Journal of Work and Environmental Health, 19*, 297-312.

Bongers PM, Kremer AM, & ter Laak J. (2002). Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist?: a review of the epidemiological literature. *American Journal of Industrial Medicine, 41*(5), 315-342.

Bortner RW & Rosenman RH. (1967). The measurement of pattern A behavior. *Journal of Chronic Diseases, 20*, 525-533.

Brannon L & Feist J. (1992). *Health psychology*. Belmont, CA: Wadsworth Publishing Company.

Burke RJ. (1984). Beliefs and fears underlying Type A behavior: what makes Sammy run -- so fast and aggressively? *Journal of Human Stress, 10*(4), 174-182.

Cannon LJ, Bernacki EJ, & Walter SD. (1981). Personal and occupational factors associated with carpal tunnel syndrome. *Journal of Occupational Medicine, 23*(4), 255-258.

Caplan RD, Cobb S, French Jr. JRP, Van Harrison R, & Pinneau Jr. SR. (1975). *Job demands and worker health: main effects and occupational differences* (No. HEW Publication No. (NIOSH) 75-160). Washington, D.C.: U.S. Department of Health, Education, and Welfare.

Carabelli RA. (1986). Waistbelt lumbosacral support: suggestion from the field. *Physical Therapy, 66*(2), 231-232.

Center for Workplace Health. (1998). *CTD downturn continues in U.S.*, 2001, from http: www.ctdnews.com/ctdnews/past_issues/jan_98.html

Chammas M, Bousquet P, Renard E, Poirier J-L, Jaffiol C, & Allieu Y. (1995). Dupuytren's disease, carpal tunnel syndrome, trigger finger, and diabetes mellitus. *The Journal of Hand Surgery, 20A*(1), 109-114.

Chen W & Coorough R. (1996). Effect of EMG-biofeedback training in reduction of muscle tension for individuals displaying type A behavior patterns. *Perceptual and Motor Skills, 62*(3), 841-842.

Chesney MA, Black GW, Chadwick JH, & Rosenman RH. (1981). Psychological correlates of the type A behavior pattern. *Journal of Behavioral Medicine, 4*(2), 217-229.

Ciriello VM, Snook SH, Blick AC, & Wilkinson PL. (1990). The effects of task duration on psychophysically-determined maximum acceptable weights and forces. *Ergonomics, 33*(2), 187-200.

Ciriello VM, Snook SH, & Hughes GJ. (1993). Further studies of psychophsically determined maximum acceptable weights and forces. *Human Factors, 35*(1), 175-186.

Costa PT & McCrae RR. (1992a). Normal personality assessment in clinical practice: the NEO Personality Inventory. *Psychological Assessment, 4*(1), 5-13.

Costa PT & McCrae RR. (1992b). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) manual*. Odessa, FL: Psychological Assessment Resources.

Cram JR. (1989). Patterns of neuromuscular activity in pain-related disorders. In C. Bischoff, H. C. Traue & H. Zenz (Eds.), *Clinical perspectives on headache and low back pain* (pp. 3-12). Toronto: Hogrefe & Huber Publishers.

Crowne DP & Marlowe D. (1964). *The approval motive: studies in evaluative dependence.* New York: Wiley.

Davis KG & Heaney CA. (2000). The relationship between psychosocial work characteristics and low back pain: underlying methodological issues. *Clinical Biomechanics, 15*, 389-406.

Davis KG, Marras WS, Heaney CA, Waters TR, & Gupta P. (2002). The impact of mental processing and pacing on spine loading: 2002 Volvo Award in biomechanics. *Spine, 27*(23), 2645-2653.

Davis KG, Marras WS, & Young DP. (2000). *A comparison of males and females during asymmetric lifting.* Paper presented at the Proceedings of the IEA 2000/HFES 2000 Congress.

Day AL & Jreige S. (2002). Examining Type A behavior pattern to explain the relationship between job stressors and psychosocial outcomes. *Journal of Occupational Health Psychology, 7*(2), 109-120.

Dembroski TM, Macdougall JM, & Lushene R. (1979). Interpersonal interaction and cardiovascular response in Type A subjects and coronary patients. *Journal of Human Stress, 5*, 28-36.

Dembroski TM, Macdougall JM, & Shields JL. (1977). Physiologic reactions to social challenge in persons evidencing the Type A coronary-prone behavior pattern. *Journal of Human Stress, 3*, 2-9.

Dembroski TM, Weiss SM, Shields JL, Haynes SG, & Manning F (Eds.). (1978). *Coronary-prone behavior*. New York: Springer-Verlag.

deZwart BCH, Doombos R, vanderWeide CJ, Frings-Dresen MHW, Caspers M, & vanderWoude LHV. (2000). *Work technique in relation to years of experience among parcel delivery drivers.* Paper presented at the Proceedings of the IEA 2000/HFES 2000 Congress.

Edwards JR & Baglioni AJ, Jr. (1991). Relationship between Type A behavior pattern and mental and physical symptoms: a comparison of global and component measures. *Journal of Applied Psychology, 76*(2), 276-290.

Ekberg K, Eklund J, Tuvesson M-A, Örtengren R, Odenrick P, & Ericson M. (1995). Psychological stress and muscle activity during data entry at visual display units. *Work and Stress, 9*(4), 475-490.

Endler NS, Edwards JM, & Vitelli R. (1991). *Endler Multidimensional Anxiety Scales (EMAS) Manual*. Los Angeles, CA: Western Psychological Services.

Feuerstein M. (1996). Workstyle: definition, empirical support, and implications for prevention, evaluation, and rehabilitation of occupational upper-extremity disorders. Chapter 11. In S. D. Moon & S. L. Sauter (Eds.), *Beyond biomechanics: psychosocial aspects of musculoskeletal disorders in office work* (pp. 177-206). Bristol, PA: Taylor & Francis.

Feuerstein M. (2002). Biobehavioral mechanisms of work-related upper extremity disorders: a new agenda for research and practice. *American Journal of Industrial Medicine, 41*(5), 293-297.

Feuerstein M & Fitzgerald TE. (1992). Biomechanical factors affecting upper extremity cumulative trauma disorders in sign language interpreters. *Journal of Occupational Medicine, 34*(3), 257-264.

Fields KB, Delaney M, & Hinkle JS. (1990). A prospective study of type A behavior and running injuries. *The Journal of Family Practice, 30*(4), 425-429.

Finsen L, Christensen H, & Bakke M. (1997). Musculoskeletal disorders among dentists and variation in dental load. *Applied Ergonomics, 29*(2), 119-125.

Flodmark BT & Aase G. (1992). Musculoskeletal symptoms and type A behavior in blue collar workers. *British Journal of Industrial Medicine, 49*, 683-687.

Friedman HS (Ed.). (1990). *Personality and disease.* New York: John Wiley & Sons, Inc.

Friedman M & Rosenman RH. (1974). *Type A behavior and your heart.* New York: Alfred A. Knopf, Inc.

Friedman M & Ulmer D. (1984). *Treating Type A behavior -- and your heart.* New York: Alfred A. Knopf, Inc.

Gaffey WR. (1973). Epidemiological studies in industry. *Journal of Occupational Medicine, 15*(10), 782-785.

Gagnon M & Smyth G. (1991). Muscular mechanical energy expenditure as a process for detecting potential risks in manual materials handling. *Journal of Biomechanics, 24*(3/4), 191-203.

Gastorf JW. (1981). Physiologic reaction of Type A's to objective and subjective challenge. *Journal of Human Stress, 7*, 16-20,27.

Gill K, Henderson J, & Pargman D. (1995). The Type A competitive runner: at risk for psychological stress and Injury? *International Journal of Sport Psychology, 26*, 541-550.

Glasscock NF, Turville KL, Joines SB, & Mirka GA. (1999). The effect of personality type on muscle coactivation during elbow flexion. *Human Factors, 41*(1), 51-60.

Gregg RL, Banderet LE, Reynolds KL, Creedon JF, & Rice VJ. (2002). Psychological factors that influence traumatic injury occurrence and physical performance. *Work, 18*(2), 133-139.

Gross JJ & Levenson RW. (1993). Emotional suppression: physiology, self-report, and expressive behavior. *Journal of Personality and Social Psychology, 64*(6), 970-986.

Hagberg M. (1992). Exposure variables in ergonomic epidemiology. *American Journal of Industrial Medicine, 21*, 91-100.

Hägg GM. (1994). *Electromyographic changes and occupationally related shoulder/neck disorders.* Paper presented at the Proceedings of the 12th Triennial Congress of the International Ergonomics Association.

Hägg GM & Åström A. (1997). Load pattern and pressure pain threshold in the upper trapezius muscle and psychosocial factors in medical secretaries with and without shoulder/neck disorders. *International Archives of Occupational and Environmental Health, 69*, 423-432.

Hägg GM, Suurküla J, & Kilbom Å. (1990). *Predictors for work related shoulder/neck disorders: a longitudinal study of female assembly workers* (No. Arbete och Hälsa 1990:10). Stockholm: Arbetarskyddsverket.

Harms-Ringdahl K & Ekholm J. (1986). Intensity and character of pain and muscular activity levels elicited by maintained extreme flexion position of the lower-cervical-upper-thoracic spine. *Scandinavian Journal of Rehabilitation Medicine, 18*, 117-126.

Hart KE. (1997). A moratorium on research using the Jenkins Activity Survey for Type A behavior? *Journal of Clinical Psychology, 53*(8), 905-907.

Hart KE & Jamieson JL. (1983). Type A behavior and cardiovascular recovery from a psychosocial stressor. *Journal of Human Stress, 9*, 18-24.

Hatcher L & Stepanski EJ. (1994). *A step-by-step approach to using the SAS system for univariate and multivariate statistics*. Cary, NC: SAS Institute Inc.

Haynes SG, Feinleib M, & Kannel WB. (1980). The relationship of psychosocial factors to coronary heart disease in the Framingham study III: Eight year incidence of coronary heart disease. *American Journal of Epidemiology, 111*, 37-58.

Herrin G, Jaraiedi M, & Anderson C. (1986). Prediction of overexertion injuries using biomechanical and psychophysical models. *American Industrial Hygiene Association Journal, 47*, 322-330.

Hobson CJ, Kamen J, Szostek J, Nethercut CM, Tiedmann JW, & Wojnarowicz S. (1998). Stressful life events: a revision and update of the Social Readjustment Rating Scale. *International Journal of Stress Management, 5*(1), 1-23.

Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, & Bouter LM. (2000). Systematic review of psychosocial factors at work and private life as risk factors for back pain. *Spine, 25*(16), 2114-2125.

Houtman ILD, Bongers PM, Smulders PGW, & Kompier MAJ. (1994). Psychosocial stressors at work and musculoskeletal problems. *Scandinavian Journal of Work and Environmental Health, 20*, 139-145.

Huang GD, Feuerstein M, Kop WJ, Schor K, & Arroyo F. (2003). Individual and combined impacts of biomechanical and work organization factors in work-related musculoskeletal symptoms. *American Journal of Industrial Medicine, 43*(5), 495-506.

Jamal M. (1985). Type A behavior and job performance: some suggestive findings. *Journal of Human Stress, 11*, 60-68.

Jenkins CD, Rosenman RH, & Friedman M. (1967). Development of an objective psycholocial test for the determination of the coronary-prone behavior pattern in employed men. *Journal of Chronic Diseases, 20*, 371-379.

Jenkins CD, Zyzanski SJ, & Rosenman RH. (1971). Progress toward validation of a computer-scored test for the Type A coronary-prone behavior pattern. *Psychosomatic Medicine, 33*(4), 193-202.

Jenkins CD, Zyzanski SJ, & Rosenman RH. (1979). *Jenkins Activity Survey: JAS Manual*. New York: The Psychological Corportation.

Jensen C, Finsen L, Hansen K, & Christensen H. (1999). Upper trapezius muscle activity patterns during repetitive manual material handling and work with a computer mouse. *Journal of Electromyography and Kinesiology, 9*, 317-325.

Joines SMB. (2002). *Using surface electromyography to study cervical extensor muscle activity: an investigation of methodological considerations and the effects of age on fatigue development and recovery.* Unpublished Doctoral dissertation, North Carolina State University, Raleigh, NC.

Kasl SV & Amick BC. (1996). Cumulative trauma disorder research: methodological issues and illustrative findsing from the perspective of psychosocial epiemiology. Chapter 16. In S. D. Moon & S. L. Sauter (Eds.), *Beyond biomechanics: psychosocial aspects of musculoskeletal disorders in office work* (pp. 263-284). Bristol, PA: Taylor & Francis.

Kelaher DP. (1996). *Substitution patterns of the quadricep muscles before and after fatiguing isokinetic knee extensions.* Unpublished Masters Thesis, North Carolina State University, Raleigh, NC.

Kilbom Å & Persson J. (1987). Work technique and its consequences for musculoskeletal disorders. *Ergonomics, 30*(2), 273-279.

King LA & Emmons RA. (1990). Conflict over emotional expression: psychological and physical correlates. *Journal of Personality and Social Psychology, 58*(5), 864-877.

King LA, Emmons RA, & Woodley S. (1992). The structure of inhibition. *Journal of Research in Personality, 26*, 85-102.

Kirkcaldy BD, Cooper CL, & Furnham A. (1999). The relationship between Type A, internality-externality, emotional distress and perceived health. *Personality and Individual Differences, 26*(2), 223-235.

Kirkcaldy BD, Shephard RJ, & Furnham AF. (2002). The influence of Type A behavior and locus of control upon job satisfaction and occupational health. *Personality and Individual Differences, 33*(8), 1361-1371.

Lambert WW, MacEvoy B, Klackenberg-Larsson I, Karlberg P, & Karlberg J. (1987). The relation of stress hormone excretion to Type A behavior and to health. *Journal of Human Stress, 13*, 128-135.

Laursen B. (1996). *Shoulder muscle forces during work: EMG-based biomechanical models.* Department of Physiology, National Institute of Occupational Health, Denmark and Department of Mathematics, Technical University of Denmark.

Lawrence BM. (2002). *Intelligent system identification applied to the biomechanical response of the human trunk during sudden loading.* Unpublished Doctoral dissertation, North Carolina State University, Raleigh, NC.

Lee C. (1992). The relations of personality and cognitive styles on job and class performance. *Journal of Organizational Behavior, 13*(2), 175-185.

Lee C, Jamieson LF, & Earley PC. (1996). Beliefs and fears and Type A behavior: implications for academic performance and psychiatric health disorder symptoms. *Journal of Organizational Behavior, 17*(2), 151-177.

Lee DJ, Niemcryk SJ, Jenkins CD, & Rose RM. (1989). Type A, amicability and injury: a prospective study of air traffic controllers. *Journal of Psychosomatic Research, 33*(2), 177-186.

Leyman E, Mirka G, Kaber D, & Sommerich CM. (2001). *Assessing the relationship between cognitive load and cervicobrachial muscle response during a typing task.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting,, Minneapolis, MN, October 8-12.

Linton SJ. (2000). A review of psychological risk factors in back and neck pain. *Spine, 25*(9), 1148-1156.

Lundberg U, Melin B, Ekström M, Dohns IE, Sandsjö L, Palmerud G, et al. (1999). Psychophysiological stress responses, muscle tension, and neck and shoulder pain among supermarket cashiers. *Journal of Occupational Health Psychology, 4*(3), 245-255.

Lutz TJ, Starr H, Smith CA, Stewart AM, Monroe MJ, Joines SM, et al. (2001). The use of mirrors during an assembly task: a study of ergonomics and productivity. *Ergonomics, 44*(2), 215-228.

Magnavita N, Bevilacqua L, Mirk P, Fileni A, & Castellino N. (1999). Work-related musculoskeletal complaints in sonologists. *Journal of Occupational and Environmental Medicine, 41*(11), 981-988.

Malchaire JB, Roquelaure Y, Cock N, Piette A, Vergracht S, & Chiron H. (2001). Musculoskeletal complaints, functional capacity, personality and psychosocial factors. *International Archives of Occupational and Environmental Health, 74*(8), 549-557.

Marras WS. (2000). Occupational low back disorder causation and control. *Ergonomics, 43*(7), 880-902.

Marras WS, Davis KG, Heaney CA, Maronitis AB, & Allread G. (2000). The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine. *Spine, 25*(23), 3045-3054.

Marras WS, Lavender SA, Leurgans SE, Rajulu SL, Allread WG, Fathallah FA, et al. (1993). The role of dynamic three-dimensional trunk motion in occupationally-related low back disorders: the effects of workplace factors, trunk position, and trunk motion characteristics on risk of injury. *Spine, 18*(5), 617-628.

Marras WS & Mirka GA. (1992). A comprehensive evaluation of the trunk response to asymmetric trunk motion. *Spine, 17*(3), 318-326.

Marras WS & Schoenmarklin RW. (1993). Wrist motions in industry. *Ergonomics, 36*(4), 341-351.

Massey WE. (1978). Carpal tunnel syndrome in pregnancy. *Obstetrical and Gynecological Survey, 33*(3), 145-148.

Medical Multimedia Group. (1998). *A patient's guide to low back pain.* Retrieved 05/04/2001, 2001, from http://www.medicalmultimediagroup.com/pated/back/back.html

Miller LC, Murphy R, & Buss AH. (1981). Consciousness of body: private and public. *Journal of Personality and Social Psychology, 41*(2), 397-406.

Montgomery DC. (2000). Experiments with a single factor: the analysis of variance. Chapter 3. In *Design and analysis of experiments* (5th ed., pp. 60-125). New York: John Wiley & Sons, Inc.

Moon SD & Sauter SL (Eds.). (1996). *Beyond biomechanics: psychosocial aspects of musculoskeletal disorders in office work.* Bristol, PA: Taylor & Francis.

Moore A, Wells R, & Ranney D. (1991). Quantifying exposure in occupational manual tasks with cumulative trauma disorder potential. *Ergonomics, 34*(12), 1433-1453.

Myers LB & Vetere A. (1997). Repressors' responses to health-related questionnaires. *British Journal of Health Psychology, 2*, 245-257.

Nadelson T. (1992). Psychological factors in upper extremity disorders: pain as a paradigm. Chapter 16. In L. H. Millender, D. S. Louis & B. P. Simmons (Eds.), *Occupational disorders of the upper extremity.* New York: Churchill Livingstone.

Palmerud G, Sporrong H, Herberts P, & Kadefors R. (1998). Consequences of trapezius relaxation on the distribution of shoulder muscle forces: an electromyographic study. *Journal of Electromyography and Kinesiology, 8*, 185-193.

Pennebaker JW. (1993). Putting stress into words: health, linguistic, and therapeutic implications. *Behaviour Research and Therapy, 31*(6), 539-548.

Pennebaker JW. (1995a). Emotion, disclosure, and health: an overview. In J. W. Pennebaker (Ed.), *Emotion, disclosure, and health* (pp. 3-10). Washington, DC: American Psychological Association.

Pennebaker JW. (1997). Writing about emotional experiences as a therapeutic process. *Psychological Science, 8*(3), 162-166.

Pennebaker JW (Ed.). (1995b). *Emotion, disclosure, and health.* Washington, DC: American Psychological Association.

Perry AR & Baldwin DA. (2000). Further evidence of associations of Type A personality scores and driving-related attitudes and behaviors. *Perceptual and Motor Skills, 91*(1), 147-154.

Phillips JM & Gatchel RJ. (2000). Extraversion-Introversion and chronic pain. Chapter 8. In R. J. Gatchel & J. N. Weisberg (Eds.), *Personality characteristics of patients with pain* (pp. 181-202). Washington, D. C.: American Psychological Association.

Pope MH & Novotny JE. (1993). Spinal biomechanics. *Journal of Biomechanical Engineering, 115*(4B), 569-574.

Price VA. (1982). *Type A behavior pattern: a model for research and practice*. New York: Academic Press.

Psychological Assessment Resources Inc. (2001). *NEO Five-Factor Inventory (NEO-FFI)*. Retrieved 04/27/2001, 2001, from http://www.parinc.com/

Punnett L. (1998). Ergonomic stressors and upper extremity disorders in vehicle manufacturing: cross sectional exposure-response trends. *Occupational and Environmental Medicine, 55*, 414-420.

Putz-Anderson V (Ed.). (1988). *Cumulative trauma disorders: A manual for musculoskeletal diseases of the upper limbs*. Bristol, PA: Taylor & Francis Inc.

Reich W. (1969). *Die Funktion des Orgasmus [The function of the orgasm]. Köln: Kiepenheuer & Wisch*.

Roto P & Kivi P. (1984). Prevalence of epicondylitis and tenosynovitis among meatcutters. *Scandinavian Journal of Work and Environmental Health, 10*, 203-205.

Rowland KF & Sokol B. (1977). A review of research examining the coronary-prone behavior pattern. *Journal of Human Stress, 3*, 26-33.

Sabour MS & Fadel HE. (1970). The carpal tunnel syndrome -- a new complication ascribed to the "pill". *American Journal of Obstetrics and Gynecology, 107*(8), 1265-1267.

Sainsbury P & Gibson JG. (1954). Symptoms of anxiety and tension and the accompanying physiological changes in the muscular system. *Journal of Neurology, Neurosurgery, and Psychiatry, 17*, 216-224.

Salminen JJ, Pentti J, & Wickström G. (1991). Tenderness and pain in neck and shoulders in relation to type A behaviour. *Scandinavian Journal of Rheumatology, 20*, 344-350.

Sarafino EP. (1990). *Health psychology: biopsychosocial interactions* (2 ed.). New York: John Wiley & Sons, Inc.

Sarason IG, Johnson JH, & Siegel JM. (1979). Assessing the impact of life changes: development of the life experiences survey. *Journal of Consulting and Clinical Psychology, 46*, 932-946.

Sarno JE. (1984). *Mind over back pain: a radically new approach to the diagnosis and treatment of back pain*. New York: William Morrow and Company, Inc.

Sauter SL & Swanson NG. (1996). An ecological model of musculoskeletal disorders in office work. Chapter 1. In S. D. Moon & S. L. Sauter (Eds.), *Beyond biomechanics: psychosocial aspects of musculoskeletal disorders in office work* (pp. 3-21). Bristol, PA: Taylor & Francis.

Schoenmarklin RW. (1991). *Biomechanical analysis of wrist motion in highly repetitive, hand-intensive industrial jobs*. Unpublished Doctoral dissertation, The Ohio State University, Columbus, OH.

Shields SA, Mallory ME, & Simon A. (1989). The body awareness questionnaire: reliability and validity. *Journal of Personality Assessment, 53*(4), 802-815.

