AMERICAN UNIVERSITY OF BEIRUT

# THE EFFECTS OF CONCURRENT PHYSICAL AND PSYCHOSOCIAL DEMANDS ON MUSCLE ACTIVATION, SUBJECTIVE WORKLOAD, AND PERFORMANCE

by
RANIA ABDUL NASSER GHALAYINI

A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Engineering Management
to the Department of Industrial Engineering and Management
of the Maroun Semaan Faculty of Engineering and Architecture
at the American University of Beirut

Beirut, Lebanon
January 2020

AMERICAN UNIVERSITY OF BEIRUT

# THE EFFECTS OF CONCURRENT PHYSICAL AND PSYCHOSOCIAL DEMANDS ON MUSCLE ACTIVATION, SUBJECTIVE WORKLOAD, AND PERFORMANCE

by

RANIA ABDUL NASSER GHALAYINI

Approved by:

Dr. Saif Al-Qaisi, Assistant Professor — Advisor
Department of Industrial Engineering and Management

Dr. Nadine Moacdieh, Assistant Professor — Member of Committee
Department of Industrial Engineering and Management

Dr. Lina Younan, Clinical Associate Professor — Member of Committee
Hariri School of Nursing

Date of thesis defense: January 27, 2020

# AMERICAN UNIVERSITY OF BEIRUT

# THESIS, DISSERTATION, PROJECT RELEASE FORM

Student Name: __Ghalayini_________Rania__________Abdul Nasser_____
Last First Middle

☑ Master's Thesis ◯ Master's Project ◯ Doctoral Dissertation

☐ I authorize the American University of Beirut to: (a) reproduce hard or electronic copies of my thesis, dissertation, or project; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes.

☑ I authorize the American University of Beirut, to: (a) reproduce hard or electronic copies of it; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes after:

**One ____ year from the date of submission of my thesis, dissertation, or project.**

**Two ____ years from the date of submission of my thesis, dissertation, or project.**

**Three ✓ years from the date of submission of my thesis, dissertation, or project.**

[signature] 29/01/2020

Signature Date

## ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my thesis advisor Dr. Saif Al-Qaisi for his continuous support and guidance throughout my graduate studies.

I also want to thank the rest of my thesis committee members: Dr. Nadine Moacdieh and Dr. Lina Younan for their help.

# AN ABSTRACT OF THE THESIS OF

Rania Abdul Nasser Ghalayini for Master of Engineering
Major: Engineering Management

Title: The Effects of Concurrent Physical and Psychosocial Demands on Muscle Activation, Subjective Workload, and Performance

Work-related musculoskeletal disorders (MSD) continue to be a serious health problem in the workplace. Past research has showed that not only physical factors (e.g. excessive repetition, awkward postures, and heavy lifting) impact the risk of developing an MSD but also psychosocial factors, such as the mental demands associated with a job. This research explored the impact of two additional psychosocial factors on the risk of developing an MSD, which are time pressure and workplace distractions. The specific objective of this research was to examine the concurrent effects of physical factors and psychosocial factors on muscle activation, mental performance, and the perceived workload level. Fifteen participants were recruited for this research. Two levels of the physical factor were investigated, including a static lift in: a neutral posture and an awkward posture. Five levels of psychosocial factors were considered, including: 1) the absence of psychosocial factors (serving as the control); 2) a mental task; 3) a mental task with time pressure; 4) a mental task with distractions; and 5) a mental task with both time pressure and distractions. The mental task involved solving a series of subtraction arithmetic equations. The time pressure was simulated by urging participants to answer as many math problems as possible in 30 seconds and by displaying a countdown. Distractions were in the form of incorrect answers presented visually and verbally by the computer. The experiment consisted of 10 trials (2 physical factors × 5 psychosocial factors). During each trial, the level of muscle activation from shoulder and low back muscles was recorded using an electromyography (EMG) device. The math performance in each trial was assessed based on the percentage of errors made and the number of correct responses. Also, participants were asked to rate their perceived workload level on the National Aeronautics and Space Administration - Task Load Index (NASA-TLX) questionnaire. The results showed that the addition of a mental task to a static physical task can actually reduce muscle tension at the low back. However, adding time pressure significantly increased muscle tension. On the other hand, shoulder muscle activity was not significantly affected by the different physical and psychosocial factors. For NASA- TLX scores, nearly all scales showed an increase in ratings when psychosocial factors were added with the physical task. Finally, math performance measures were not significantly different in nearly all the experimental conditions, indicating that minor or moderate increases in physical and/or psychosocial demands do not significantly affect mental performance.