Simmons BP & Wyman ET. (1992). Occupational injuries of the elbow. Chapter 13. In L. H. Millender, D. S. Louis & B. P. Simmons (Eds.), *Occupational disorders of the upper extremity*. New York: Churchill Livingstone.

Smith-Jackson T. (1998). *Irrelevant speech, verbal task performance, and focused attention: a laboratory examination of the performance dynamics of open-plan offices*. Unpublished dissertation, North Carolina State University, Raleigh, NC.

Snook SH & Jensen RC. (1984). Cost. Chapter 5. In M. H. Pope, J. W. Frymoyer & G. Andersson (Eds.), *Occupational low back pain* (pp. 115-121). New York: Praeger.

Sparacino J. (1979). The Type A behavior pattern: a critical assessment. *Journal of Human Stress, 5*, 37-51.

Spence JT, Helmreich RL, & Pred RS. (1987). Impatience versus achievement strivings in the type A pattern: differential effects on students' health and academic achievement. *Journal of Applied Psychology, 72*(4), 522-528.

Spielberger CD. (1983). *Manual for the State-Trait Anxiety Inventory (STAI)*. Palo Alto, CA: Consulting Psychologists Press.

Sporrong H, Palmerud G, Kadefors R, & Herberts P. (1998). The effect of light manual precision work on shoulder muscles -- an EMG analysis. *Journal of Electromyography and Kinesiology, 8*(3), 177-184.

Steel RGD, Torrie JH, & Dickey DA. (1997). *Principles and procedures of statistics: a biometrical approach* (3rd ed.). New York: The McGraw-Hill Companies, Inc.

Stolworthy TM. (1996). *A comparison of hardiness and Type A behaviors to type of worker's compensation claim*. United States International University.

Stone M. (1985). Maudley Personality Inventory. In D. J. Keyser & R. C. Sweetland (Eds.), *Test critiques* (Vol. I, pp. 279-283). Kansas City, MO: Test Corporation of America.

Stout C & Bloom LJ. (1982). Type A behavior and upper respiratory infections. *Journal of Human Stress, 8*, 4-8.

Sudhakaran S. (2003). *Effect of personality type on performance of an overhead task*. Unpublished Masters Thesis, North Carolina State University, Raleigh, NC.

Sutherland VJ & Cooper CL. (1991). Personality, stress and accident involvement in the offshore oil and gas industry. *Personality and Individual Differences, 12*(2), 195-204.

Takala E-P & Viikari-Juntura E. (1991). Muscular activity in simulated light work among subjects with frequent neck-shoulder pain. *International Journal of Industrial Ergonomics, 8*, 157-164.

Taylor JA. (1953). A personality scale of manifest anxiety. *The Journal of Abnormal and Social Psychology, 48*(2), 285-290.

Traue HC. (1995). Inhibition and muscle tension in myogenic pain. Chapter 8. In J. W. Pennebaker (Ed.), *Emotion, disclosure, and health* (pp. 155-175). Washington, DC: American Psychological Association.

Van Galen GP, Muller ML, Meulenbroek RG, & Van Gemmert AW. (2002). Forearm EMG response activity during motor performance in individuals prone to increased stress reactivity. *American Journal of Industrial Medicine, 41*(5), 406-419.

Vasseljen O, Holte KA, & Westgaard RH. (2001). Shoulder and neck complaints in customer relations: individual risk factors and perceived exposures at work. *Ergonomics, 44*(4), 355-372.

Veiersted KB, Westgaard RH, & Andersen P. (1990). Pattern of muscle activity during stereotyped work and its relation to muscle pain. *International Archives of Occupational and Environmental Health, 62*, 31-41.

Veiersted KB, Westgaard RH, & Andersen P. (1993). Electromyographic evaluation of muscular work pattern as a predictor of trapezius myalgia. *Scandinavian Journal of Work and Environmental Health, 19*, 284-290.

Vingard E, Alfredsson L, Hagberg M, Kilbom A, Theorell T, Waldenstrom M, et al. (2000). To what extent do current and past physical and psychosocial occupational factors explain care-seeking for low back pain in a working population? Results from the Musculoskeletal Intervention Center-Norrtalje Study. *Spine, 25*(4), 493-500.

Vogelsang LM, Williams RL, & Lawler K. (1994). Lifestyle correlates of carpal tunnel syndrome. *Journal of Occupational Rehabilitation, 4*(3), 141-152.

Wadden TA, Anderson CH, Foster GD, & Love W. (1983). The Jenkins Activity Survey: does it measure psychopathology? *Journal of Psychosomatic Research, 27*(4), 321-325.

Wade JB & Price DD. (2000). Nonpathological factors in chronic pain: implications for assessment and treatment. Chapter 4. In R. J. Gatchel & J. N. Weisberg (Eds.), *Personality characteristics of patients with pain* (pp. 89-107). Washington, D. C.: American Psychological Association.

Waersted M, Bjorklund RA, & Westgaard RH. (1991). Shoulder-muscle tension induced by two VDU-based tasks of different complexity. *Ergonomics, 34*(2), 137-150.

Waersted M, Bjorklund RA, & Westgaard RH. (1994). The effect of motivation on shoulder-muscle tension in attention-demanding tasks. *Ergonomics, 37*(2), 363-376.

Waersted M & Westgaard RH. (1996). Attention-related muscle activity in different body regions during VDU work with minimal physical activity. *Ergonomics, 39*(4), 661-676.

Warren N, Dillon C, Morse T, Hall C, & Warren A. (2000). Biomechanical, psychosocial, and organizational risk factors for WRMDS: population-based estimates from the Connecticut upper-extremity surveillance project (CUSP). *Journal of Occupational Health Psychology, 5*(1), 164-181.

Watson D & Pennebaker JW. (1989). Health complaints, stress, and distress: exploring the central role of negative affectivity. *Psychological Review, 96*(2), 234-254.

Webster BS & Snook SH. (1990). The cost of compensable low back pain. *Journal of Occupational Medicine, 32*(1), 13-15.

Webster BS & Snook SH. (1994). The cost of 1989 workers' compensation low back pain claims. *Spine, 19*, 1111-1116.

Weinberger DA. (1990). The construct validity of the repressive coping style. Chapter 14. In J. L. Singer (Ed.), *Repression and dissociation: implications for personality theory, psychopathology, and health* (pp. 337-386). Chicago: The University of Chicago Press.

Weinberger DA, Schwartz GE, & Davidson RJ. (1979). Low-anxious, High-anxious, and repressive coping styles: psychometric patterns and behavioral and physiological responses to stress. *Journal of Abnormal Psychology, 88*(4), 369-380.

Weisberg JN & Keefe FJ. (1999). Personality, individual differences, and psychopathology in chronic pain. Chapter 4. In R. J. Gatchel & D. C. Turk (Eds.), *Psychosocial factors in pain: critical perspectives* (pp. 56-73). New York: The Guilford Press.

Westgaard RH & Bjorklund RA. (1987). Generation of muscle tension additional to postural muscle load. *Ergonomics, 30*(6), 911-923.

Westgaard RH, Vasseljen O, & Holte KA. (2001). Trapezius muscle activity as a risk indicator for shoulder and neck pain in female service workers with low biomechanical exposure. *Ergonomics, 44*(3), 339-353.

Wickström G. (2000). Personal email correspondence with subject: The A type questionnaire.

Wickström G, Pentti J, Hyytiänen K, & Uutela A. (1989). Type A behaviour and back pain. *Work and Stress, 3*(2), 203-207.

Williams RL, Moore CA, Pettibone TJ, & Thomas SP. (1992). Construction and validation of a brief self-report scale of self-management practices. *Journal of Research in Personality, 26*, 216-234.

Wolf FG, Keane MS, Brandt KD, & Hillberry BM. (1993). An investigation of finger joint and tendon forces in experienced pianists. *Medical Problems of Performing Artists, 8*, 84-95.

13. APPENDICES

13.1 KINESTHETIC AND PROPRIOCEPTIVE AWARENESS QUESTIONNAIRE (KPAQ)

(KPAQ)

Listed below are a number of statements related to a variety of normal kinds of feelings and bodily reactions. Read each item and decide how well the statement reflects you personally. It's best to go with your first judgment and not to spend too long mulling over any one question.

Use the response scale provided to choose your answer and mark your answer sheet accordingly

	NEVER true about me	OCCASIONALLY true about me	**SOMETIMES true about me**	**FREQUENTLY true about me**	**ALWAYS true about me**
140. I am aware of my overall body posture.	A	B	C	D	E
141. I am aware of how far I am bending over when I have to bend to do something.	A	B	C	D	E
142. I am aware of strain in my muscles.	A	B	C	D	E
143. I can provide definite information regarding the specific location and severity of pain/discomfort in my body when the doctor asks me what symptoms I am having.	A	B	C	D	E
144. I can exert the correct amount of force/pressure required to do a task even without thinking about it.	A	B	C	D	E
145. I am sensitive to changes in the position of my legs even without looking at them.	A	B	C	D	E
146. I can touch my nose with my index fingers, even with my eyes closed.	A	B	C	D	E
147. I can tell when I should stop doing something (e.g., lifting) before it causes me pain or injury.	A	B	C	D	E
148. I can tell where my hands are located without even looking at them.	A	B	C	D	E
149. I can tell how tired I will be after a task when I first start doing it.	A	B	C	D	E
150. I can feel even the slightest touch (e.g., a small raindrop or an ant crawling) on my skin.	A	B	C	D	E
151. I know my own strength.	A	B	C	D	E

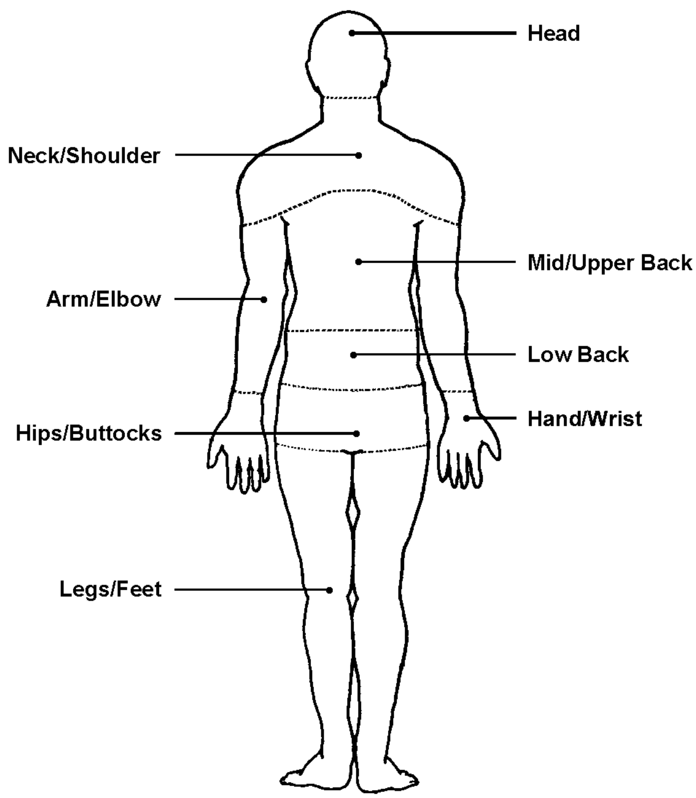
13.2 MUSCULOSKELETAL DISCOMFORT SURVEY (MDS)

Subject ID: ____________ **Survey #** **1** **2** **3pN** **3pS** **3cN** **3cS** **4**

Musculoskeletal Discomfort Survey

Mark the body diagram below with an X anywhere you feel discomfort/pain right now.

For any place you mark, rate the level of discomfort/pain using the rating scale provided. Mark and rate the left and/or right sides separately where appropriate.



Back View

Subject ID: ____________ **Survey # 1 2 3pN 3pS 3cN 3cS 4**

For each region of the body where you marked an ***X*** *on the body diagram, rate the intensity level of discomfort/pain that you feel* *<u>right now</u>* *by placing a straight line on the scale provided. Place the mark where you feel your present pain is relative to the left and right endpoints of the scale. Mark and rate the left and/or right sides separately where appropriate.*

	NO pain at all	**WORST imaginable pain**
Head		
Neck/shoulder – Left		
Neck/shoulder – Right		
Arm/elbow – Left		
Arm /elbow – Right		
Hand/wrist – Left		
Hand/wrist – Right		
Upper/mid back – Left		
Upper/mid back – Right		
Low back – Left		
Low back – Right		
Legs/feet – Left		
Legs/feet – Right		

13.3 PROXY SURVEY

From: NGDP Research Team
c/o Dr. Gary A. Mirka
Department of Industrial Engineering
Box 7906
North Carolina State University
Raleigh, NC 27695-7906

Dear Research Participant,

This letter has been provided to you by a valued participant in our research study. The participant has given permission for you to complete the attached survey on his/her behalf. Instructions for completing the survey are included on the survey form. Please take the time to complete the survey and return it to our research team. Don't forget to note your relationship to the person who has provided you this survey. There is a space provided on the survey form for you to provide this information. A stamped, addressed envelope is provided for you to use to return the survey. Please return the survey by November 30, 2001. Your time is greatly appreciated. You are helping us to complete a valuable research effort.

If you have any questions regarding this correspondence, please feel free to contact Naomi F. Glasscock at 513-4493 (email: nfglassc@eos.ncsu.edu) or Dr. Gary A. Mirka at 515-6399 (email: mirka@eos.ncsu.edu).

Sincere thanks,

Naomi F. Glasscock

Participant Identification Number ___________________

Survey Questionnaire

You have been provided this survey by someone who you know. Listed below are a number of statements related to a variety of normal kinds of feelings and behaviors. Please read each item and decide how well the statement reflects him/her personally. Each person is different, so there are no "right" or "wrong answers. It is best to go with your first judgment and not to spend too long mulling over any one question.

Use the response scales provided to choose your answer and circle the response that you have chosen.

1. Ordinarily, how rapidly does he/she eat?

A. He/she is usually the first one finished.
B. He/she eats a little faster than average.
C. He/she eats at about the same speed as most people.
D. He/she eats more slowly than most people.

2. How often does he/she do more than one thing at a time, such as working while eating, reading while dressing, or figuring out problems while driving?

A. He/she does almost always does several things at once, even if it doesn't seem practical.
B. He/she does several things at once whenever practical.
C. He/she sometimes does this when he/she is short of time.
D. He/she rarely or never does more than one thing at a time.

3. When he/she listens to someone talking, how often does he/she "put words in the person's mouth" to hurry that person along?

A. Frequently
B. Occasionally
C. Almost never
D. Never

4. Would you rate him/her as

A. definitely hard-driving and competitive?
B. probably hard-driving and competitive?
C. probably relaxed and easygoing?
D. definitely relaxed and easygoing?

5. Does he/she tend to do most things in a hurry?

A. Definitely yes
B. Probably yes
C. Probably no
D. Definitely no

6. How is his/her temper?

A. Fiery and hard to control
B. Strong but controllable
C. No problem
D. He/she almost never gets angry

7. How often does he/she take his/her work home at night?

A. Rarely or never
B. Once a week or less
C. More than once a week
D. Almost all of the time

8. Compared to others, he/she hurries

A. much more of the time.
B. a little more of the time.
C. a little less of the time.
D. much less of the time.

9. Compared to others, he/she is precise (careful about detail)

A. much more precise.
B. a little more precise.
C. a little less precise.
D. much less precise.

10. Compared to others, he/she approaches life in general

A. much more seriously.
B. a little more seriously.
C. a little less seriously.
D. much less seriously.

	NEVER true	OCCASIONALLY true	SOMETIMES true	FREQUENTLY true	ALWAYS true
1. He/she is aware of his/her distressing emotions.	**A**	**B**	**C**	**D**	**E**
2. He/she loses his/her temper and becomes very angry.	**A**	**B**	**C**	**D**	**E**
3. He/she is impatient and always in a hurry.	**A**	**B**	**C**	**D**	**E**
4. He/she hides his/her emotions well.	**A**	**B**	**C**	**D**	**E**
5. He/she always tells me how he/she feels.	**A**	**B**	**C**	**D**	**E**
6. He/she is a very emotional person.	**A**	**B**	**C**	**D**	**E**

What is your relationship to the person who provided you with this survey (e.g., friend, roommate, sister, father, boss, girlfriend, etc)? Please include all that apply.

____

13.4 GRAPHICAL REPRESENTATION OF NONSIGNIFICANT RESULTS

Selected graphs of nonsignificant results are included in this Appendix for reference. These were mentioned in the text in the specific section that described the results.

13.4.1 Phase II Laboratory Experiment of Assembly Task

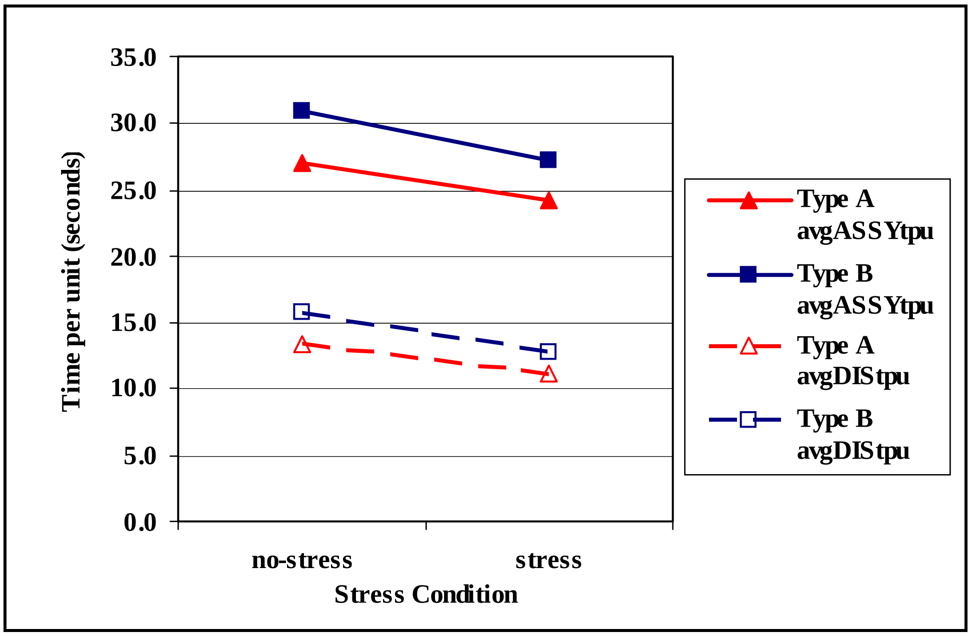


Figure 13-1. Nonsignificant interaction effect (p=0.2564 and p=0.2186) of personality type (TYPE) and stress condition (STRESS) on average assembly (avgASSYtpu) and disassembly (avgDIStpu) performance times.

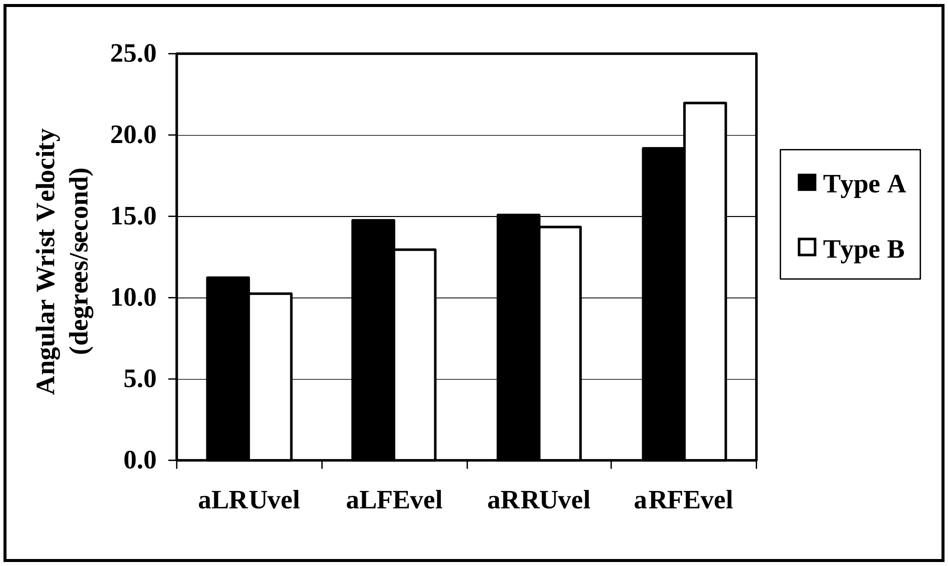


Figure 13-2. Nonsignificant effects of personality type (TYPE) on angular wrist velocities.

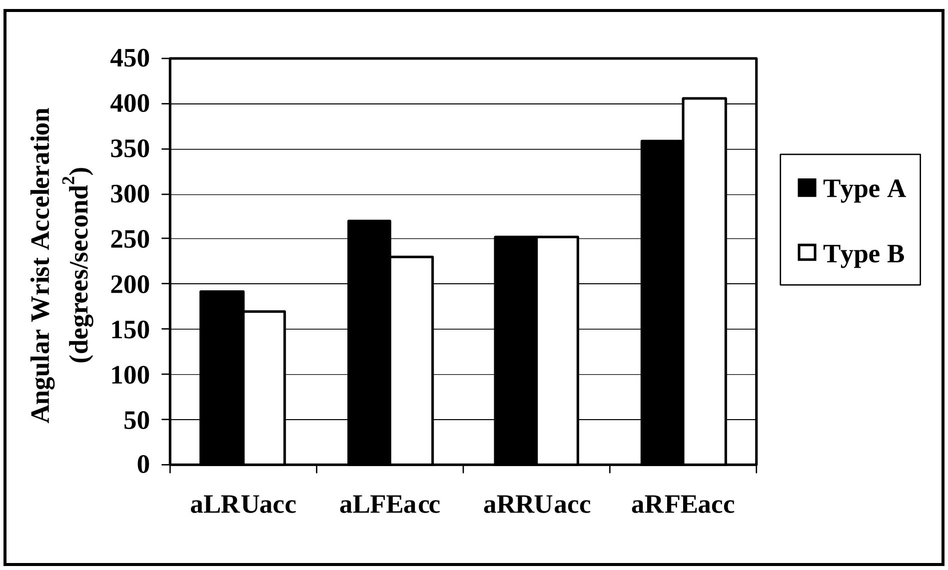


Figure 13-3. Nonsignificant effects of personality type (TYPE) on angular wrist accelerations.