CONTENTS

# ILLUSTRATIONS

# TABLES

# CHAPTER 1

# INTRODUCTION

## 1.1. Work-Related Musculoskeletal Disorders

Work-related musculoskeletal disorders (MSD) continue to be a serious health problem in the workplace. They include injuries and disorders that affect muscles, bones, nerves, tendons, ligaments, and/or cartilages (World Health Organization, 2003). In 2015, the incidence rate of MSDs among workers of all occupations from private, state, and local government accounted for 31% (356,910 cases) (Bureau of Labor Statistics, 2016). MSDs have considerable social and economic implications because of the labor lost due to sick leave and impairment. Therefore, it has been investigated abundantly in the ergonomics literature in order to understand its causes and how it can be prevented.

## 1.2. Causes of Musculoskeletal Disorders

### *1.2.1. Physical Demands*

The physical job demands or features have been identified as one of the major contributing factors to MSDs in the workplace. The most commonly reported physical tasks with reasonable evidence for causing work-related MSDs include excessive repetition, awkward postures, and heavy lifting (Da Costa and Vieira, 2010). Other physical job features that are frequently cited as risk factors for MSDs include: rapid work pace, insufficient recovery time, forceful manual exertions, mechanical pressure concentrations, and segmental or whole-body vibration (Punnett and Wegman, 2004).

Furthermore, physical tasks that require sustaining static postures have been linked with back MSDs (Knibbe & Friele, 1996).

### *1.2.2. Psychosocial Demands*

A less obvious, contributing factor to work-related MSDs is a poor and stressful psychosocial work environment. Stress has been defined as the imbalance between a person's perception of the demands from the environment and his/her perceived resources to meet those demands (Frankenhaeuser et al., 1989). Therefore, anything above a person's mental capacity causes stress, and anything far below a person's mental capacity, such as monotonous and repetitive work, causes stress. The Inverted-U hypothesis states that stress increase induces arousal, thus improving performance up to a certain optimum level, after which performance begins to decline (Welford, 1973). Such psychosocial factors include exposure to high job demands and low job control, work dissatisfaction, effort-reward imbalance, and low social support (Bongers et al., 1993). Psychosocial factors affect the mechanical load by causing changes in posture, forces exerted, and movement. For example, time pressure has been linked to MSD because it increases the number of hurried movements having high accelerations or poor postures (Bongers et al., 1993). Moreover, psychosocial conditions and mental stress can lead to physiological changes, such as increasing catecholamines, cortisol, blood pressure, heart rate, and muscle sympathetic nerve activity (Lundberg, 2002; Callister et al., 1992).

Lundberg et al. (2002) found that a mental task activated the same motor units in muscles as a physical task. Even without the presence of a physical task – such as during work breaks – mental stress may leave the low threshold motor units active, preventing muscle relaxation. Lundberg et al. (1994) showed that the trapezius muscle in the shoulder and neck regions increased in muscle activation (or muscle tension) when exposed to mental demands. Another study by Waersted et al. (1991) revealed that the complexity of the mental task can also increase the trapezius muscle activity.

### *1.2.3. Interaction of Physical and Psychosocial Demands*

A cross sectional study has showed a relationship between physical demands, work stress, and MSDs (Waters et al., 2007). Flodgren et al. (2009) concluded that mental load of short periods does not induce increases in muscle activity when superimposed with low repetitive physical work. Mehta and Agnew (2011) proposed that the difference in results between different experiments where mental demand was added to low static load is due to the difference in the experiments' duration; when a decrease in trapezius muscle activity was detected, the experiment was conducted for 10 sec only. While experiments which showed an increase in muscular activity where conducted over lengthy duration which may have affected muscle recovery and lead to increased and/or sustained muscle activity.

However, mental tasks increase muscle activation when combined with a physically-demanding task. In a study by Larsson et al. (1995), participants were exposed to fatiguing static contractions of the neck and shoulder muscles. When a mental task was introduced with the static contractions, participants experienced further increases in shoulder muscle activation. Nimbarte et al. (2012) found that the addition of a mentally-demanding task (memory and arithmetic tasks), before and after heavy physical work, lead to an increase in muscle activation at the shoulder and neck regions during the physical exertion. The mental effort may have caused an increase in muscle stiffness which was sustained during the physical exertion. A study highlighting the effect of simultaneously performing high force levels and mental task showed a decline in the shoulder muscle activity compared with physical activity alone (Mehta & Agnew, 2011). At high physical intensities, it was shown that mental load had a greater effect on static work than dynamic work in decreasing muscle activity and impairing mental performance. The rationale behind this observation was that static exertions alone require more muscular activity and have higher perceived effort and workload than dynamic exertions. Thus, when a mental task was added to a static, rather than a dynamic exertion, the attentional costs and delay in information processing were higher in the static case (Mehta & Agnew, 2013). Mehta and Agnew (2011) when altering the level of the physical load in the presence of a mental task showed that force fluctuation versus physical loads followed a U shape. At the high and low extremes of physical loads' spectrum, force fluctuations were high, while at 25% MVC fluctuations were at their lowest. This increase in force fluctuation at high levels during mental task was explained by a decrease in joint steadiness due to the decrease in the available attentional resources needed to keep the same physical level, while at low physical levels the short duration of the task is believed to have induced boredom (Welford, 1973).

Furthermore, studies have shown that adding a mental task during a lifting task further increases the compressive spinal loading (Davis et al., 2002; Marras et al., 2000). The spinal loading was mostly influenced with complex mental tasks done simultaneously with lifting task, then with increased pacing independent of mental processing, and finally with mental tasks performed before the lift. Also, an interaction between the psychosocial variables was found because spinal loading increased in the presence of both pacing and mental tasks. It was explained that mental tasks lead to the overreaction of the musculoskeletal system because of the time pressure limit it imposes. This overreaction shows itself through an increase in the co-activation of the torso muscle and lesser control on trunk movements (Davis et al., 2002).

### 1.3. Job Occupations Containing Combination of Stressors

There are many jobs where the worker is exposed to physical and psychosocial demands simultaneously. Cashiers who work at supermarkets, banks, and post offices, data entry workers, construction laborers, and assembly line workers are involved with repetitive tasks while time pressured and without having much control over their work. Such jobs may have low to moderate physical demand but have high psychosocial demand.

Moreover, healthcare workers are at high risk of MSDs due to their high exposure to physical and psychosocial demands. The nursing occupation, which serves as the primary motivation for this research, contains these combinations of stressors – physical, mental, temporal, and distraction stress. Nurses are exposed to: physical stress when manually handling or transferring patients; mental stress when having to recall patients' conditions and/or the appropriate treatments and medications to use; time pressure when having to respond to an emergency situation or to attend to multiple patients at a time; and workplace distractions when having to disregard irrelevant information or noise in the work environment. In MSD incident rates, nursing assistants ranked second while registered nurses ranked sixth (Bureau of Labor Statistics, 2016). Many studies have shown that low back pain is among the most frequently occurring

MSDs among nurses with a prevalence rate of 44.1%-54.7% (Ando et al., 2000; Tinubu et al., 2010). These factors collectively may be impacting the nurses' quality of care, performance, and their risks of developing MSDs.

### 1.4. Study Objectives

The present study sought to understand the impact of different psychosocial factors, including mental demands, time pressure, and workplace distractions, and their collective effects on humans. The psychosocial factors were investigated when presented concurrently with different levels of physical loads. Their impacts on the human were assessed in terms of muscle activation levels at the shoulder and low back regions, since these regions report the highest rates of MSDs. Also, this research assessed the effects on mental performance and the human's perception of the overall workload level. Past research have analyzed the effects of physical tasks and mental tasks performed concurrently on humans' risks of developing MSDs; however, the impact of both time pressure and workplace distractions in mental tasks have not yet been examined. In summary, the objective of this research was to examine the concurrent effects of psychosocial factors and physical factors on muscle activation, mental performance, and the perceived workload level.

# CHAPTER 2

# METHODS

## 2.1. Participants

Fifteen male participants in good health were recruited for this study. The Physical Activity Readiness Questionnaire (PAR-Q, British Columbia Ministry of Health) was used to screen participants for cardiac and other health problems, such as dizziness, chest pain, or heart trouble (Appendix A; Hafen and Hoeger, 1994). Any participant who answered yes to any of the questions on the PAR-Q was excluded from the study. The experimental procedures and the demands of the testing were explained to all participants and their signatures were obtained on informed consent forms approved by the AUB institutional review board (IRB) (Appendix B). Basic demographic information of the participants was collected (Appendix C). The average (standard deviation) age, weight, and height of the participants were 21.8 (2.3) years, 78.6 (13.6) kg, and 177.5 (4.7) cm, respectively.