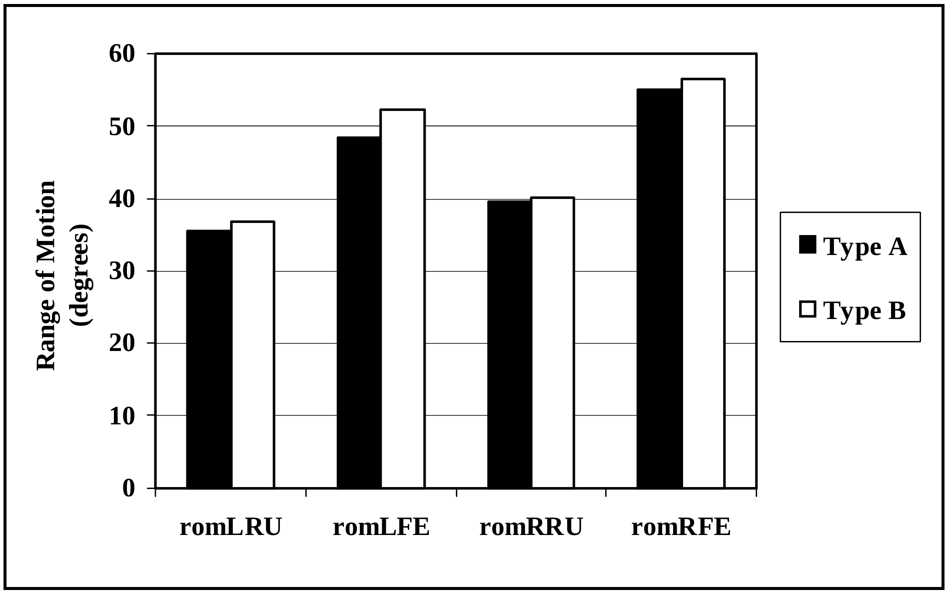


Figure 13-4. Nonsignificant effects of personality type (TYPE) on wrist range of motion values.

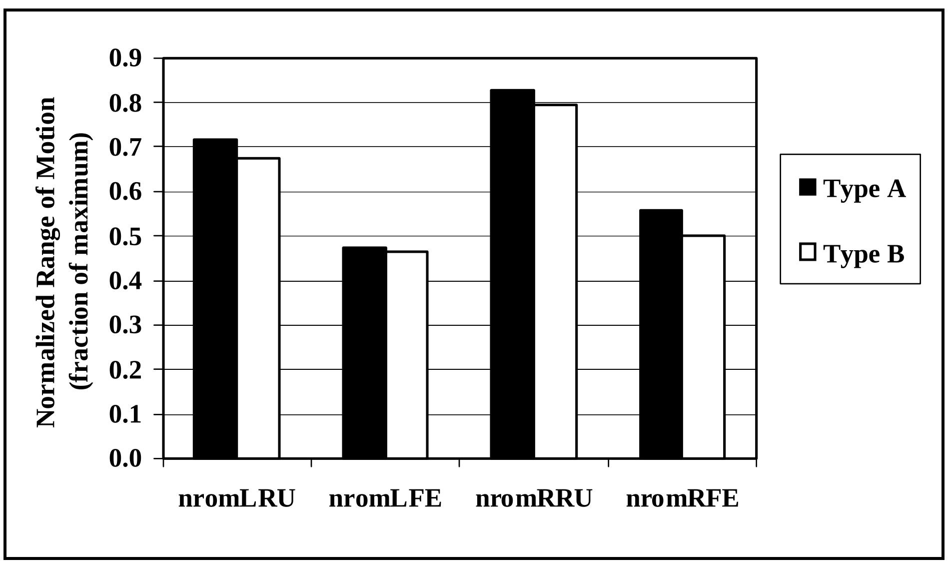


Figure 13-5. Nonsignificant effects of personality type (TYPE) on normalized wrist range of motion values.

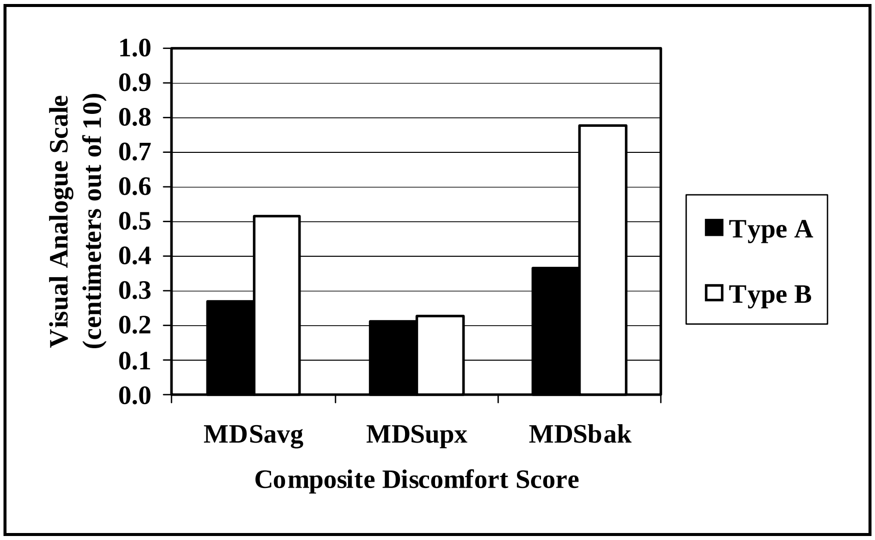


Figure 13-6. Nonsignificant effects of personality type (TYPE) on composite discomfort scores for post-task administrations only (48 observations).

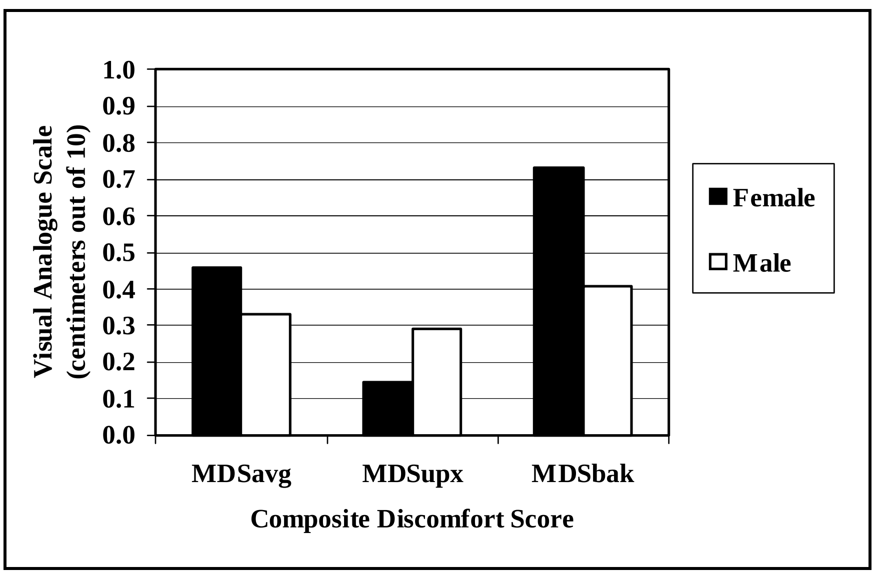


Figure 13-7. Nonsignificant effects of gender (GENDER) on composite discomfort scores for post-task administrations only (48 observations).

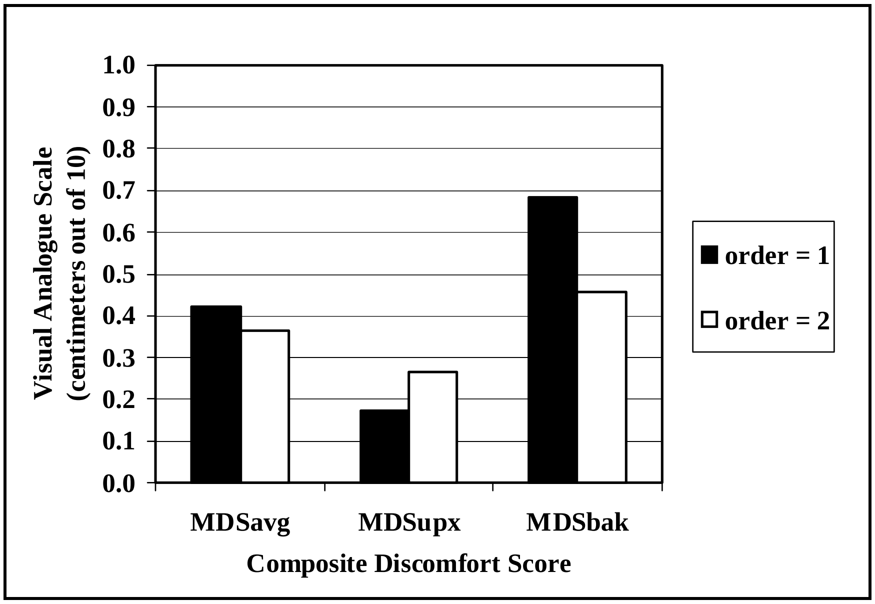


Figure 13-8. Nonsignificant effects of stress condition order (ORDER) on composite discomfort scores for post-task administrations only (48 observations).

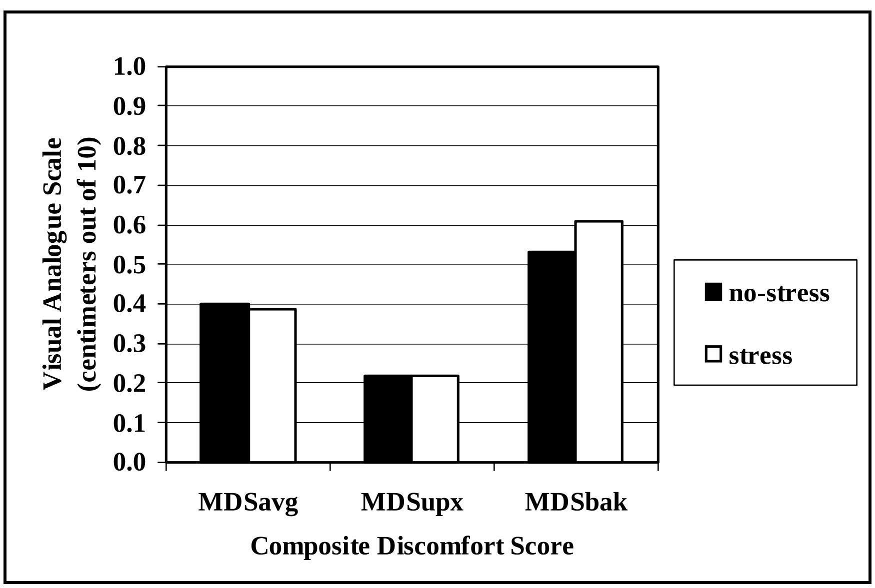


Figure 13-9. Nonsignificant main effects of stress condition (STRESS) on composite discomfort scores for post-task administrations only (48 observations).

13.4.2 Phase III Laboratory Experiment of Pipetting and Computer Tasks

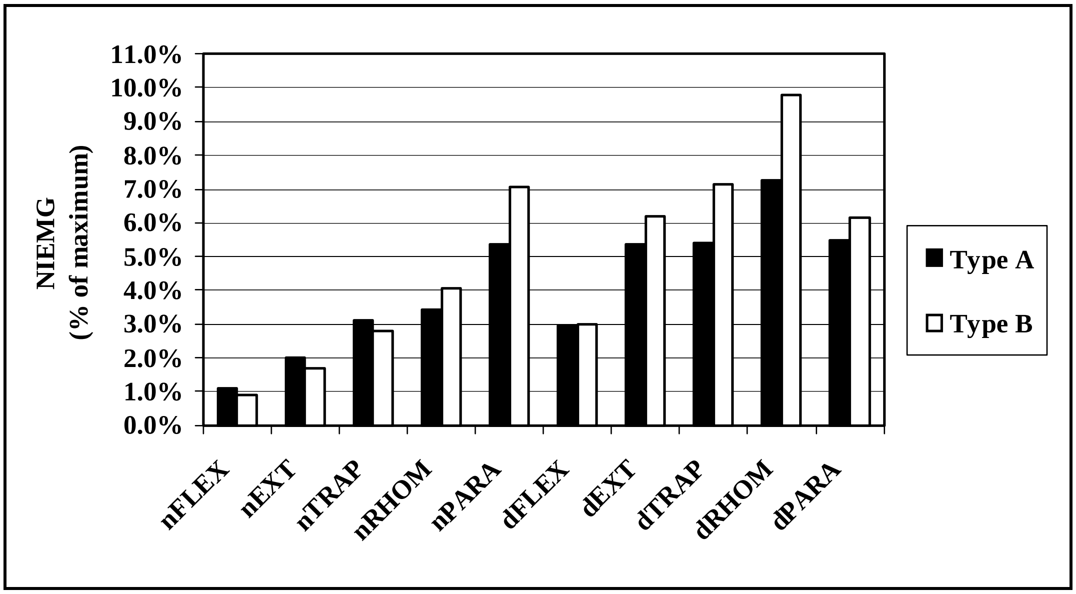


Figure 13-10. Nonsignificant effects of personality type (TYPE) on pipetting NIEMG mean values.

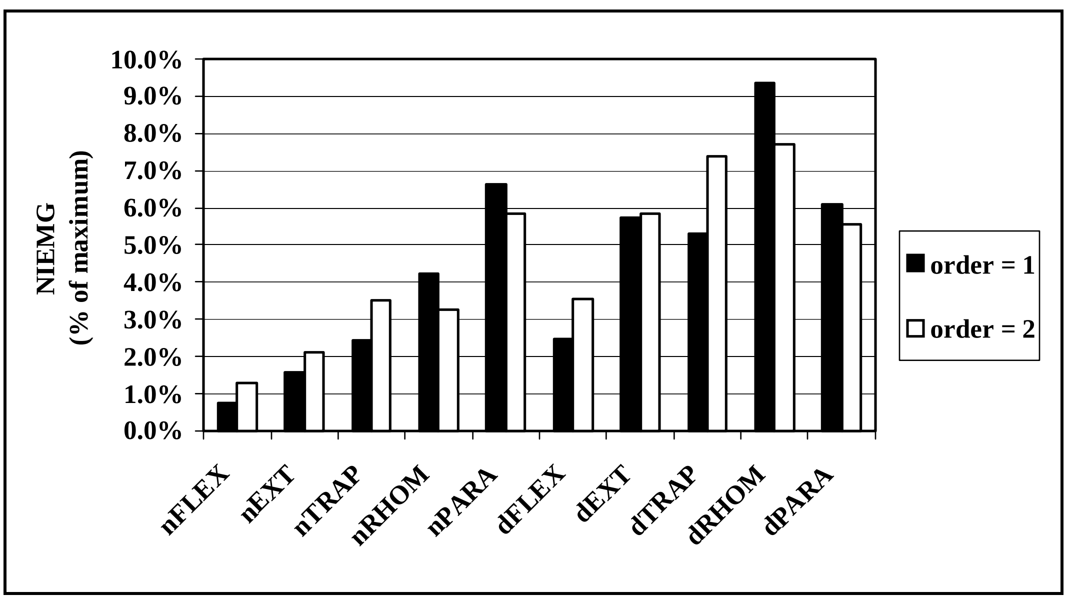


Figure 13-11. Nonsignificant effects of stress condition order (ORDER) on pipetting NIEMG mean values.

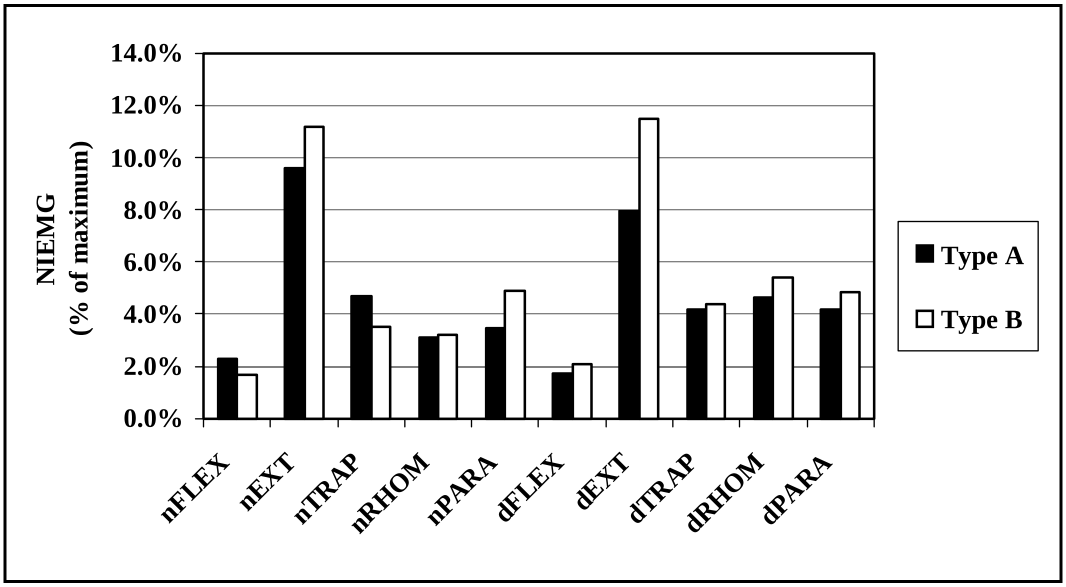


Figure 13-12. Nonsignificant effects of personality type (TYPE) on computer NIEMG mean values.

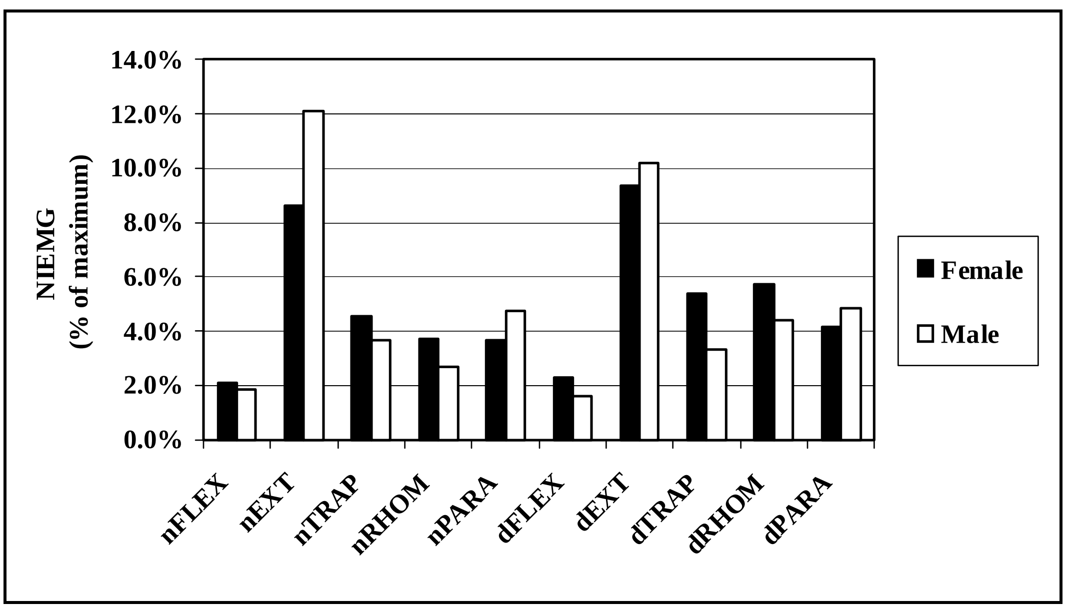


Figure 13-13. Nonsignificant effects of gender (GENDER) on computer NIEMG mean values.

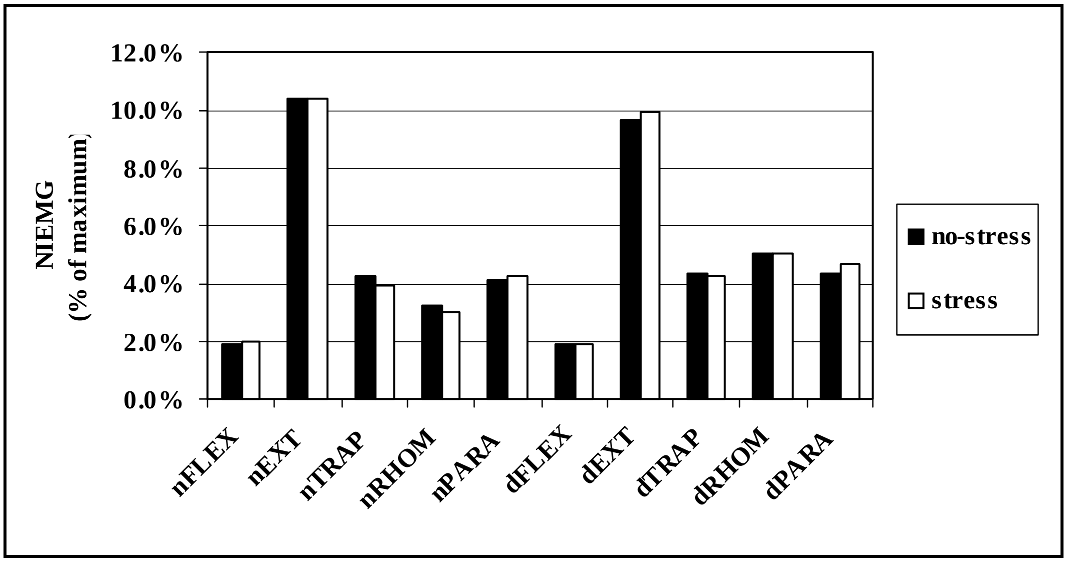


Figure 13-14. Nonsignificant effects of stress condition (STRESS) on computer NIEMG mean values.

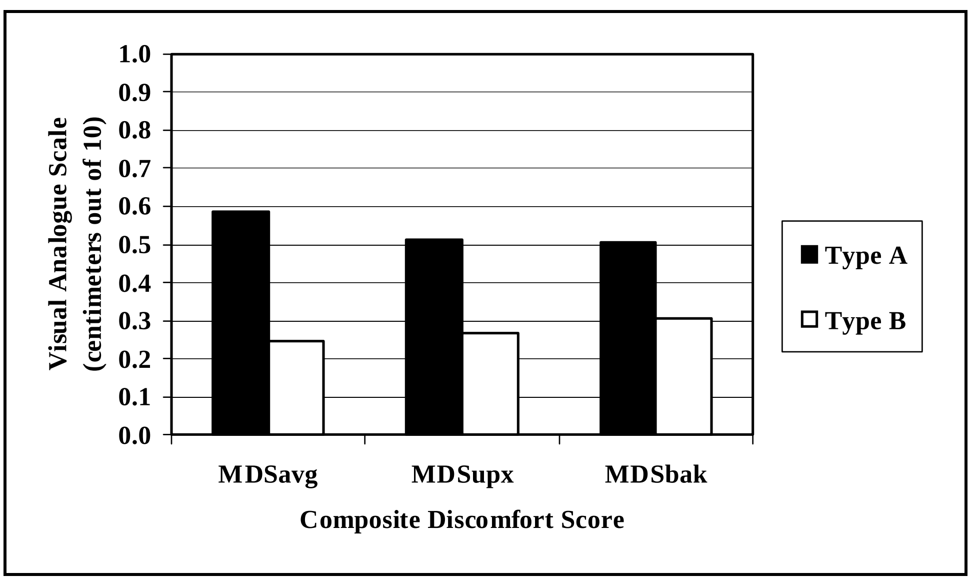


Figure 13-15. Nonsignificant effects of personality type (TYPE) on composite discomfort scores for pipetting post-task administrations only (50 observations).