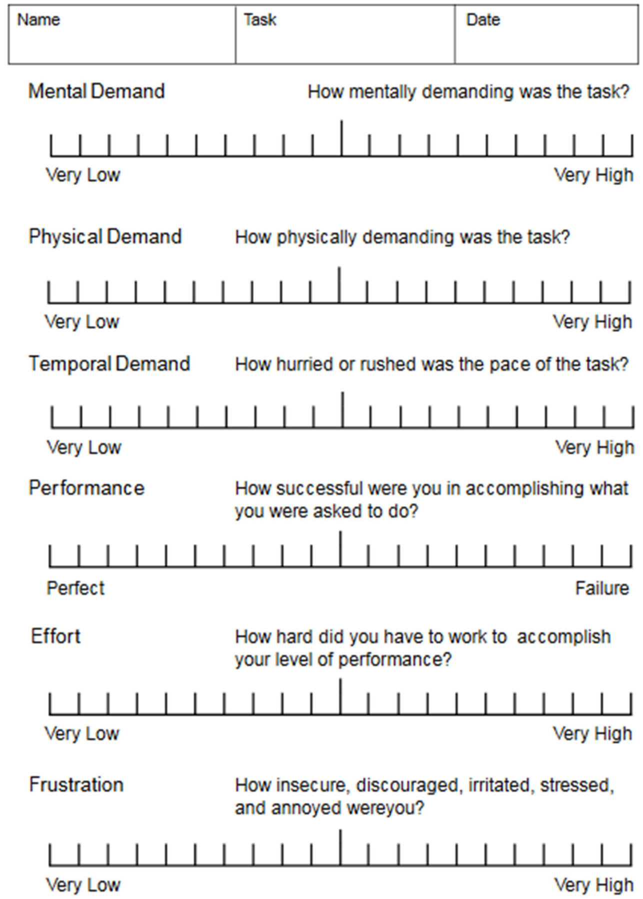
## 2.2. Tools and Equipment

### *2.2.1 Electromyography (EMG) system*

A Tringo wireless EMG system (Delsys Inc., Boston, MA, USA) was used to measure the electrical activities of muscles in the shoulder (upper trapezius) and low back (lumbar erector spinae) regions. The EMG device measures muscle activation via electrodes placed over the muscle, providing information about the impact of an individual muscle or a group of muscles in the generation of a certain force (De Luca, 1997). The surface EMG electrodes were two Trigno sensors (Delsys Inc.) with a single differential configuration, a parallel bar (99.9% pure silver) contact area, and a fixed inter-electrode distance of 10 mm. They were set at a band-pass filter of 20–450 Hz and a common mode rejection ratio of 80 dB. EMG data was collected at a sampling rate of 2000 Hz and processed using the root mean square method with a time window of 0.125 s and an overlap of 0.0625 s (De Luca, 1997; Konrad, 2005). The EMGworks software (Delsys Inc.) was used for processing and analyzing the collected data.

### *2.2.2 National Aeronautics and Space Administration - Task Load Index (NASA-TLX)*

The NASA-TLX questionnaire was used by participants to rate their perceived workload immediately after each experimental task (Hart and Staveland, 1988). The questionnaire consists of six scales – including mental demands, physical demands, temporal demands, performance, effort, and frustration – to assess the perceived workload level associated with a task. Figure 1 presents the NASA-TLX questionnaire along with the corresponding question asked for each scale.



| Name | Task | Date |
| --- | --- | --- |
| | | |

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

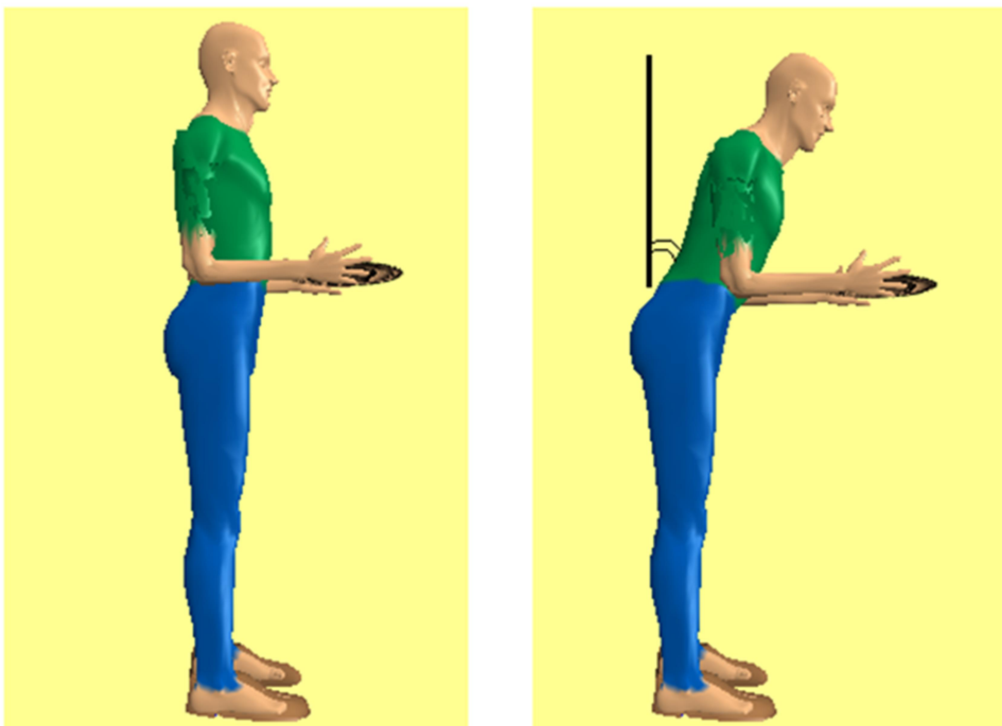
**Figure 1.** NASA-TLX Questionnaire.

### 2.3. Experimental Tasks

The experimental tasks could be divided into two main categories: the physical tasks and the psychosocial tasks. This study investigated both task categories performed concurrently. The physical tasks consisted of two tasks, including:

- A static lift in a neutral posture (N): this task involved holding a 7 kg weight while standing erect with the upper arms perpendicular to the ground and the forearms parallel to the ground. Figure 2a shows the posture that will be adopted during this lift.

- A static lift in an awkward posture (A): this task involved holding a 7 kg weight while standing with the back flexed approximately 20°, upper arm perpendicular to the ground, and forearm parallel to the ground. Figure 2b shows the posture that will be adopted during this lift.



(a) (b)

**Figure 2.** The static lift in a: (a) neutral posture and (b) awkward posture.

In addition, five different psychosocial tasks were considered concurrently with the aforementioned physical tasks, including the following:

- Absence of psychosocial stress: the participant was not presented with any form of psychosocial stress; that is, participants were performing only the physical tasks.
- Mental task (M): the participant was asked to answer a series of math problems at a comfortable pace.
- Mental task under time pressure (MT): the participant was asked to answer a series of math problems, under time pressure. Time pressure was simulated by urging the participant to answer as many math problems as possible in 30 seconds and by displaying a countdown to increase the sense of urgency.
- Mental task with distractions (MD): the participant was asked to answer a series of math problems while being distracted verbally and visually. Distractions were in the form of incorrect answers presented suddenly at the center of the computer screen (Calibri font, red text, and size 199) while also being vocalized by the computer. The distractions were presented for a random subset of the math problems, making them less predictable.
- Mental task under time pressure and with distractions (MTD): the participant was asked to answer a series of math problems, under time pressure, while also being distracted verbally and visually. Time pressure and distractions were simulated in the same manner as in the MT and MD tasks, respectively.

In considering all possible combinations of the physical and psychosocial stress, the experiment involved a total of 10 trials (Table 1). The mental task involved answering a series of math subtraction problems of two digit numbers. Participants were asked to provide their answers verbally, as the experimenter recorded their responses on an answer sheet. The math equations were presented at the center of a PowerPoint presentation on a computer screen (Calibri font, black text, size 170). The distance between the screen and the participant and, also, the angle of the screen were set according to each participant's preference and comfort.

**Table 1.** All possible combinations of the physical and psychosocial tasks, including their acronyms used hereafter.

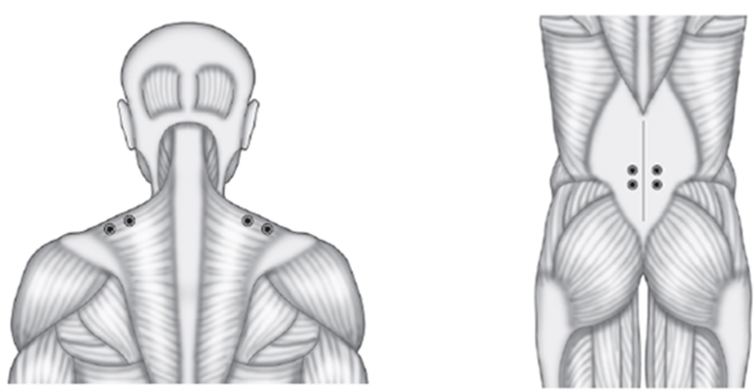
<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Physical Tasks</th></tr>
<tr><th>Neutral Posture (N)</th><th>Awkward Posture (A)</th></tr>
<tr><th rowspan="5">Psychosocial Tasks</th><th>Absence of Psychosocial Stress</th><td>N</td><td>A</td></tr>
<tr><th>Mental Task (M)</th><td>N-M</td><td>A-M</td></tr>
<tr><th>Mental Task under Time Pressure (MT)</th><td>N-MT</td><td>A-MT</td></tr>
<tr><th>Mental Task with Distractions (MD)</th><td>N-MD</td><td>A-MD</td></tr>
<tr><th>Mental Task under Time Pressure and with Distractions (MTD)</th><td>N-MTD</td><td>A-MTD</td></tr>
</table>

### 2.4. Experimental Procedures

Each participant was given an orientation, introducing them to the equipment, data collection procedures, and specifics of the experimental tasks. After the orientation, they were asked to provide their consent to participate in this research by signing the

IRB form. Then their demographic information was recorded, such as age, height, weight, gender, and physical activity level. They began with a warm-up session for three minutes consisting of different stretches for the joints involved. Then preparations were made to ready the participants for EMG data acquisition from muscles of the shoulder and low back regions. The skin over the muscle sites was shaved and cleaned with alcohol to enhance EMG signal detection. Specifically, the EMG sensors were attached at the following muscle sites:

- Upper trapezius: 2 cm lateral to the midpoint of the lead line between the spinous process of C7 and the posterolateral border of the acromion. The sensor was oriented parallel to the muscle fibers (Figure 3a) (Criswell, 2011; McLean et al., 2003).
- Lumbar erector spinae: 2 cm lateral to the L3 vertebra and parallel to the spine (Figure 3b) (Criswell, 2011).