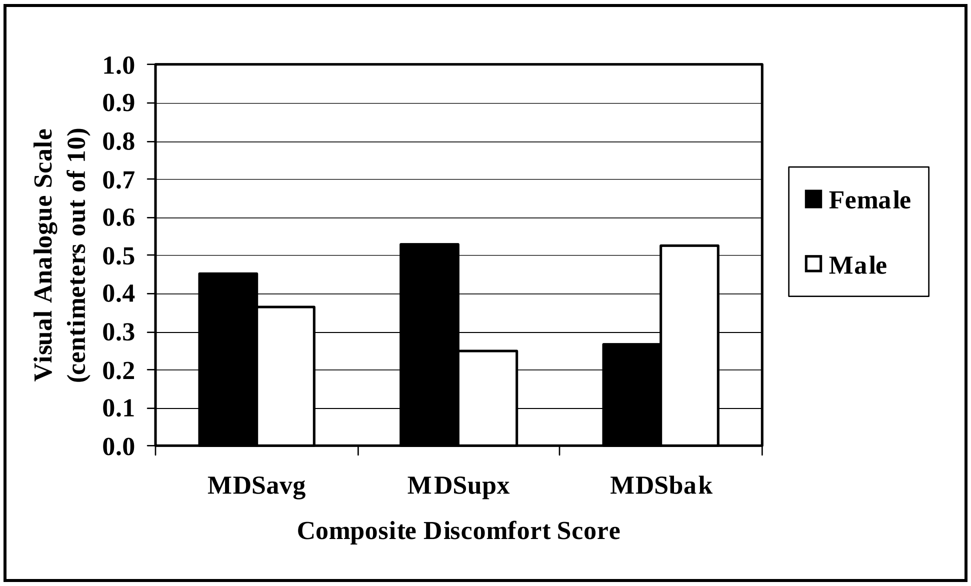


Figure 13-16. Nonsignificant effects of gender (GENDER) on composite discomfort scores for pipetting post-task administrations only (50 observations).

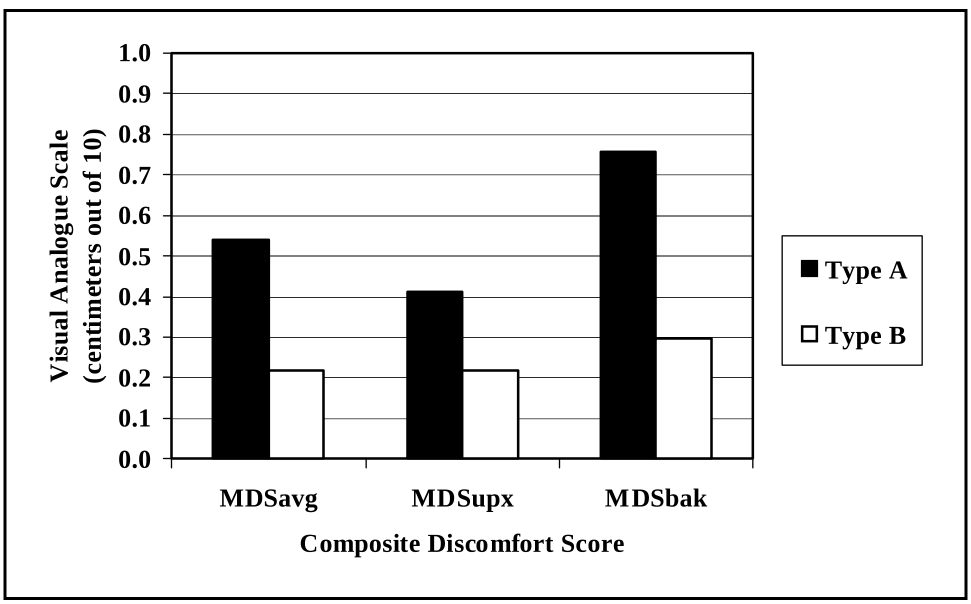


Figure 13-17. Nonsignificant effects of personality type (TYPE) on composite discomfort scores for computer post-task administrations only (50 observations).

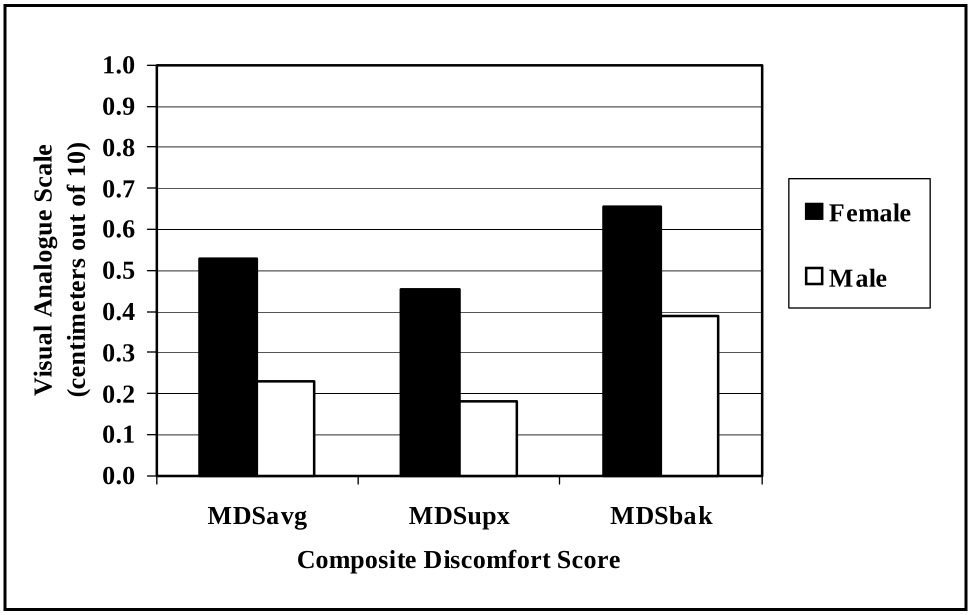


Figure 13-18. Nonsignificant effects of gender (GENDER) on composite discomfort scores for computer post-task administrations only (50 observations).

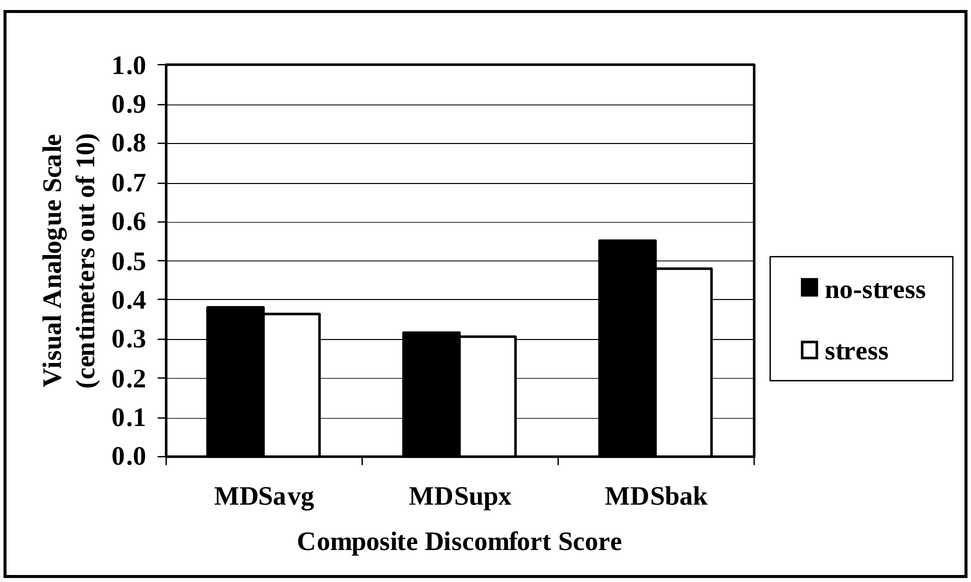


Figure 13-19. Nonsignificant main effects of stress condition (STRESS) on composite discomfort scores for computer post-task administrations only (50 observations).

13.5 HIGHER ORDER INTERACTIONS FROM PHASE II LABOROATORY STUDY

13.5.1 Physical Traits – Anthropometry

Seventeen (17) anthropometry variables were analyzed using a between-subjects ANOVA with Model #2 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. The ANOVA analysis revealed a significant 3-way interaction effect ($F\{1,16\} = 4.92$, $p=0.0414$) of TYPE x GENDER x ORDER for arm length (AL). The mean arm length values for each TYPE x GENDER x ORDER combination can be seen in Figure 13-20.

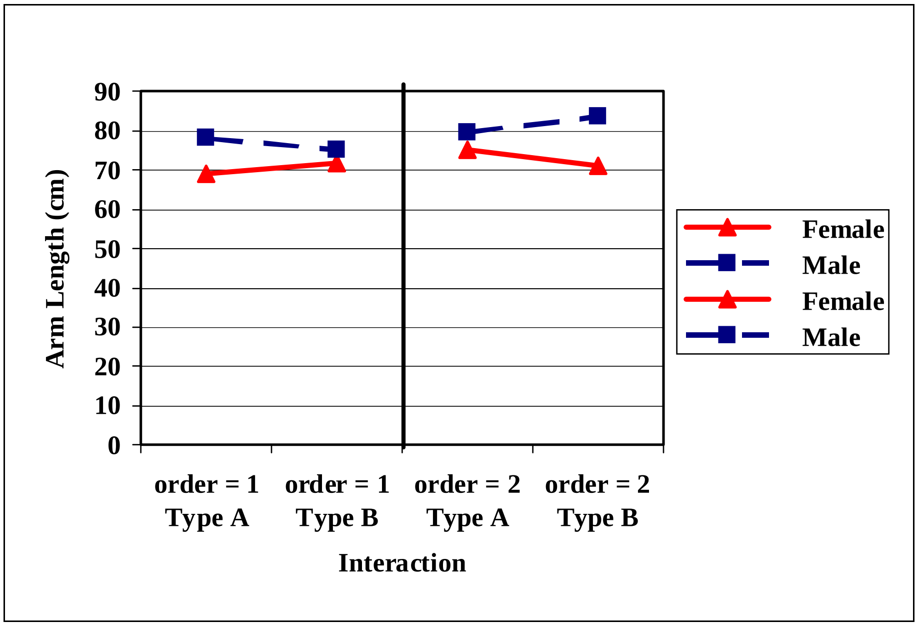


Figure 13-20. Significant 3-way interaction effect (p=0.0414) of personality type (TYPE), gender (GENDER), and stress condition order (ORDER) on arm length.

13.5.2 Workstyle – Performance

13.5.2.1 Between-subjects Effects

Task performance times (avgDIStpu and avgASSYtpu) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. There were no significant 3-way interaction effects.

13.5.2.2 Within-subjects Effects

Task performance times (avgDIStpu and avgASSYtpu) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. There were no significant 3-way or 4-way interaction effects. However, the 3-way interaction effect of GENDER x ORDER x STRESS for avgASSYtpu was almost significant ($F\{1,16\} = 4.42$, $p=0.0517$). The mean avgASSYtpu values for each GENDER x ORDER x STRESS combination can be seen in Figure 13-21.

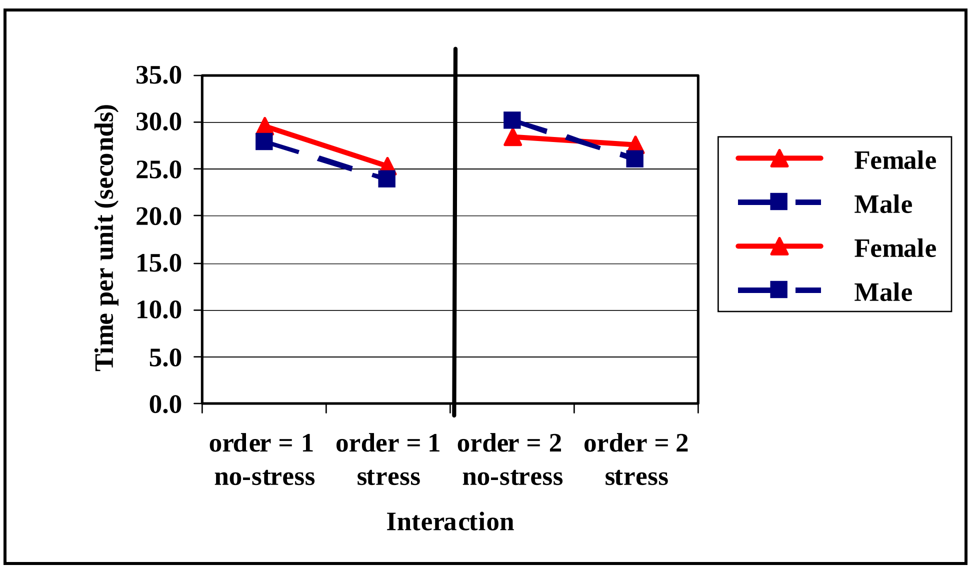


Figure 13-21. Almost significant 3-way interaction effect (p=0.0517) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on average assembly performance time (avgASSYtpu).

13.5.3 Workstyle – Wrist Motion Kinematics

13.5.3.1 Between-subjects Effects

Wrist motion kinematics variables (20 variables) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. There were no 3-way interaction effects.

13.5.3.2 Within-subjects Effects

Wrist motion kinematic variables (20 variables) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS.

The analysis resulted in a significant 3-way interaction effect of GENDER x ORDER x STRESS for aLRUvel (p=0.0250), aLRUacc (p=0.0365), romLFE (p=0.0448) and nromLFE (p=0.0435). The mean aLRUvel values for each GENDER x ORDER x STRESS combination can be seen in Figure 13-22. The mean aLRUacc values for each GENDER x ORDER x STRESS combination can be seen in Figure 13-23. The mean romLFE values for each GENDER x ORDER x STRESS combination can be seen in Figure 13-24. The mean nromLFE values for each GENDER x ORDER x STRESS combination can be seen in Figure 13-25.

The analysis resulted in a significant 4-way interaction effect of TYPE x GENDER x ORDER x STRESS for romRFE (p=0.0233) and nromRFE (p=0.0239). The mean romRFE values for each TYPE x GENDER x ORDER x STRESS combination can be seen in Figure 13-26. The mean nromRFE values for each TYPE x GENDER x ORDER x STRESS combination can be seen in Figure 13-27.

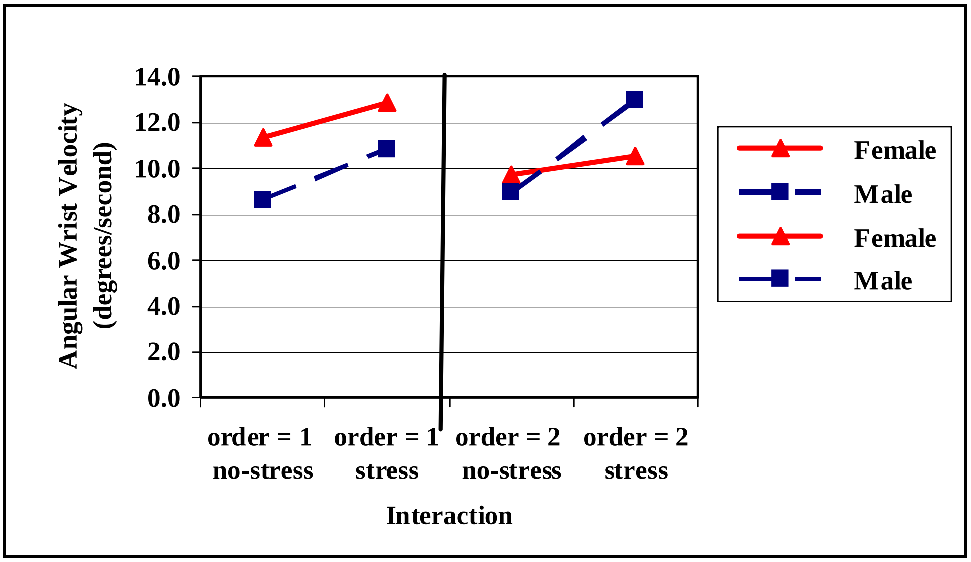


Figure 13-22. Significant 3-way interaction effect (p=0.0250) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on aLRUvel.

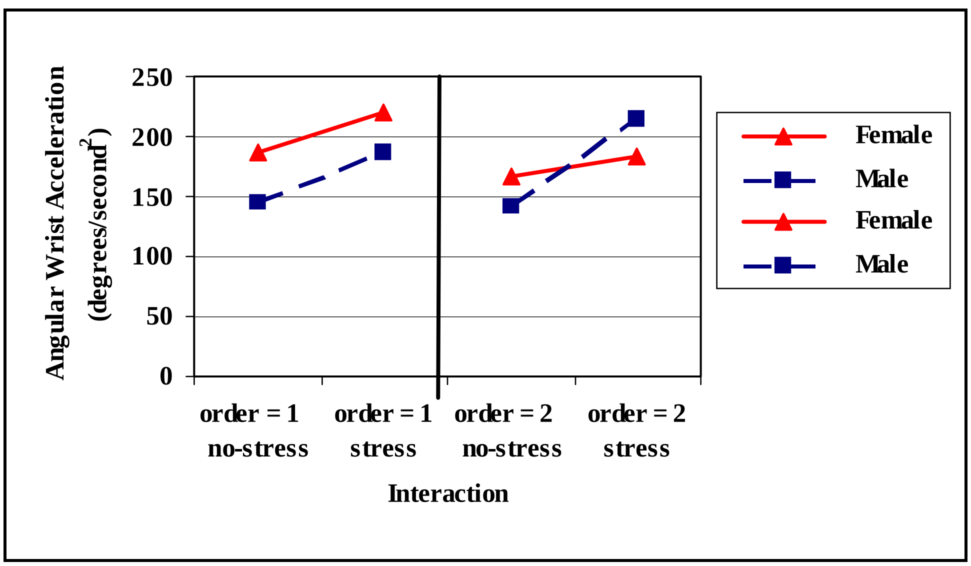


Figure 13-23. Significant 3-way interaction effect (p=0.0365) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on aLRUacc.

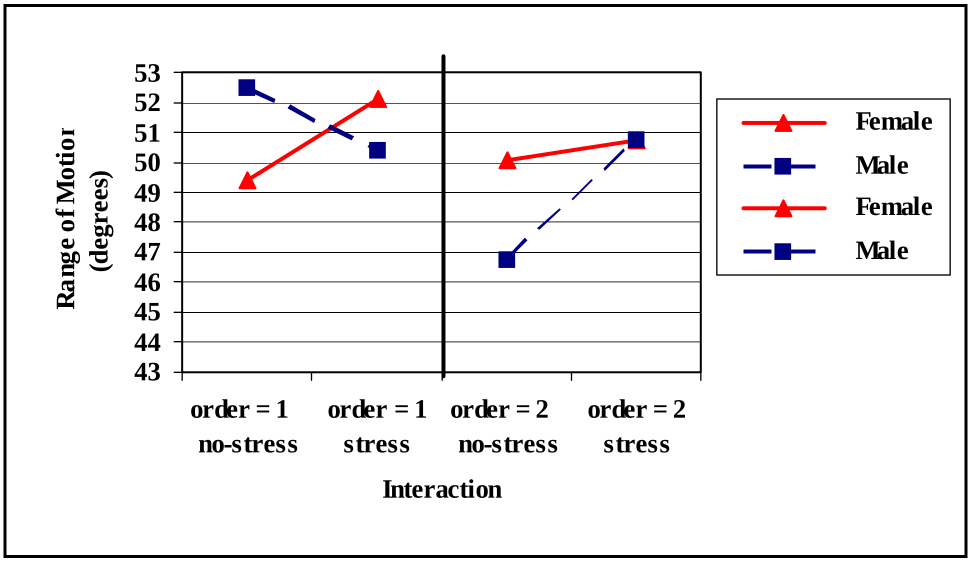


Figure 13-24. Significant 3-way interaction effect (p=0.0448) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on romLFE.

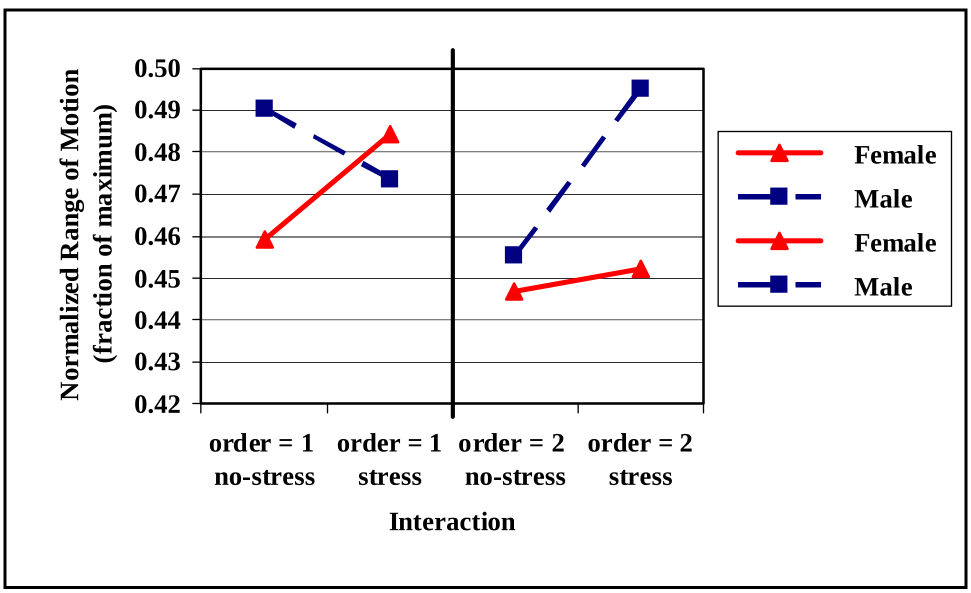


Figure 13-25. Significant 3-way interaction effect (p=0.0435) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on nromLFE.