(a) (b)

**Figure 3.** EMG sensor locations for the: (a) upper trapezius and (b) lumbar erector spinae muscles (Criswell, 2011).

To permit EMG interpretation, the EMG signals were normalized to each participant's maximum voluntary contractions (MVC). This was achieved by dividing the EMG data from the experimental tasks by the maximum EMG signal detected in the MVC of the same muscle, reporting the data as a percentage of the MVC (%MVC). A different MVC exercise was performed for each investigated muscle as follows:

- Upper Trapezius: The participant was in a seated erect posture with no back support. The shoulder was abducted 90° with the neck laterally flexed to the same side, rotated to the opposite side, and extended. In this posture, the participant was asked to perform maximal neck extension and shoulder abduction against manual resistance applied at the head and above the elbow (Ekstrom et al., 2005; Zanca et al., 2014). Figure 4a illustrates the required posture in this MVC, along with the force directions to be generated by the participant (blue arrows) and experimenter (red arrows).
- Lumbar erector spinae: The participant was lying prone with both hands under the forehead. They were asked to gradually hyperextend their upper trunk and hips as much as possible against gravity (Ng and Richardson, 1994; Konrad, 2005). Figure 4b illustrates the required posture in this MVC, along with the force directions to be generated by the participant (blue arrows).

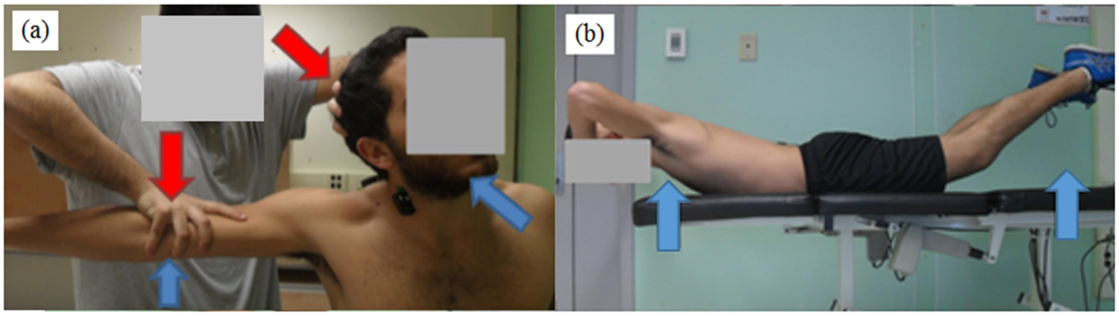



**Figure 4.** MVC exercise for the: (a) upper trapezius and (b) lumbar erector spinae. The blue arrows represent the forces generated by the participant, and the red arrows represent the force resistance of the experimenter.

Prior to collecting data, participants were trained on each MVC exercise, ensuring correct performance. They were asked to gradually exert up to their maximal force in 3 to 5 s, maintain it for 3 s, and gradually decrease their force in 3 s (Konrad, 2005). Each MVC exertion was repeated three times. Repetitions were separated with 30 to 60 s of rest, and MVC sets were separated with 2 min of rest (Konrad, 2005). The maximum EMG activity of the three repetitions was used for normalizing the EMG data. During MVC exertions, EMG data was collected for a period of 15 seconds, giving participants enough time to reach their maximum exertion.

After the MVC exertions, participants were required to perform the ten experimental tasks described in Table 1. The order of task presentation was randomized for each participant using simple randomization. Tasks were separated with 1 min of rest to avoid muscular fatigue. If more time was requested, they were allowed to rest until they feel ready for the next task. During each task, EMG activities were recorded from the upper trapezius and lumbar erector spinae. Each task lasted for 30 s. This duration was made known to the participants only in cases where time pressure was present. For trials without time pressure, time was not mentioned; rather, participants were instructed to perform the task requirements until the experimenter stopped the task.

Mental workload during the tasks was assessed based on their performance on the math problems and their subjective ratings on the NASA-TLX questionnaire. The experimenter recorded each answer provided by the participant on an answer sheet. After the experiment, the number of errors made by the participant in each task was computed. This number of errors was normalized by dividing it by the total number of questions answered in the same trial, reporting the result as "% error." Also, the "number of correct" answers was counted in each trail as another dependent variable for performance measure. Furthermore, after each task, participants were asked to provide their subjective ratings on the NASA-TLX questionnaire. They were asked to base their ratings solely on how they personally perceive the task to be without considering the thoughts of others. The dependent variable "Overall NASA" was computed as the average of the ratings over all six scales of the NASA TLX.

### 2.5. Experimental Design and Statistical Analysis

The EMG lower back muscle activity was the only data set which was not significantly different from a normal distribution, while all the other data was not normally distributed ($p < 0.05$). Thus, repeated measures analysis of variance (ANOVA) was used to analyze the lower back EMG muscle activity, but the rest of the data was analyzed using the non-parametric Friedman test using IBM SPSS Statistics (SPSS Inc., Chicago, IL). A significance level ($\alpha$) of 5% was used. The dependent variables consisted of: the average EMG activities of the shoulder and low back muscles, the ratings on each NASA-TLX scale, the overall NASA, the number of correct, and % error.