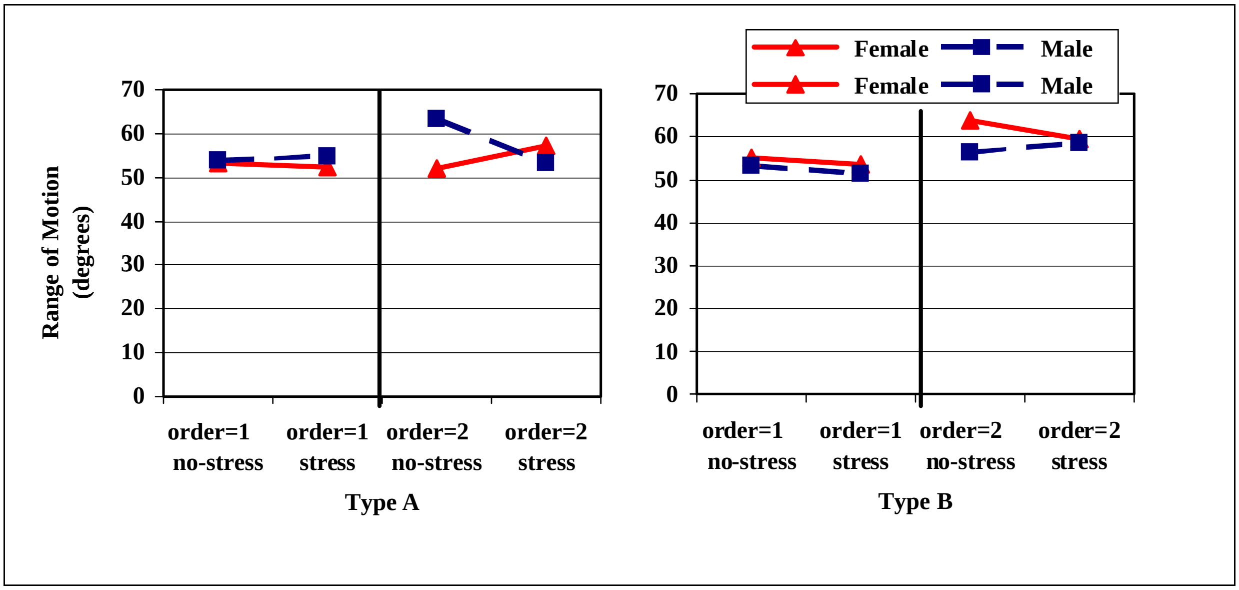


Figure 13-26. Significant 4-way interaction effect (p=0.0233) of personality type (TYPE), gender (GENDER), stress condition order (ORDER), and stress (STRESS) on romRFE.

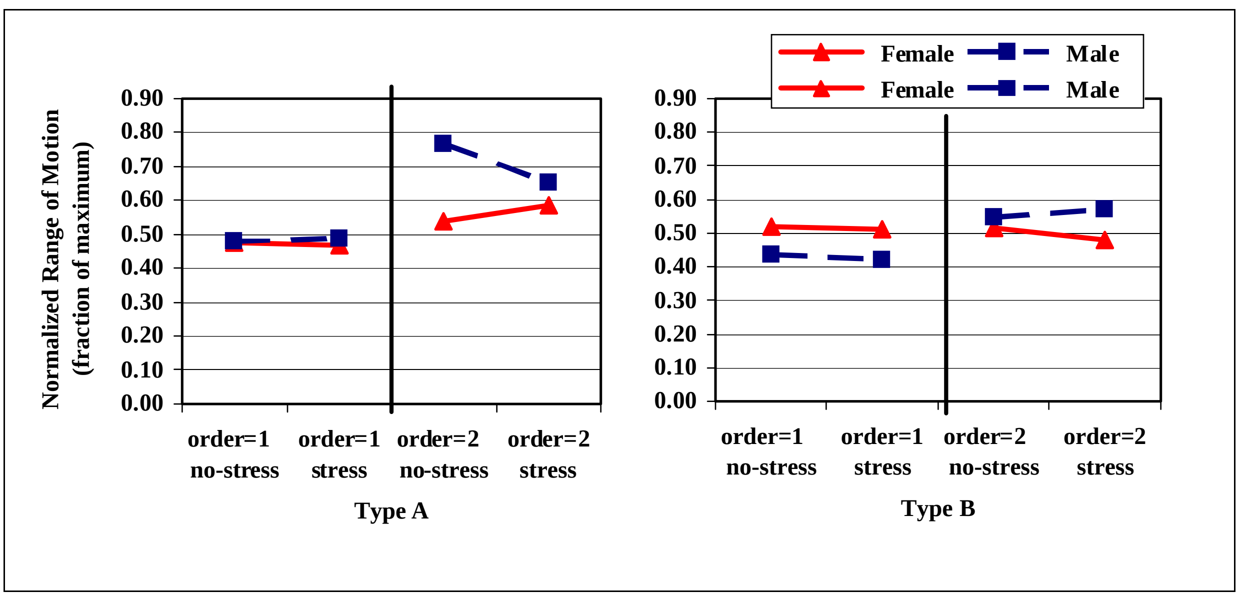


Figure 13-27. Significant 4-way interaction effect (p=0.0239) of personality type (TYPE), gender (GENDER), stress condition order (ORDER), and stress (STRESS) on nromRFE.

13.5.4 Specific Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety

13.5.4.1 Self-reported Musculoskeletal Discomfort

13.5.4.1.1 Between-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. The ANOVA analysis revealed no significant 3-way interaction effects for the between-subjects variables.

13.5.4.1.2 Within-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. The ANOVA analysis revealed a significant 3-way interaction effect of TYPE x ORDER x STRESS ($F\{1,16\} = 5.92$, $p=0.0271$). The mean scores for each TYPE x ORDER x STRESS combination can be seen in Figure 13-28. The ANOVA analysis also revealed a significant 3-way interaction effect of GENDER x ORDER x STRESS ($F\{1,16\} = 8.88$, $p=0.0088$). The mean scores for each GENDER x ORDER x STRESS combination can be seen in Figure 13-29.

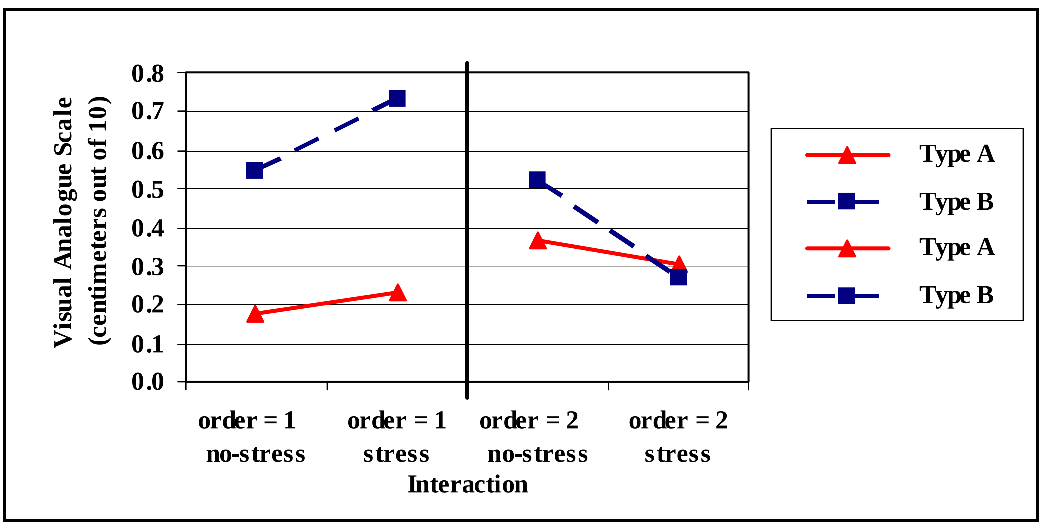


Figure 13-28. Significant 3-way interaction effect (p=0.0271) of personality type (TYPE), stress condition order (ORDER), and stress (STRESS) on MDSavg discomfort scores for post-task administrations only (48 observations).

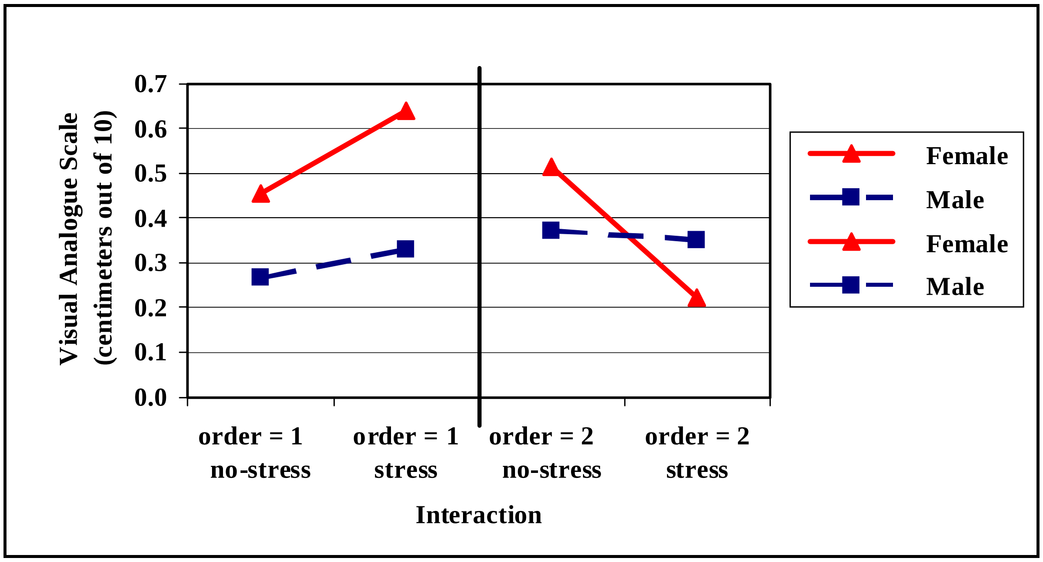


Figure 13-29. Significant 3-way interaction effect (p=0.0088) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on MDSavg discomfort scores for post-task administrations only (48 observations).

13.5.4.2 Self-reported State Anxiety

13.5.4.2.1 Between-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. The ANOVA analysis revealed a significant 3-way interaction effect of TYPE x GENDER x ORDER ($F\{1,16\} = 7.98$, $p=0.0122$). The mean scores for each TYPE x GENDER x ORDER combination can be seen in Figure 13-30.

13.5.4.2.2 Within-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. The ANOVA analysis revealed a significant 3-way interaction effect of GENDER x ORDER x STRESS ($F\{1,16\} = 5.90$, $p=0.0273$). The mean scores for each GENDER x ORDER x STRESS combination can be seen in Figure 13-31.

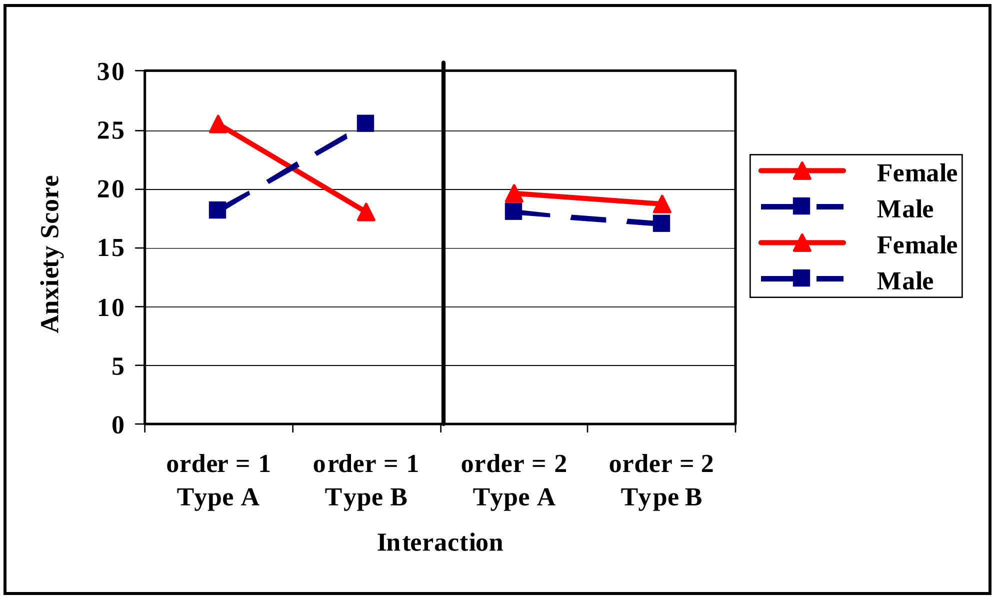


Figure 13-30. Significant 3-way interaction effect (p=0.0122) of personality type (TYPE), gender (GENDER), and stress condition order (ORDER) on state anxiety scores for post-task administrations only (48 observations).

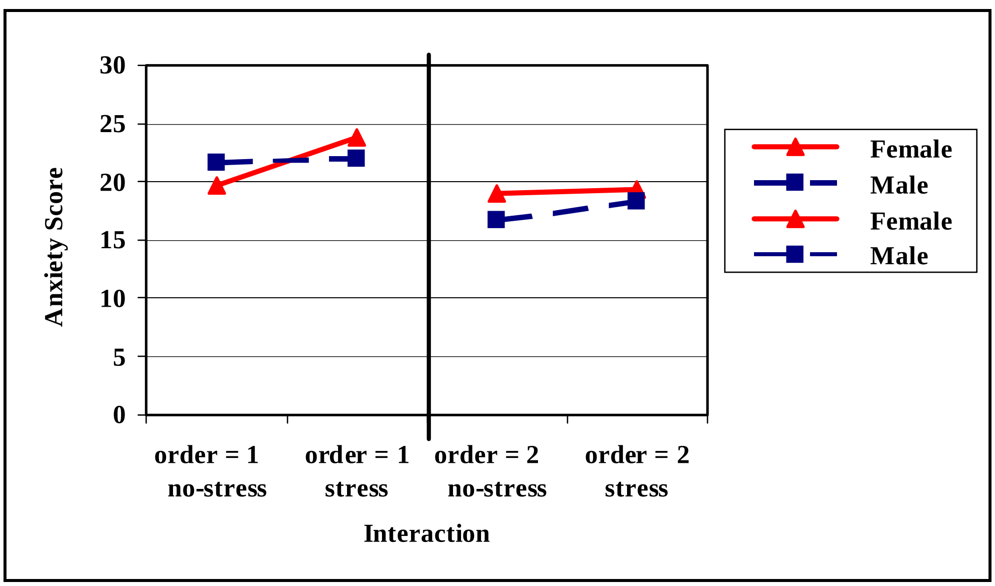


Figure 13-31. Significant 3-way interaction effect (p=0.0273) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on state anxiety scores (ANXtot) for post-task administrations only (48 observations).

13.6 PART NUMBER LIST FOR COMPUTER TASK

The list of part numbers was displayed on a single sheet of 8.5 x 11 inch paper that contained no other markings. The part numbers were displayed in bold 18 point Courier New font. The item numbers were displayed in regular 16 point Courier new font. The list of part numbers is provided here.

1	**AL39NV10EM**
2	**QF28BN47IW**
3	**RC02PW85US**
4	**WP98KJ32DF**
5	**MU10CE92RI**
6	**GA67LH85PQ**
7	**OD93ME18WP**
8	**IS94VB06YU**
9	**FJ86UC74SL**
10	**HG15KO70TA**
11	**AL39NV10EM**
12	**QF28BN47IW**
13	**RC02PW85US**
14	**WP98KJ32DF**
15	**MU10CE92RI**
16	**GA67LH85PQ**
17	**OD93ME18WP**
18	**IS94VB06YU**
19	**FJ86UC74SL**
20	**HG15KO70TA**
21	**AL39NV10EM**
22	**QF28BN47IW**
23	**RC02PW85US**
24	**WP98KJ32DF**
25	**MU10CE92RI**
26	**GA67LH85PQ**
27	**OD93ME18WP**
28	**IS94VB06YU**
29	**FJ86UC74SL**
30	**HG15KO70TA**

13.7 MATLAB CODE FOR PROCESSING EMG SIGNAL

```
%       "EMGTrialsProcess.M"
%           function
%
%   created by Naomi Glasscock
%           28 Feb 03
%   date of this revision - 04 May 2003
%
% created directly from "EMGCheckHRPlotREV6.M" (revision 6 of original
processing code)
% for Dissertation EMG Study.
%
% !!! CAUTION !!! This file must be run first for resting file
G??STAND.CVT prior to running % for task trials
%
% Use to call routine to filter the EMG signal to remove environment
% noise and motion artifacts
%
% Use to smooth data, extra smooth data, remove heart rate (HR), compute
means,
% and output data with & without HR removed
%
% Use to plot trapezius, rhomboid, & paraspinalis data for any or all
subjects
% to inspect for heart rate and smoothing if plotting turned on (by
setting
% "plot" variables).
%
% Use to call routine to generate reduced EMG data by removing unwanted
timeframes
% from the data (e.g., when assay plates were being switched, after part
number list
% was completed, etc.)
%

function[HRmax, newHRmax] = EMGTrialsProcess(stress,dataFILE,filetype,
subnum, sumFID, rtnFID, meanFID, theHRmax);

%%% stress = integer indicating stress condition (0 = no stress, 1 =
stress)
%%% dataFILE = file name of file to be processed
%%% subnum = integer representing subject number
%%% sumFID = file ID for outputting data (fraction differences between
removing heart rate and not removing heart rate)
%%% rtnFID = file ID for outputting data (means and standard deviations
with/without heart rate removed after
%%%      reducing the EMG data by taking out unwanted timeframes from the
signal
```

```
%%% meanFID = file ID for outputting data (means with/without heart rate
removed of the non-reduced EMG data
%%% theHRmax = computed amplitude of the heart rate signal obtained from
the heart rate trigger channel (HRtrig)
%%%      from the resting file


close all

dataFILE  %prints current data file name to screen

%%% Set "PLOT" variables
plot1ON = 1; %set = 0 to turn off plotting of orig, smooth, & extrasmooth
data plotting, set = 1 to plot
plot2ON = 1; %set = 0 to turn off plotting of smooth, smooth with HR
removed, and extrasmooth data, set = 1 to plot
plotINSPECT = 1; %set = 0 to turn off HR algorithm inspection plotting for
computing efficiency, set = 1 to plot


%%% These lines can be uncommented and made executable as required (e.g.,
to run the code as a stand alone code
%%% after commenting out the "function" line)
%subnum = 75  %can uncomment this to run this function as stand alone
%subID = 'G75'  %can uncomment this to run this function as stand alone
%dataFILE = strcat(subID,'STAND.CVT') % can uncomment this to run function
as stand alone
%filetype = 999 % if max/resting file that was collected with
"naomi5s.asu" over +-10volts
%filetype = 111 % if PIP file that was collected with "naomi10m.asu" over
+-5volts
%filetype = 222 % if COM file that was collected with "naomi5m.asu" over
+-5volts


%%% Load the data file into an array
array = load(dataFILE);


%%% These indicate which channels are which muscles.  Here channel
actually indicates the column of data.
%%% The EMG channel as collected was "channel used here minus 2"
%channel/column 1   is time
%channel/column 2   is cycle
%channel/column 3   is EMG chan 1 Lflex
%channel/column 4   is EMG chan 2 Rflex
%channel/column 5   is EMG chan 3 Lext
%channel/column 6   is EMG chan 4 Rext
%channel/column 7   is EMG chan 5 Ltrap
%channel/column 8   is EMG chan 6 Rtrap
%channel/column 9   is EMG chan 7 Lrhom
%channel/column 10  is EMG chan 8 Rrhom
```

```
%channel/column 11  is EMG chan 9 Lpara
%channel/column 12  is EMG chan 10 Rpara
%channel/column 13  is EMG chan 11 trigger


%%% Center the data around zero if required for filtering
%%% This is not needed if it is done in EMGFilter subroutine, but it must
be done before filtering
%array = array - 2048; % subtract off mean bits from 0 to 4096 range

 %%% FILTER the data by calling the filtering routine
freq = 1024;
filtdata(:,1:2)=array(:,1:2);
filtdata(:,13)=array(:,13);
for channel=3:12,
   data = array(:,channel);
   fchanl = 1;
   [f,absX,filtarray]=EMGFilter(data,freq,fchanl);
   filtdata(:,channel) = filtarray(:,1);
end;


%%% CONVERT the data from bits to volts
if filetype == 901,
   filtdata = 20/4096 * filtdata;  % convert to volts, resting files were
collected from +- 10 volts
end
if filetype == 999,
   filtdata = 20/4096 * filtdata;  % convert to volts, maxes were
collected from +- 10 volts
end
if filetype == 111,
   filtdata = 10/4096 * filtdata;  % convert to volts, trials were
collected from +- 5 volts
end
if filetype == 222,
   filtdata = 10/4096 * filtdata;  % convert to volts, trials were
collected from +- 5 volts
end

%%% Replace columns 1 (time) and 2 (cycle) in filtered array with original
data, not data converted to volts
filtdata(:,1:2)=array(:,1:2);


%%% CHECK results of filtering by printing and plotting - This can be
commented out.
%%%
%
%size(filtdata), pause;
%filtdata(1:10,:), pause;
```

```
%plot(filtdata(1:10,9)), title('FIRST 10 data points of filtered data for
channel 9'),
%  xlabel('Data points 1 thru 10'), ylabel('EMG in volts'),  pause;
%filtdata(5111:5120,:), pause;
%plot(filtdata(5111:5120,9)), title('LAST 10 data points of filtered data
for channel 9'),
%  xlabel('Data points 5111 thru 5120'), ylabel('EMG in volts'),  pause;
%
%%%
%%% END plotting and printing section for checking filtering


%%% Clear the original data array and repopulate with the filtered data
clear array;
array = filtdata;



%%% SMOOTH the data over a specified number of points.  Creates delayed
smoothing.
%
smqty = 3; % number of points to smooth over.  Can be even or odd.
[M,N] = size(array);
smarray(:,1) = array(:,1);  %sets time column
smarray(:,2) = array(:,2);  %sets cycle column
smarray(1,3:N) = array(1,3:N);
smarray(2,3:N) = mean(array(1:2,3:N));
smarray(3,3:N) = mean(array(1:3,3:N));
smarray(4,3:N) = mean(array(1:4,3:N));
for row = smqty:M,
   firstrow = row-smqty+1;
   temparray = array(firstrow:row,3:N);
   size(temparray);
   smarray(row,3:N) = mean(temparray);
end


%%% EXTRA-SMOOTH the data over a specified number of points.  This
smoothing is not "delayed."
%
xsmqty = 31; % number of points to smooth over !!! MUST BE ODD !!! for
this algorithm
[M,N] = size(array);
xsmarray(:,1) = array(:,1);  %sets time column
xsmarray(:,2) = array(:,2);  %sets cycle column

%%% OLD algorithm no longer used and commented out.  Remains for
reference.
%%% THIS is the OLD algorithm that computed the mean of the PREVIOUS
"xsmqty" points
%%% and therefore was "delayed" compared to the original data
%
```

```
%for row = 1:xsmqty,
%   temparray = array(1:row,3:N);
%   xsmarray(row,3:N) = mean(temparray);
%   %xsmarray(row,3:N) = mean(array(1:row,3:N))
%end
%clear temparray;
%
%for row = xsmqty:M,
%   firstrow = row-xsmqty+1;
%   temparray = array(firstrow:row,3:N);
%   size(temparray);
%   xsmarray(row,3:N) = mean(temparray);
%end
%%%
%%% End OLD algorithm


%%% NEW algorithm now used.
%%% THIS is the NEW algorithm that computes the mean of the PREVIOUS
(xsmqty-1)/2 points
%%% and the FOLLOWING (xsmqty-1)/2 points.  This has no "delay" compared
to the original data
%
break1 = (xsmqty-1)/2;
break2 = M - break1;
for row = 1:2,
   firstrow = 1;
   lastrow = 5;
   temparray = array(firstrow:lastrow,3:N);
   % CAUTION - The dimension is required (e.g., col or row) in the mean
routine
   % otherwise it takes one mean of the whole array and uses it for every
column
   xsmarray(row,3:N) = mean(temparray,1);
end
for row = 3:break1,
   firstrow = 1;
   lastrow = (2*row)-1;
   %array(1,:), pause;
   temparray = array(firstrow:lastrow,3:N);
   %size(temparray), temparray(1,:), pause;
   % CAUTION - The dimension is required (e.g., col or row) in the mean
routine
   % otherwise it takes one mean of the whole array and uses it for every
column
   xsmarray(row,3:N) = mean(temparray,1);
   %size(xsmarray), xsmarray(1,:), pause;
end
clear temparray;
for row = break1+1:break2,
   firstrow = row-break1;
   lastrow = row+break1;
```

```
   temparray = array(firstrow:lastrow,3:N);
   % CAUTION - The dimension is required (e.g., col or row) in the mean
routine
   xsmarray(row,3:N) = mean(temparray,1);
end
clear temparray;
for row = break2+1:M-2,
   firstrow = row-(M-row);
   lastrow = M;
   temparray = array(firstrow:lastrow,3:N);
   % CAUTION - The dimension is required (e.g., col or row) in the mean
routine
   xsmarray(row,3:N) = mean(temparray,1);
end
for row = M-1:M,
   firstrow = M-4;
   lastrow = M;
   temparray = array(firstrow:lastrow,3:N);
   % CAUTION - The dimension is required (e.g., col or row) in the mean
routine
   xsmarray(row,3:N) = mean(temparray,1);
end
clear temparray;
%%%
%%% End NEW algorithm for extra-smoothing



%%% RECTIFY and PLOT the data
rectify = 1;
if rectify == 1,
   rarray = abs(array);
   rsmarray = abs(smarray);
   rxsmarray = abs(xsmarray);
   clear array
   clear smarray
   clear xsmarray
   %
   %
   %
   %%% PLOT the processed data if "plot" variable was turned on at
beginning of code
   if plot1ON == 1,
      for chan = 7:12,  %plots Ltrap, Rtrap, Lrhom, Rrhom, Lpara, Rpara
      %for chan = 9:9,  %plots only Lrhom
      %for chan = 11:11,  %plots only Lpara
         schan = int2str(chan);
         titlstring1 = strcat(' COL# ',schan);
         titlstring2 = strcat(dataFILE,titlstring1);
         titlstring = strcat(titlstring2, ' - RECTIFIED & Unsmoothed
(red), Smoothed (cyan), Xtra (magenta)');
         figure(7), plot(rarray(:,chan),'r-'), title(titlstring),
```

```
        xlabel('Data point'), ylabel('EMG in volts');  pause;
        hold
        figure(7), plot(rsmarray(:,chan),'c-'), pause;
        figure(7), plot(rxsmarray(:,chan),'m-'), pause;
        close
      end
   end
end


%%% Establish the heart rate trigger channel which will be used to detect
presence of heart rate signal
%%%
HRtrigchan = 9;  % use LeftRhom channel to screen for HR
%HRtrigchan = 11;  % use LeftPara channel to screen for HR
%HRtrigchan = 12;  % use RightPara channel to screen for HR



%%% Begin DETECTION and REMOVAL algorithm
%%% DETECT heart rate in HR trigger channel and remove from six channels
%%%
%
HRchan = rxsmarray(:,HRtrigchan);  % HR algorithm uses the extra smoothed
data to "find" the HR
HRflag = 0;
HRct = 0;
HRmax = max(HRchan);
if filetype == 901,
   %inserted this because G63 & G75 had HR at first/last row which didn't
get smoothed enough, so HRmax too high
   theHRmax = max(HRchan(break1:break2,1));
   %theHRmax = HRmax;
end
cutoff = 0.50*theHRmax; %uses theHRmax from STAND.CVT resting file to
detect "beginning" (e.g., rise in signal) of HR
%cutoff = 0.55*HRmax; %uses HRmax of current file
cutoff2 = 0.4*theHRmax;  %uses theHRmax from STAND.CVT resting file to
detec "ending" (e.g., fall in signal) of HR
ptsSinceLast = 400;  %algorithm will only detect a minimum of 1 heart rate
beat in approximately 0.4 second span
replaceFLAG = 0;
newHRmax = theHRmax;

%%% Use some commands to print stuff to the screen to check/insure which
HRmax's and cutoff's are getting used by
%%% each file.  Comment out when no longer need.
%   break1
%   break2
%   HRmax
%   theHRmax
%   cutoff
```

```
%   cutoff2
%   newHRmax
%   pause;

%%% Algorithm will generate computed output on smoothed data, not extra-
smoothed data
%%% Set a newarray to the "smoothed" data
newarray = rsmarray;

for row = 1:M,
   signal = HRchan(row);
   ptsSinceLast = ptsSinceLast + 1;
   if HRflag == 0,
      if ptsSinceLast > 400,
         if signal > cutoff,
            HRflag = 1;
            HRct = HRct + 1;
            theROW = row;
            ptsSinceLast = 0;
            replaceFLAG = 1;
         end
      end
   end
   if HRflag == 1,
      if replaceFLAG == 1,
         untilEND = M - theROW;
         if theROW > 200,
            mean1ST = theROW - 200;
            mean1END = mean1ST + 100;
            if untilEND > 200,
               mean2ST = theROW + 100;
               mean2END = mean2ST + 100;
               replaceST = theROW - 100;
               replaceEND = theROW + 100;
            end
            if untilEND <= 200,
               mean2ST = mean1ST;
               mean2END = mean1END;
               replaceST = theROW - 100;
               replaceEND = theROW + 100;
               if replaceEND > M,
                  replaceEND = M;
               end
            end
         end
         if theROW <= 200,
            mean2ST = theROW + 100;
            mean2END = mean2ST + 100;
            mean1ST = mean2ST;
            mean1END = mean2END;
            replaceST = theROW - 100;
            replaceEND = theROW + 100;
```

```
            if replaceST <= 0,
               replaceST = 1;
            end
         end

         % CHECK means here.  make sure that the dimension (e.g., col or
row) doesn't need to be in
         % CONFIRMED !!
         mean1(1,:) = mean(newarray(mean1ST:mean1END,:));
         mean1(2,:) = mean(newarray(mean2ST:mean2END,:));

         replace(1,:) = mean(mean1);
         %replace(1,:) = mean(mean1,1), pause;  %this produces same result
as above

         for NEWrow = replaceST:replaceEND,
            newarray(NEWrow,:) = replace(1,:);
         end
         replaceFLAG = 0;
      end
      if signal < cutoff2,
         HRflag = 0;
      end
   end
end

finalarray(:,1:6) = rsmarray(:,1:6);
finalarray(:,7:12) = newarray(:,7:12);
finalarray(:,13) = rsmarray(:,13);
%size(rsmarray)
%size(newarray)
%size(finalarray)
%pause;
%
%%%
%%% End DETECTION and REMOVAL algorithm



%%% PLOT results if "plotting" variables were turned on at beginning of
code
if plot2ON == 1,
   tchan = int2str(HRtrigchan);
   titlstring31 = strcat(' HRtrigCOL# ',tchan);
   titlstring32 = strcat(dataFILE,titlstring31);
   titlstring30 = strcat(titlstring32, ' orig (red), HRremoved (cyan),
xsmooth (magenta)');
   figure(10), hold, plot(rsmarray(:,HRtrigchan),'r-'),
title(titlstring30),
   xlabel('Data point'), ylabel('EMG in volts');  %pause;
   figure(10), plot(newarray(:,HRtrigchan),'c-'), pause;
   figure(10), plot(rxsmarray(:,HRtrigchan),'m-'), pause;
```

```
end


%%% Begin RANDOM DISPLAY & INSPECTION routine
%%% GENERATE random display intervals and INSPECT results of HR removal
algorithm for each channel
%%% This generates several 5-second intervals to display plots of (1)
smoothed, (2) extra-smoothed,
%%% and (3) smoothed with HR removed.
howlong = length(newarray);
duration = 5120; % show 5 seconds to see if HR algorithm is working
j = 0; % initialize the frame number for the captured movie

if plotINSPECT == 1,
   for chan = 7:12,
      schan = int2str(chan);
      titlstring1 = strcat(' COL# ',schan);
      titlstring2 = strcat(dataFILE,titlstring1);
      titlstring = strcat(titlstring2, ' - orig smoothed (red), HRremoved
(cyan), Xsmooth (magenta)');

      numloops = 1;
      if filetype == 111, numloops = 5; end;
      if filetype == 222, numloops = 5; end;

      for loop = 1:numloops,
         RN = round(howlong*rand(1));
         %pause;
         RNst = RN - duration/2 + 1;
         RNend = RN + duration/2;
         if RNst <= 0,
            RNst = 1;
            RNend = duration;
         end
         if RNend > howlong,
            RNend = howlong;
            RNst = howlong - duration + 1;
         end
         strngRNst = int2str(RNst);
         strngRNend = int2str(RNend);
         strngloop = int2str(loop);
         strng0 = strcat('Data point for loop = ',strngloop);
         strng1 = strcat(strng0,' from rows  ');
         strng2 = strcat(strng1,strngRNst);
         strng3 = strcat(strng2,' to ');
         strng4 = strcat(strng3,strngRNend);
         figure(11), hold, plot(rsmarray(RNst:RNend,chan),'r-'),
title(titlstring),
         xlabel(strng4), ylabel('EMG in volts');  pause;
         figure(11), plot(newarray(RNst:RNend,chan),'c-'), pause;
         figure(11), plot(rxsmarray(RNst:RNend,chan),'m-'), pause;
         % Capture figure as movie frame
```

```
         % this works, but it still doesn't get the whole Figure frame
with title
         %j=j+1;
         %MM(j) = getframe(gcf);
         close
      end
   end
end
%%%
%%% End RANDOM DISPLAY & INSPECTION routine


%MOVIE(M,N,FPS) plays the movie M, N times, at FPS frames per second.
default N=1 FPS=12
%movie(MM,1,1);
%pause;
% It doesn't recognize this function, so it must not be in this version of
Matlab
%movieFILE = 'HRinspect.avi';
%movie2avi(MM,movieFILE,'fps',1);


%%% Calculate an "effective heart rate" for this file
HRct
%pause;
timeSECS = M/1024;
timeMINS = timeSECS/60;
effHR = HRct/timeMINS;


%%% Calculate means of arrays with/without heart rate removed
wHRunrem = mean(rsmarray);  %with HR unremoved
wHRrem = mean(finalarray)   %with HR removed
%%% Calculate differences between data with heart rate removed and
unremoved
dif = wHRrem - wHRunrem;
percdif = dif ./ wHRunrem;
%pause;


%%% Print output of differences between HR removed and unremoved to sumFID
fprintf(sumFID,'%3i %5i %3i %12s  %3i %12.5f %12.5f  %5i
%8.1f',subnum,filetype,stress,dataFILE,HRtrigchan,HRmax,theHRmax,HRct,effH
R);
for col = 7:12,
   fprintf(sumFID,'%12.5f  ',percdif(1,col));
end
fprintf(sumFID,'\n');


%%% Print output of means for "HR removed" to meanFID
desc = ('HRremv');
```

```
fprintf(meanFID,'%3i %5i %3i %12s  %8s
%3i',subnum,filetype,stress,dataFILE,desc,HRtrigchan);
for col = 3:12,
   fprintf(meanFID,'%12.5f  ',wHRrem(1,col));
end
fprintf(meanFID,'\n');
%%% Print output of means for "HR unremoved" to meanFID
desc = ('withHR');
fprintf(meanFID,'%3i %5i %3i %12s  %8s
%3i',subnum,filetype,stress,dataFILE,desc,HRtrigchan);
for col = 3:12,
   fprintf(meanFID,'%12.5f  ',wHRunrem(1,col));
end
fprintf(meanFID,'\n');



%%% Call routine to generate reduced EMG data by removing time frames from
signal (e.g.,
%%% where assay plates were being switched, after completion of part
number list, etc.)
%%% For finalarray data - with "HR removed"
[RTNarray1] = EMGReduce(finalarray, dataFILE,filetype, subnum);
RwHRout = mean(RTNarray1)
stdRwHRout = std(RTNarray1)
%pause;

%%% Print output of means of reduced EMG data for "HR removed" to rtnFID
desc = ('RwHRout');
fprintf(rtnFID,'%3i %5i %3i %15s  %14s
%3i',subnum,filetype,stress,dataFILE,desc,HRtrigchan);
for col = 3:12,
   fprintf(rtnFID,'%12.5f  ',RwHRout(1,col));
end
fprintf(rtnFID,'\n');
%%% Print output of standard deviations of reduced EMG data for "HR
removed" to rtnFID
desc = ('stdRwHRout');
fprintf(rtnFID,'%3i %5i %3i %15s  %14s
%3i',subnum,filetype,stress,dataFILE,desc,HRtrigchan);
for col = 3:12,
   fprintf(rtnFID,'%12.5f  ',stdRwHRout(1,col));
end
fprintf(rtnFID,'\n');


%%% Call routine to generate reduced EMG data by removing time frames from
signal (e.g.,
%%% where assay plates were being switched, after completion of part
number list, etc.)
%%% For rsmarray data - with "HR unremoved"
[RTNarray2] = EMGReduce(rsmarray, dataFILE,filetype, subnum);
```

```
RwHRin = mean(RTNarray2)
stdRwHRin = std(RTNarray2)
%pause;

%%% Print output of means of reduced EMG data for "HR unremoved" to rtnFID
desc = ('RwHRin');
fprintf(rtnFID,'%3i %5i %3i %15s  %14s
%3i',subnum,filetype,stress,dataFILE,desc,HRtrigchan);
for col = 3:12,
   fprintf(rtnFID,'%12.5f  ',RwHRin(1,col));
end
fprintf(rtnFID,'\n');
%%% Print output of standard deviations of reduced EMG data for "HR
unremoved" to rtnFID
desc = ('stdRwHRin');
fprintf(rtnFID,'%3i %5i %3i %15s  %14s
%3i',subnum,filetype,stress,dataFILE,desc,HRtrigchan);
for col = 3:12,
   fprintf(rtnFID,'%12.5f  ',stdRwHRin(1,col));
end
fprintf(rtnFID,'\n');


%%% Clear arrays from memory
clear RTNarray1 RTNarray2;
clear rarray rsmarray rxsmarray newarray finalarray temparray;
clear wHRunrem wHRrem dif percdif;
clear HRchan;
clear mean1 replace;

%%% REMINDER of channel/column numbers
%%% These indicate which channels are which muscles.  Here channel
actually indicates the column of data.
%%% The EMG channel as collected was "channel used here minus 2"
%channel/column 1   is time
%channel/column 2   is cycle
%channel/column 3   is EMG chan 1 Lflex
%channel/column 4   is EMG chan 2 Rflex
%channel/column 5   is EMG chan 3 Lext
%channel/column 6   is EMG chan 4 Rext
%channel/column 7   is EMG chan 5 Ltrap
%channel/column 8   is EMG chan 6 Rtrap
%channel/column 9   is EMG chan 7 Lrhom
%channel/column 10  is EMG chan 8 Rrhom
%channel/column 11  is EMG chan 9 Lpara
%channel/column 12  is EMG chan 10 Rpara
%channel/column 13  is EMG chan 11 trigger
```

13.8 HIGHER ORDER INTERACTIONS FROM PHASE III LABOROATORY STUDY

13.8.1 Physical Traits – Anthropometry

13.8.1.1 Between-subjects Effects for Pipetting Task

Eighteen (18) anthropometry variables were analyzed using a between-subjects ANOVA with Model #2 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER (stress condition order for pipetting task). The analysis revealed no significant 3-way interactive effects.

13.8.1.2 Between-subjects Effects for Computer Task

The same eighteen (18) anthropometry variables were analyzed using a between-subjects ANOVA as previously described to determine the effects of TYPE, GENDER, and ORDER, where ORDER represented the stress condition order for computer task. The analysis revealed no significant 3-way interactive effects.

13.8.2 Workstyle – Performance

13.8.2.1 Between-subjects Effects

Task performance times (avgPIPtpc and avgCOMtpp) were analyzed using separate mixed ANOVA analyses with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and stress condition ORDER. The analyses revealed no significant 3-way interaction effects for avgPIPtpc or avgCOMtpp.

13.8.2.2 Within-subjects Effects

Task performance times (avgPIPtpc and avgCOMtpp) were analyzed using separate mixed ANOVA analyses with Model #1 as previously described to determine the main and interactive effects of STRESS. The analyses revealed significant 3-way interaction effects for avgPIPtpc or avgCOMtpp.

13.8.3 Physiological Response – Muscle Tension/Activity during Pipetting

13.8.3.1 Between-subjects Effects

The pipetting task NIEMG variables (10 variables) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and stress condition ORDER. The analysis resulted in a significant 3-way interaction effect of TYPE x GENDER x ORDER for nFLEX ($F\{1,17\} = 4.84$, $p=0.0419$) and nTRAP ($F\{1,17\} = 4.61$, $p=0.0466$). Mean values for each TYPE x ORDER x STRESS combination for nFLEX and nTRAP are shown in Figure 13-32 and Figure 13-33, respectively.

13.8.3.2 Within-subjects Effects

The pipetting task NIEMG variables (10 variables) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. The analysis resulted in a significant 3-way interaction effect of GENDER x ORDER x STRESS for dFLEX ($F\{1,17\} = 14.18$, $p=0.0015$) and nTRAP ($F\{1,17\} = 6.36$, $p=0.0220$). The mean dFLEX and nTRAP values are shown for each GENDER x ORDER x STRESS combination in Figure 13-34 and Figure 13-35, respectively.

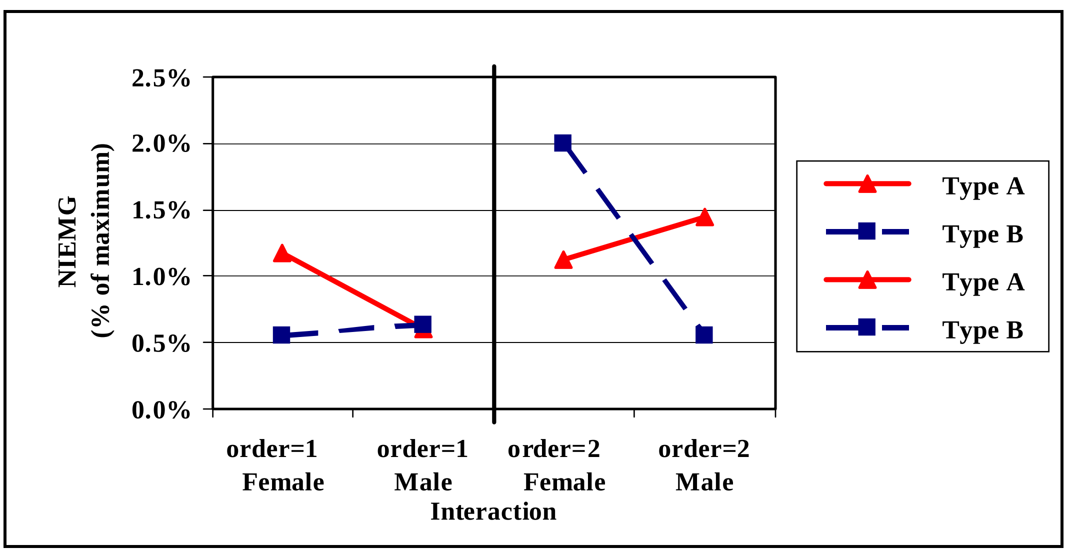


Figure 13-32. Significant 3-way interaction effect (p=0.0419) of personality type (TYPE), gender (GENDER), and stress condition order (ORDER) on pipetting task nFLEX NIEMG mean values.

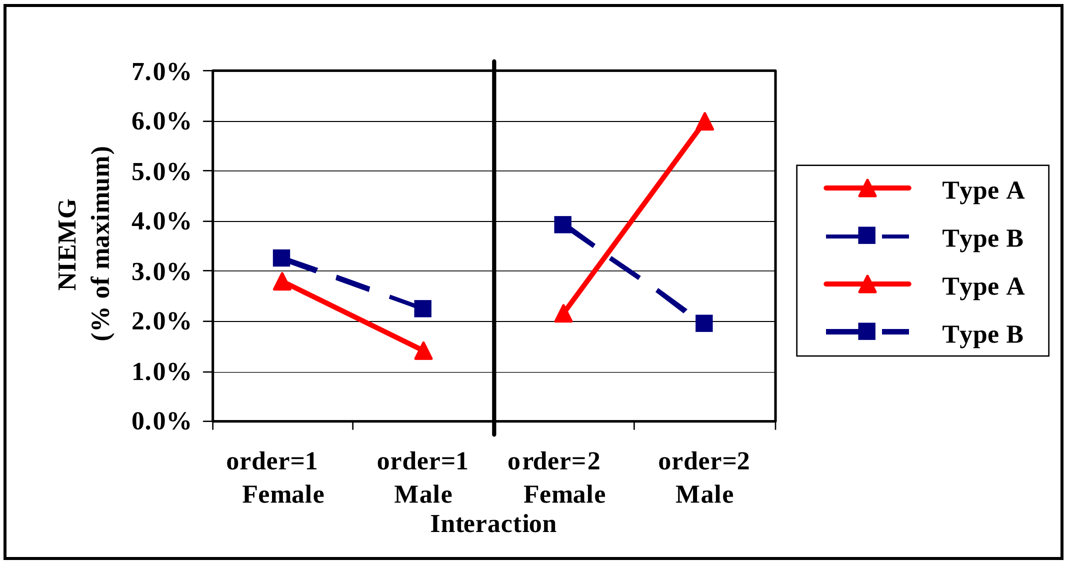


Figure 13-33. Significant 3-way interaction effect (p=0.0466) of personality type (TYPE), gender (GENDER), and stress condition order (ORDER) on pipetting task nTRAP NIEMG mean values.