For the low back EMG data, two models were examined, which were:

- Model 1 (*P(2) * M(2)*) which consisted of two factors, the physical factor with two levels (normal and awkward static lifts) and the mental factor with two levels (absence of psychosocial stress and presence of mental math alone).
- Model 2 (*P(2) * T(2) * D(2)*) which consisted of three factors: the physical factor with two levels (normal and awkward static lifts), time pressure with two levels (absence and presence of time pressure), and distraction with two levels (absence and presence of distraction). In this model, the mental task was always present and therefore was not analyzed. The purpose of this second model was to investigate the interactions between the psychosocial factors.

Post-hoc tests were performed for the parametric test using pairwise comparisons of estimated marginal means with a Bonferroni adjustment. For the data sets that were tested using the non-parametric Friedman test, post-hoc pairwise comparisons were performed using a Wilcoxon Signed Ranks test to identify the specific pairs that were significantly different. The Wilcoxon signed-rank test is a non-parametric test used for paired data to assess whether their median difference is equal to zero. When testing the psychosocial factor effect at each posture (neutral and awkward) for the trapezius EMG data and NASA-TLX data, the critical alpha value $\alpha$ was adjusted using Bonferroni's inequality ($\alpha' = \alpha/k = 0.005$ where k is the number of tests undertaken = 10). Also, when testing the factor effects on the math performance measures, the critical alpha value $\alpha$ was adjusted using Bonferroni's inequality ($\alpha' = \alpha/k = 0.008$ where k is the number of tests undertaken = 6).

# CHAPTER 3

# RESULTS

## 3.1. EMG

### *3.1.1. Lower Back Muscle Activity*

This section presents the results of the analysis of the low back muscle activity. In checking for outliers, there was one outlier in the low back EMG data. Since this data point was unusual and could possibly be a result of noise in the EMG signal, the data for that one participant was excluded for this dependent variable in all the models.

#### 3.1.1.1. Model 1: P (2)*M (2)

Table 2 summarizes the p-values from the ANOVA output for the main and interaction effects for the lower back EMG.

**Table 2.** The ANOVA p-values of the main and interaction effects associated with the lower back EMG data. Values with asterisks (*) represent significant p-values.

| **Effect** | **ANOVA p-value** |
|---|---|
| Physical | <0.0005* |
| Mental | 0.02* |
| Physical*Mental | 0.42 |

In this model the Physical*Mental interaction effect was not significant, so the individual main effects were studied individually.

3.1.1.1.1. Physical Factor's Effect

The physical factor had a significant effect on the EMG lower back. Table 3 presents the mean (standard error) EMG activity of the lower back when holding a weight in a normal and awkward posture. As so, the mean EMG activity of lower back was significantly lower in a normal posture as compared to an awkward posture ($p < 0.05$).

**Table 3.** Mean (standard error) EMG lower back muscle activity associated with each level of the physical main effect. The asterisk (*) indicates a significant p-value.

| | **Low Back EMG (%MVC)** | **p-value** |
|---|---|---|
| **Normal Posture** | 19.4(1.9) | <0.0005* |
| **Awkward Posture** | 33.2(2.4) | |

3.1.1.1.2. Mental Factor's Effect

The mental factor had a significant effect on the EMG lower back. Table 4 presents the mean (standard error) EMG activity of the lower back when holding a weight in the absence of psychosocial stress and in the presence of mental math alone. As so, the mean EMG activity of lower back was significantly higher in the absence of psychosocial stress compared to the presence of mental math alone ($p < 0.05$).

**Table 4.** Mean (standard error) EMG lower back muscle activity associated with each level of the mental main effect. The asterisk (*) indicates a significant p-value.

| | **Low Back EMG (%MVC)** | **p-value** |
|---|---|---|
| **Absence of Psychosocial Stress** | 27.7(2.3) | 0.02* |
| **Presence of Mental Math Alone** | 24.9(1.6) | |

3.1.1.2. Model 2: P (2)*T (2)*D (2)

Table 5 summarizes the p-values from the ANOVA output for the main and interaction effects for the lower back EMG.

**Table 5.** The ANOVA p-values of the main and interaction effects associated with the lower back EMG data. Values with asterisks (*) represent significant p-values.

| **Effect** | **ANOVA p-value** |
|---|---|
| Physical | <0.0005* |
| Time Pressure | 0.04* |
| Distraction | 0.46 |
| Physical*Time Pressure | 0.06 |
| Physical*Distraction | 0.45 |
| Time Pressure*Distraction | 0.08 |
| Physical*Time Pressure*Distraction | 0.92 |

In this model, all the interaction effects were not significant, so the individual main effects – including physical, time pressure, and distraction – were studied individually.