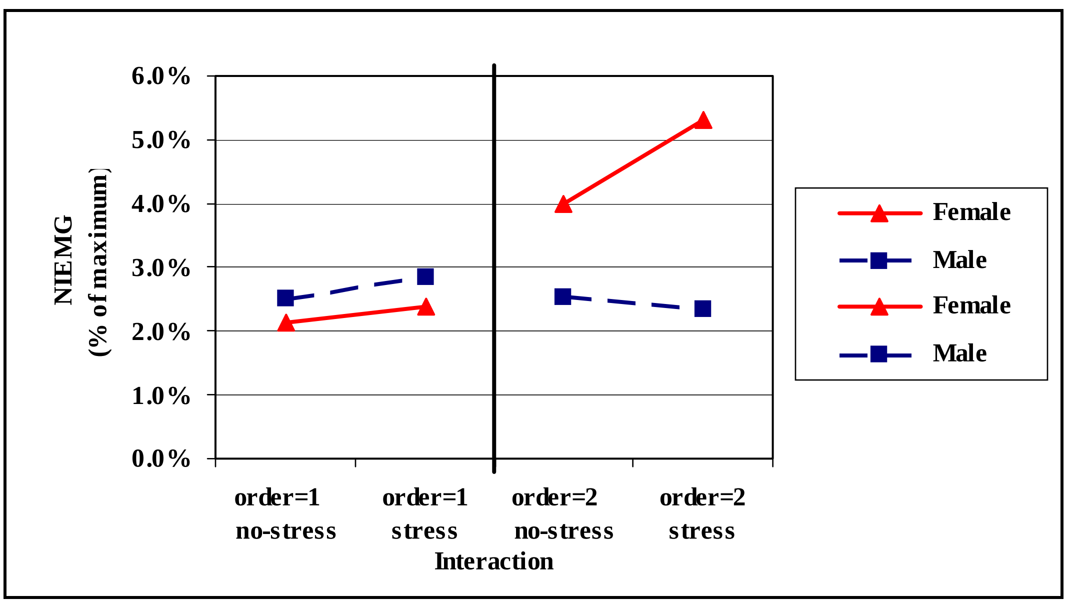


Figure 13-34. Significant 3-way interaction effect (p=0.0015) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on pipetting task dFLEX NIEMG mean values.

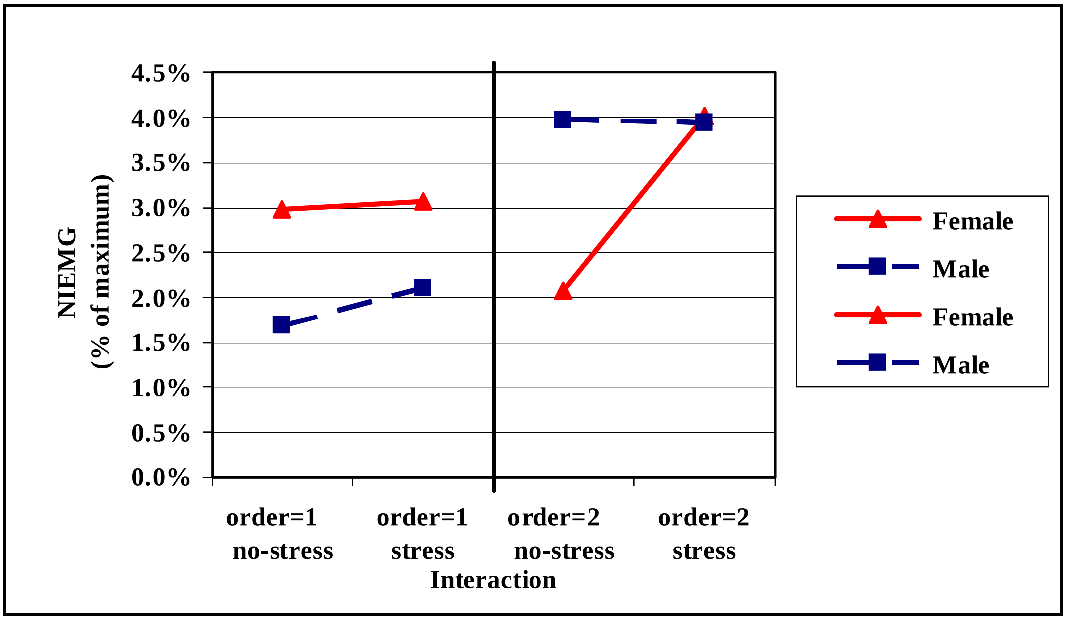


Figure 13-35. Significant 3-way interaction effect (p=0.0220) of gender (GENDER), stress condition order (ORDER), and stress (STRESS) on pipetting task nTRAP NIEMG mean values.

13.8.4 Physiological Response – Muscle Tension/Activity during Computer Entry

13.8.4.1 Between-subjects Effects

The computer task NIEMG variables (10 variables) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and stress condition ORDER. The analysis revealed no significant 3-way interaction effects for the between-subjects variables.

13.8.4.2 Within-subjects Effects

The computer task NIEMG variables (10 variables) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. The analysis resulted in a significant 3-way interaction effect of TYPE x ORDER x STRESS for dRHOM ($F\{1,17\} = 11.49$, $p=0.0035$). Mean values for each TYPE x ORDER x STRESS combination are shown in Figure 13-36.

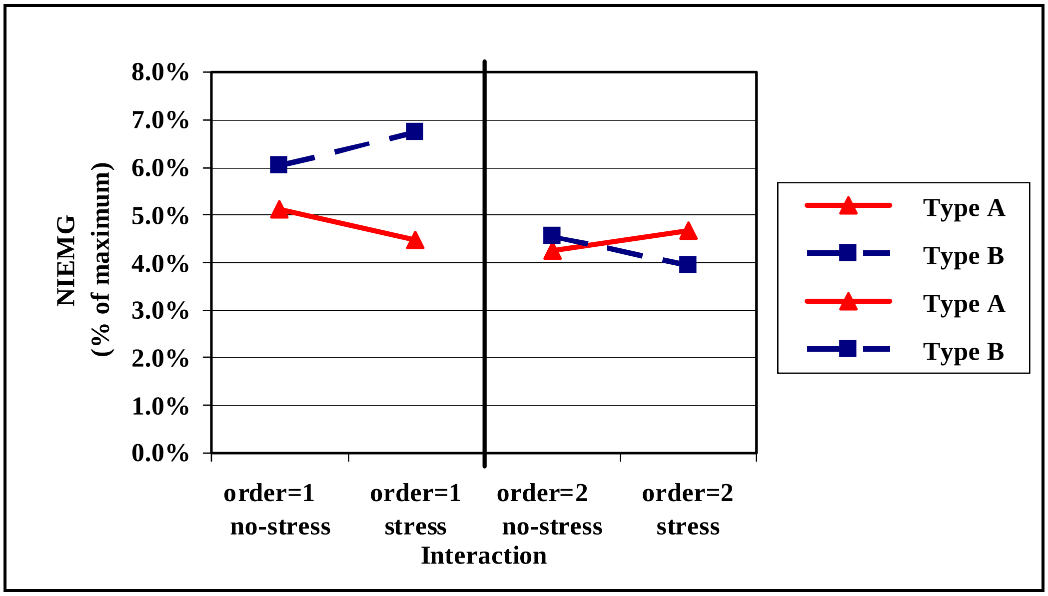


Figure 13-36. Significant 3-way interaction effect (p=0.0035) of personality type (TYPE), stress condition order (ORDER), and stress (STRESS) on computer task dRHOM NIEMG mean values.

13.8.5 Specific Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety – Following Pipetting Task Conditions

13.8.5.1 Self-reported Musculoskeletal Discomfort and Anxiety

13.8.5.1.1 Between-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) and anxiety scores (ANXtot) were analyzed using mixed ANOVA's with Model #1 previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. This analysis revealed no significant 3-way interaction effects for the between-subjects variables.

13.8.5.1.2 Within-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) and anxiety scores (ANXtot) were analyzed using mixed ANOVA's with Model #1 as previously described to determine the main and interactive effects of STRESS. This analysis revealed no significant 3-way interaction effects of STRESS.

13.8.6 Specific Reporting Behaviors for Self-reported Musculoskeletal Discomfort and Anxiety – Following Computer Task Conditions

13.8.6.1 Self-reported Musculoskeletal Discomfort

13.8.6.1.1 Between-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. This analysis revealed no significant 3-way interaction effects for the between-subjects variables.

13.8.6.1.2 Within-subjects Effects

Musculoskeletal discomfort scores (MDSavg, MDSupx, and MDSbak) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. This analysis revealed no significant 3-way interaction effects of STRESS.

13.8.6.2 Self-reported State Anxiety

13.8.6.2.1 Between-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of TYPE, GENDER, and ORDER. This analysis revealed no significant 3-way interaction effects of the between-subjects variables.

13.8.6.2.2 Within-subjects Effects

Anxiety scores (ANXtot) were analyzed using a mixed ANOVA with Model #1 as previously described to determine the main and interactive effects of STRESS. This analysis revealed a significant ($F\{1,17\} = 13.16$, $p=0.0021$) 4-way interaction effect of TYPE x GENDER x ORDER x STRESS.

13.9 VERIFICATION OF ANALYSIS OF VARIANCE (ANOVA) ASSUMPTIONS

13.9.1 Descriptions of Evaluations

The assumptions require that the model residuals be normally and independently distributed with a mean of zero and a constant variance. Selected data were tested for compliance with assumptions underlying the Analysis of Variance (ANOVA) procedures using both graphical and quantitative evaluations. Each of these evaluations is described in Table 13-1 and Table 13-2.

Table 13-1. Quantitative evaluations for checking data compliance with ANOVA assumptions.

Plot or Statistic	Evaluation	Possible Findings	Related Assumptions	Consequences of Violation
COMPUTE Shapiro-Wilk statistic for testing normality of residuals (generated from SAS PROC UNIVARIATE)	Inspect associated p-value that represents the chance that the data are obtained from a normal population. If the value is less than 0.001, then generally reject the null hypothesis of normality	(1) nonsignificant p-value reflecting normality (2) significant p-value reflecting possible nonnormality	**normality** of residuals	moderate departure (especially with small sample sizes) not usually serious
PERFORM Bartlett's test for homogeneity of variance of data (generated from SAS HOVTEST in one-way ANOVA)	If associated p-value is less than 0.001, then may indicate nonhomogeneiety of variance (but very sensitive to normality of data).	(1) nonsignificant p-value reflecting homogeneity of variance (2) significant p-value reflecting possible nonhomogeneity of variance.	**homogeneity of variance** across treatments	moderate departure (especially with small sample sizes) not usually serious
compiled from information obtained from Montgomery (2000) and Hatcher & Stepanski (1994).				

Table 13-2. Graphical techniques for checking data compliance with ANOVA assumptions.

Plot or Statistic	Evaluation	Possible Findings	Related Assumptions	Consequences of Violation
PLOT Residuals vs. Predicted Values	Inspect plot to see that the residuals are structureless and show no relationship(s) with the magnitude of the predicted values.	(1) megaphone – indicating that the measurement error decreases/increases with the magnitude of the measurement. (2) nonnormal, skewed data where variance may be a function of mean	(1) **homogeneity of variance** of residuals (2) residuals centered around zero (mean ~ 0)	F-test is only slightly affected with equal sample sizes and fixed effects, so significance levels and power may be slightly different than reported.
PLOT Residuals vs. TIME (time-ordered subject number) (by TYPE) (by GENDER) (by ORDER) (by STRESS)	Inspect plot to see that no obvious trend or shape emerges that would indicate correlation(s) between residuals overall and/or for specific levels of independent variables.	(1) megaphone – indicating possible improvement or degradation of procedures or experimenter skills) (2) shift – indicating a shift in the equipment or procedures	**independently** distributed residuals	Consequences can serious and may be difficult or impossible to correct after data is collected. Problems should be prevented (e.g., with good training, reliable equipment, and proper randomization).
PLOT Normal Probability Plot of Residuals	Inspect plot to see if data generates relatively straight line. Central values are more significant than tails. Inspect for outliers.	(1) rather straight line with no outliers (2) relatively straight line with outliers (3) non-straight line	**normality** of residuals	moderate departures are not generally serious in fixed effects ANOVA
PLOT Stem-and-Leaf histogram of residuals (generated from SAS PROC UNIVARIATE)	Inspect to see if data appears to be normally distributed and centered around zero.	(1) skewed (2) flat or peaked (3) outliers (4) multimodal	errors are normally and independently distributed with mean of zero and constant variance	moderate departure (especially with small sample sizes) not usually serious
PLOT Normal Probability Plot of Residuals (generated from SAS PROC UNIVARIATE)	Inspect plot to see if data generates relatively straight line. Central values are more significant than tails. Inspect for outliers.	(1) rather straight line with no outliers (2) relatively straight line with outliers (3) non-straight line	**normality** of residuals	moderate departures are not generally serious in fixed effects ANOVA
PLOT Residuals by TYPE by GENDER by ORDER by STRESS	Inspect plot to see if there are variables that affect the response.	Patterns emerging in the plots indicate that the variable affects the response.	all significant independent variables are accounted for	none if variable is included in the analysis
compiled from information obtained from Montgomery (2000) and Hatcher & Stepanski (1994).				

13.9.2 Selected Results from Verification of the ANOVA Assumptions for Phase II Performance Data

The performance data (avgDIStpu and avgASSYtpu variables) were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Section 13.9.1. All plots and computed statistics indicate that the data meet the assumptions that the residuals are normally and independently distributed with mean zero and constant variance. The p-values associated with the Shapiro-Wilk normality statistic and the Bartlett's homogeneity of variance tests are provided in Table 13-3. The Shapiro-Wilk normality statistic for the residuals produced a p-value of 0.7767 for avgDIStpu and 0.6184 for avgASSYtpu. The Bartlett's test for homogeneity of variance between the eight TYPExGENDERxORDER groups of averaged data resulted in p-values of 0.8182 for avgDIStpu and 0.0332for avgASSYtpu. The Bartlett's test for homogeneity of variance between the sixteen TYPExGENDERxORDERxSTRESS groups resulted in p-values of 0.7357 for avgDIStpu and 0.0721 for avgASSYtpu.

The residuals plotted against predicted values can be seen in Figure 13-37. The residuals plotted against time (i.e., time ordered subject numbers) can be seen in Figure 13-38. Histograms of the residuals are shown in Figure 13-39. Normal probability plots for the residuals are shown in Figure 13-40.

Table 13-3. P-values for testing assumptions of task performance ANOVA's.

Performance Variable	Shapiro-Wilk for residuals (see description for Column 2)	Bartlett's for 8 non-averaged TGO groups (see description for Column 3)	Bartlett's for 8 averaged TGO groups (see description for Column 4)	Bartlett's for 16 TGOS groups (see description for Column 5)
avgDIStpu	0.7767	0.7195	0.8182	0.7357
avgASSYtpu	0.6184	0.0892	0.0332	0.0721

Column 2: contains the p-value for Shapiro-Wilk (S-W) normality statistic for residuals.
Column 3: contains the p-value for Bartlett's test for homogeneity of variance between 8 TYPExGENDERxORDER groups (TGO) of non-averaged data from both stress conditions (maximum 6 observations per group).
Column 4: contains p-value for Bartlett's test for homogeneity of variance between 8 TYPExGENDERxORDER (TGO) groups of data averaged across 2 stress conditions (maximum 3 observations per group).
Column 5: contains p-value for Bartlett's test for homogeneity of variance between 16 TYPExGENDERxORDERxSTRESS (TGOS) groups of data (maximum 3 observations per group).

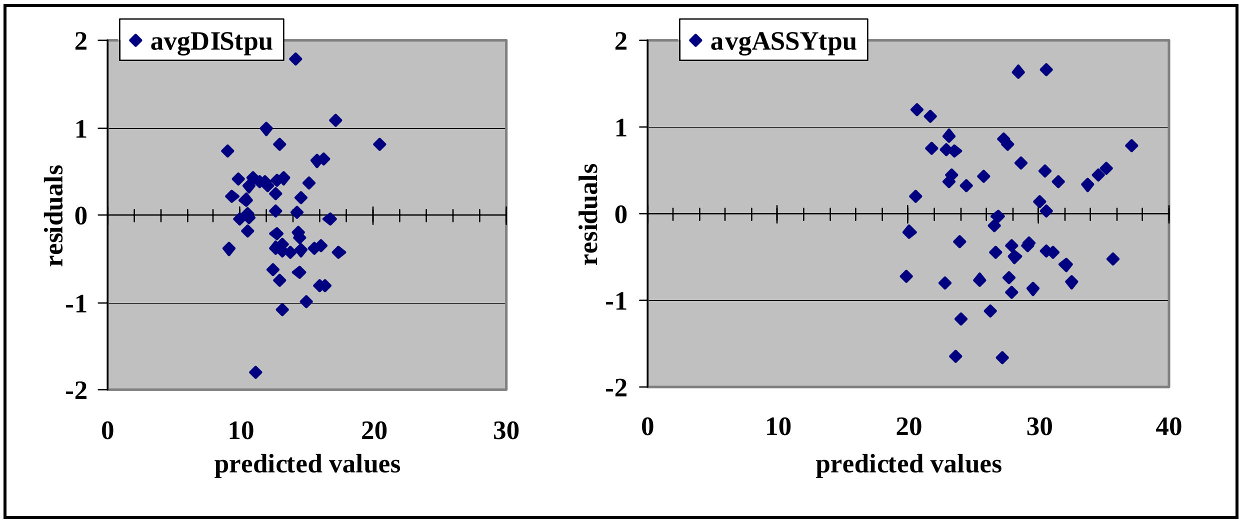


Figure 13-37. Residuals vs. predicted values for avgDIStpu and avgASSYtpu.

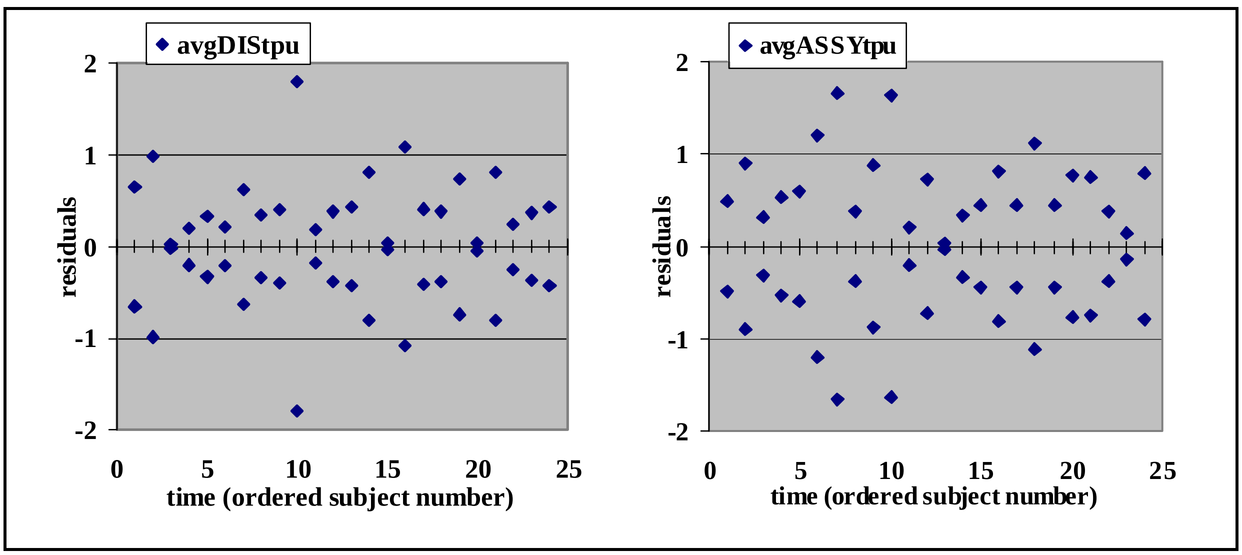


Figure 13-38. Residuals vs. time-ordered subject number for avgDIStpu and avgASSYtpu.

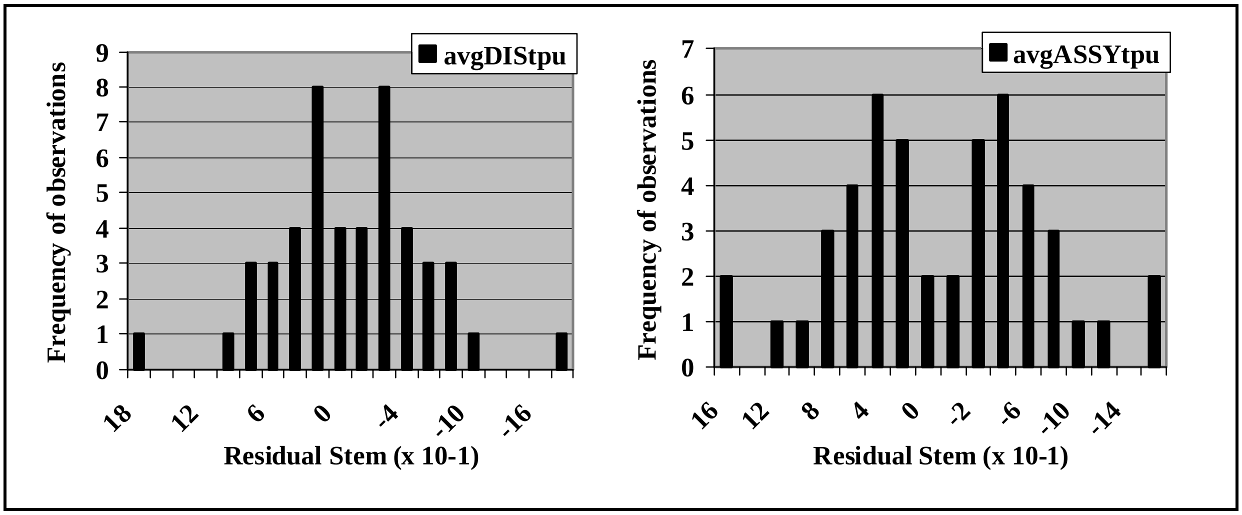


Figure 13-39. Histograms of avgDIStpu and avgASSYtpu residuals.

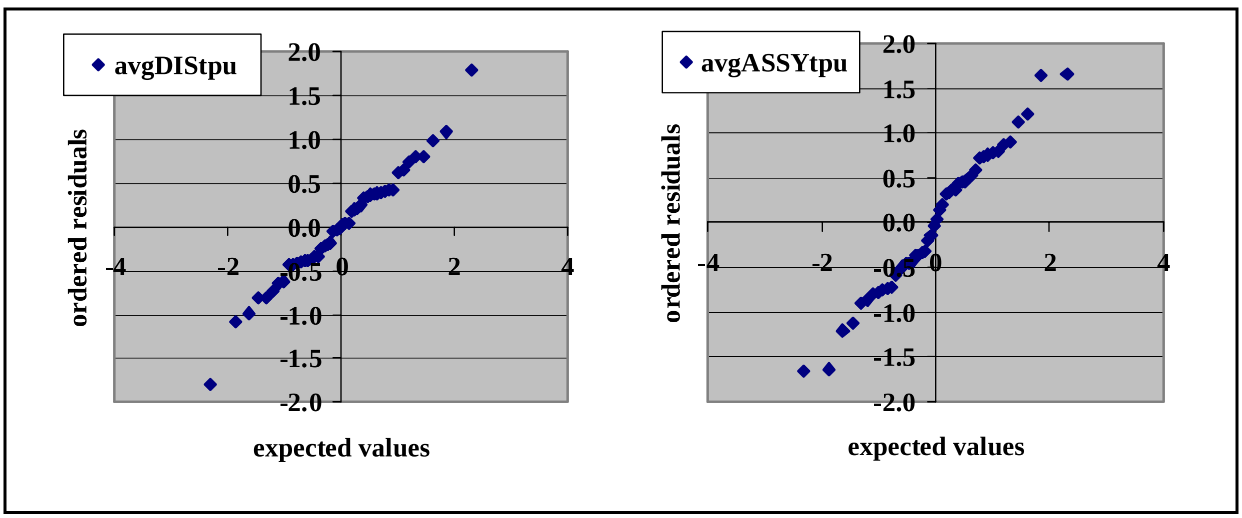


Figure 13-40. Normal probability plot of the avgDIStpu and avgASSYtpu ordered residuals versus expected values of normal order statistics.

13.9.3 Selected Results from Verification of the ANOVA Assumptions for Phase II Wrist Motion Kinematics Data

The wrist motion kinematics data were evaluated for compliance with the required assumptions for the Analysis of Variance (ANOVA) procedures as described in Section 13.9.1. All plots and computed statistics indicate that the data meet, or only moderately violate, the assumptions that the residuals are normally and independently distributed with mean zero and constant variance. Selected results of this verification process are provided here. The p-values associated with the Shapiro-Wilk normality statistic and the Bartlett's homogeneity of variance tests for all 20 variables are provided in Table 13-4. The plots are shown for the romRFE and nromRFE range of motion variables and for the aLFEacc and aRFEacc kinematics variables. Plots for the range of motion variables are provided in Figure 13-41 through Figure 13-44. Plots for the kinematics variables are provided in Figure 13-45 through Figure 13-48.

The residuals plotted against predicted values can be seen in Figure 13-41 and Figure 13-45. The residuals plotted against time (i.e., time ordered subject numbers) can be seen in Figure 13-42 and Figure 13-46. Histograms of the residuals are shown in Figure 13-43 and Figure 13-47. Normal probability plots for the residuals are shown in Figure 13-44 and Figure 13-48.

Table 13-4. P-values for testing assumptions of wrist motion kinematics ANOVA's.

Wrist Monitor Dependent Variable	**Shapiro-Wilk for residuals (see description for Column 2)**	**Bartlett's for 8 non-averaged TGO groups (see description for Column 3)**	**Bartlett's for 8 averaged TGO groups (see description for Column 4)**	**Bartlett's for 16 TGOS groups (see description for Column 5)**
nLRUpos	0.4272	0.0361	0.5225	0.4654
nLFEpos	**0.0001**	**0.0002**	0.0689	0.0713
nRRUpos	0.0369	0.1222	0.6335	0.8116
nRFEpos	0.1885	0.0767	0.4943	0.7299
aLRUvel	0.6648	0.2900	0.5718	0.8608
aLFEvel	0.5709	**0.0003**	**0.0036**	**0.0054**
aRRUvel	0.3907	0.0874	0.6487	0.7517
aRFEvel	**0.0002**	0.0265	0.3909	0.4278
aLRUacc	0.7512	0.5369	0.7730	0.6199
aLFEacc	0.8455	**0.0037**	0.0383	**0.0056**
aRRUacc	0.7022	0.2208	0.6763	0.4674
aRFEacc	**<0.0001**	**0.0029**	0.1075	0.1007
romLRU	0.4157	0.1966	0.8086	0.9131
romLFE	0.8287	0.0305	0.4664	0.2054
romRRU	0.1690	**0.0008**	0.1754	0.1107
romRFE	0.0305	0.0377	0.6169	0.5406
nromLRU	0.7437	**0.0024**	0.2477	0.2152
nromLFE	0.8910	**<0.0001**	0.0554	0.0423
nromRRU	0.5241	0.0231	0.5770	0.6520
nromRFE	**0.0017**	**0.0005**	0.0806	0.0420

Column 2: contains the p-value for Shapiro-Wilk (S-W) normality statistic for residuals.
Column 3: contains the p-value for Bartlett's test for homogeneity of variance between 8 TYPExGENDERxORDER groups (TGO) of non-averaged data from both stress conditions (maximum 6 observations per group).
Column 4: contains p-value for Bartlett's test for homogeneity of variance between 8 TYPExGENDERxORDER (TGO) groups of data averaged across 2 stress conditions (maximum 3 observations per group).
Column 5: contains p-value for Bartlett's test for homogeneity of variance between 16 TYPExGENDERxORDERxSTRESS (TGOS) groups of data (maximum 3 observations per group).

Significant p-values ($p \leq 0.001$) shaded and bolded. Almost significant p-values bolded ($p \leq 0.01$)

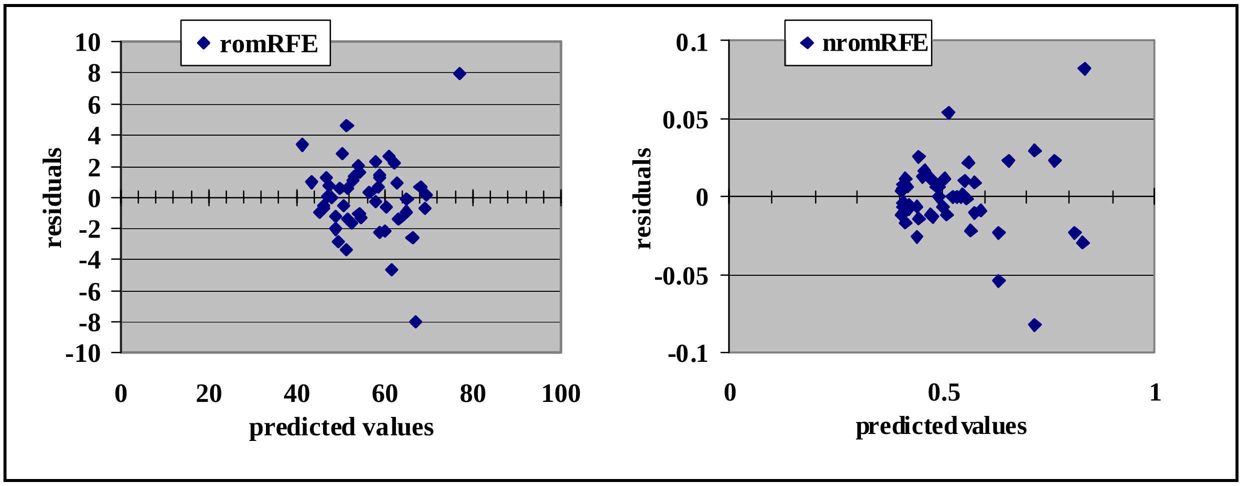


Figure 13-41. Residuals vs. predicted values for romRFE and nromRFE.

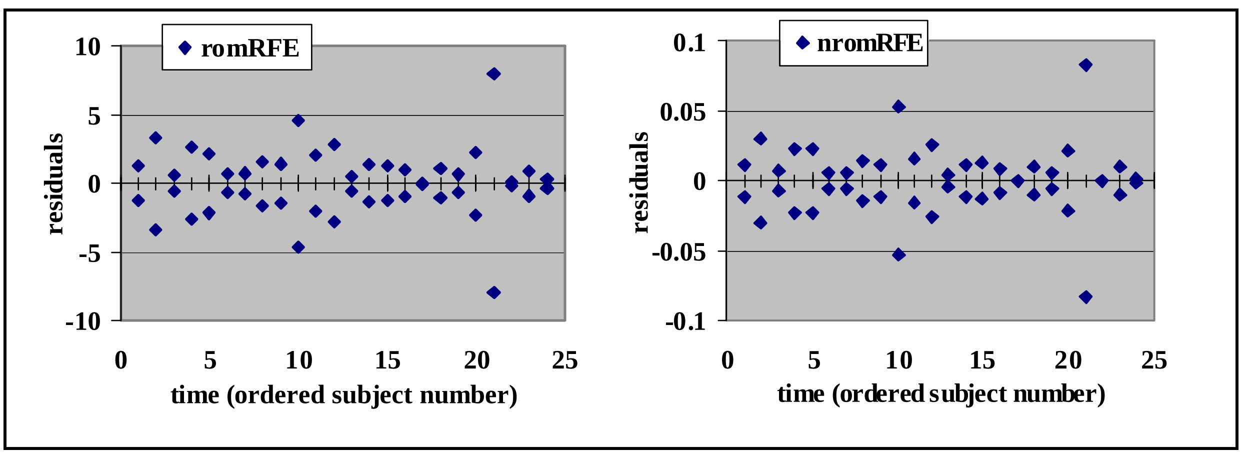


Figure 13-42. Residuals vs. time-ordered subject number for romRFE and nromRFE.

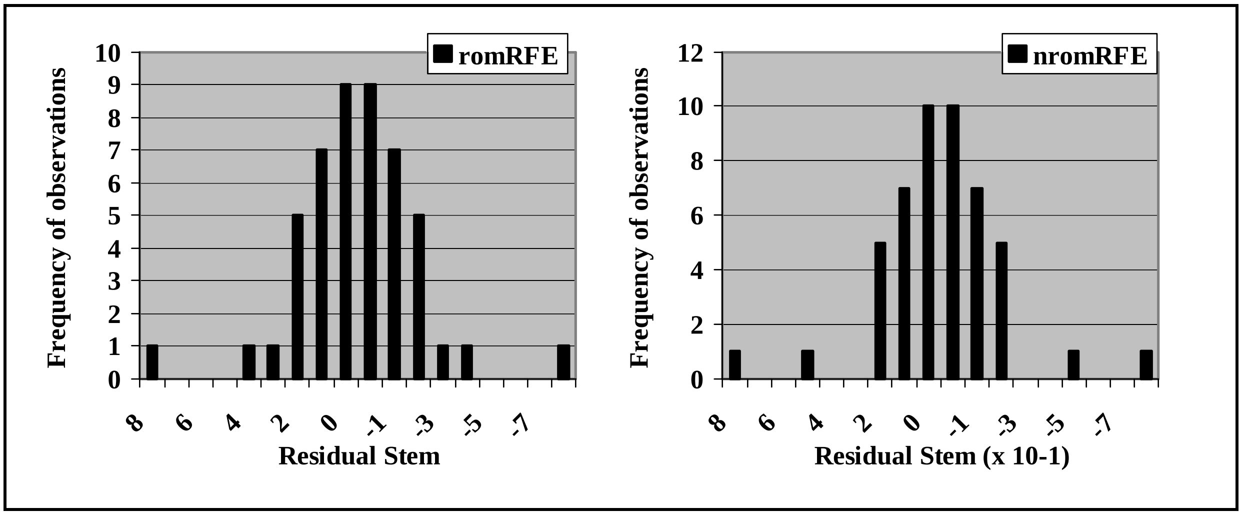


Figure 13-43. Histograms of romRFE and nromRFE residuals.

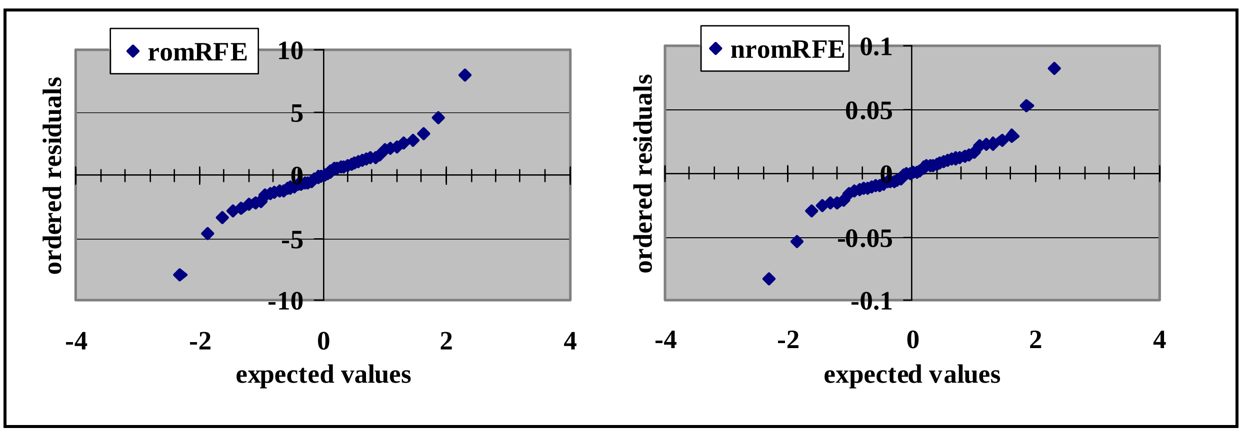


Figure 13-44. Normal probability plots of the romRFE and nromRFE ordered residuals versus expected values of normal order statistics.

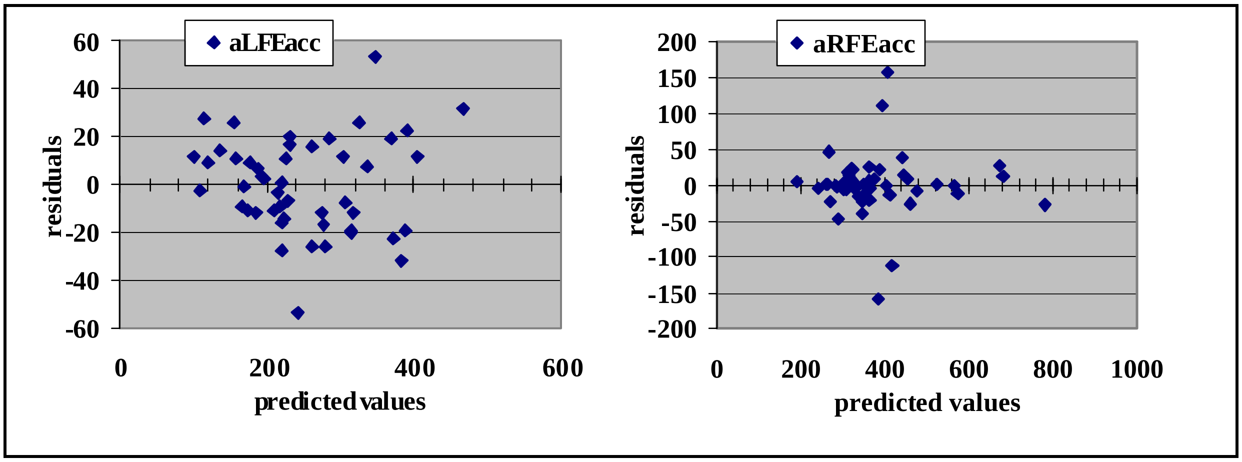


Figure 13-45. Residuals vs. predicted values for aLFEacc and aRFEacc.

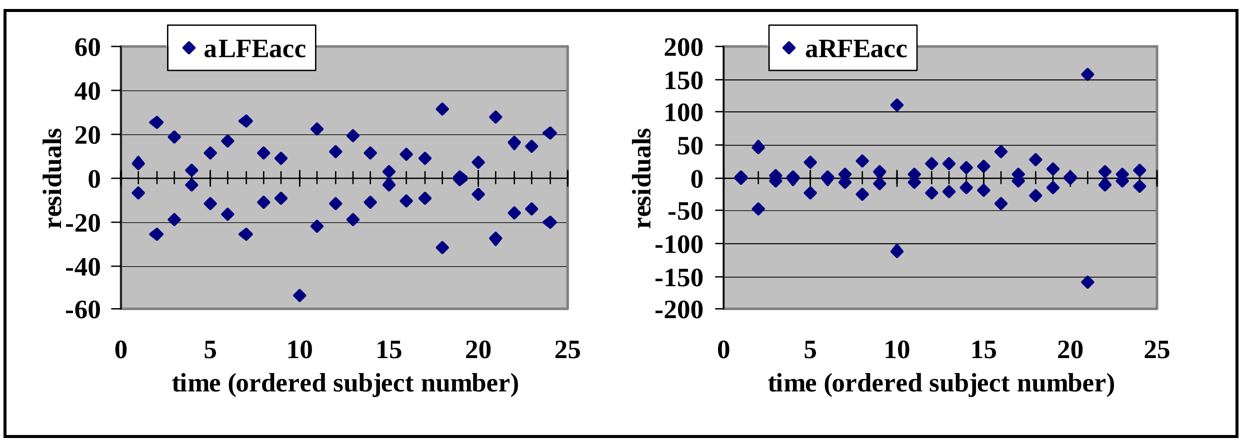


Figure 13-46. Residuals vs. time-ordered subject number for aLFEacc and aRFEacc.

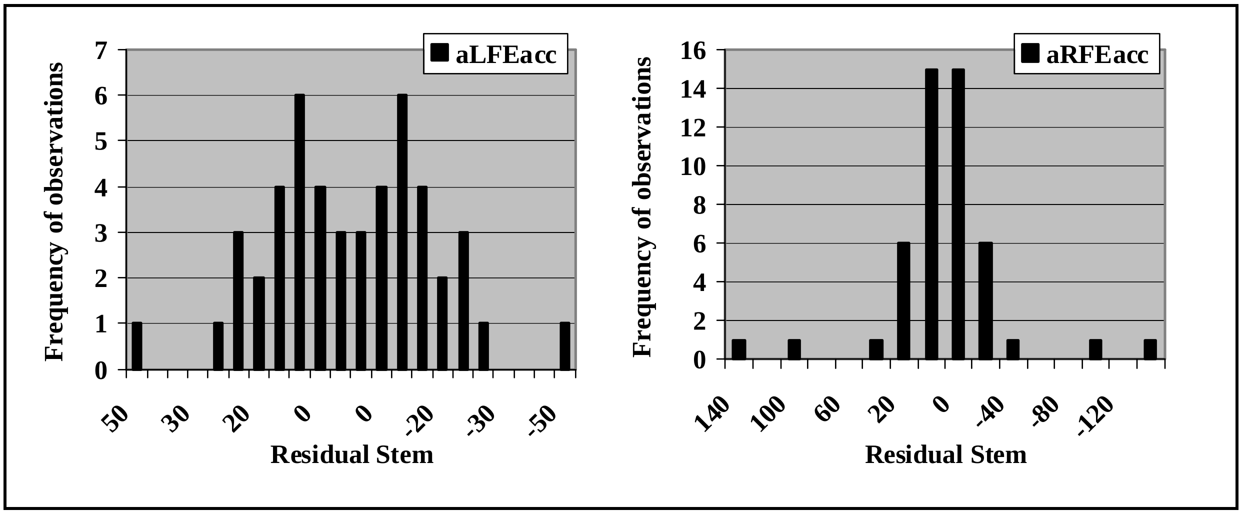


Figure 13-47. Histograms of aLFEacc and aRFEacc residuals.

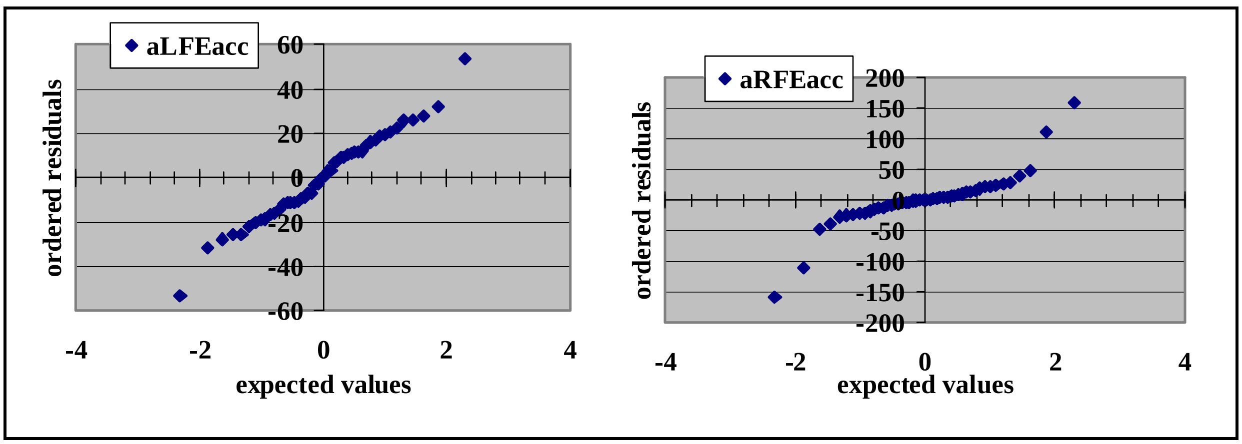


Figure 13-48. Normal probability plots of the aLFEacc and aRFEacc ordered residuals versus expected values of normal order statistics.