3.1.1.2.1. Physical Factor's Effect

The physical factor as in the previous model had a significant effect on the EMG lower back. Table 6 presents the mean (standard error) EMG activity of the lower back when holding a weight in a normal and awkward posture. As so, the mean EMG activity of the lower back was significantly lower in a normal posture as compared to an awkward posture ($p < 0.05$).

**Table 6.** Mean (standard error) EMG lower back muscle activity associated with each level of the physical main effect. The asterisk (*) indicates a significant p-value.

| | **Low Back EMG (%MVC)** | **p-value** |
|---|---|---|
| **Normal Posture** | 19.7(1.8) | <0.0005* |
| **Awkward Posture** | 31.7(2.2) | |

3.1.1.2.2. Time Pressure Factor's Effect

The time pressure factor had a significant effect on the EMG of the lower back. Table 7 presents the mean (standard error) EMG activity of the lower back when holding a weight in the absence and presence of time pressure. As so, the mean EMG activity of the lower back was significantly lower in the absence of time pressure as compared to the presence of time pressure ($p < 0.05$).

**Table 7.** Mean (standard error) EMG lower back muscle activity associated with each level of the time pressure main effect. The asterisk (*) indicates a significant p-value.

| | **Low Back EMG (%MVC)** | **p-value** |
|---|---|---|
| **Absence of Time Pressure** | 25.1(1.7) | 0.041* |

| | | |
|---|---|---|
| **Presence of Time Pressure** | 26.3(1.8) | |

3.1.1.2.3. Distraction Factor's Effect

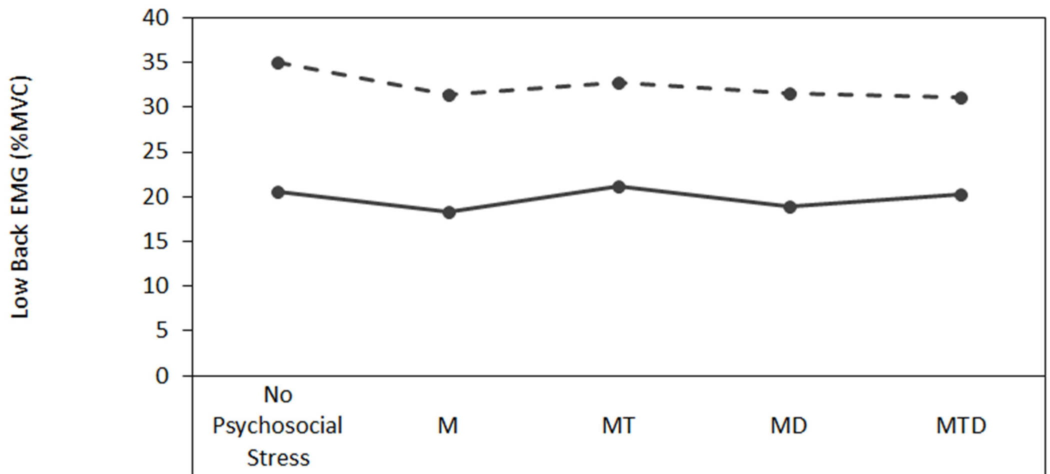
The main effect for distraction was not statistically significant in the data of the lower back EMG. In other words, there was no sufficient evidence to show that the lower back EMG means were different between the presence and absence of distraction as shown in Table 8.

**Table 8.** Mean (standard error) EMG lower back muscle activity associated with each level of the distraction main effect.

| | **Low Back EMG (%MVC)** | **p-value** |
|---|---|---|
| **Absence of Distraction** | 25.9(1.7) | 0.46 |
| **Presence of Distraction** | 25.5(1.8) | |

3.1.1.3. Across All Levels

The graph shown in Figure 5 summarizes the low back EMG means across all levels. As can be seen in the graph, the awkward low back EMG was always greater than the neutral low back EMG. Also for the same physical posture (neutral or awkward), the low back EMG activity in the presence of psychosocial stress (M, MT, MD, MTD) was always less than low back EMG in the absence of psychosocial stress except in the case of trial N_MT which had higher low back EMG than trial N.




| | No Psychosocial Stress | M | MT | MD | MTD |
|---|---|---|---|---|---|
| Neutral | 20.5 (9.1) | 18.3 (5.9) | 21.2 (6.4) | 19.0 (7.4) | 20.2 (7.8) |
| Awkward | 35.0 (10.4) | 31.5 (8.2) | 32.8 (9.1) | 31.6 (8.2) | 31.1 (8.3) |

**Figure 5**. Low Back EMG means (standard deviation) for all combinations of the physical and psychosocial factors.

### *3.1.2. Trapezius Muscle Activity*

This section presents the results of the analysis of trapezius muscle activity. In checking for outliers, there were outliers from two participants identified in the data. However, the outliers were kept because the actual data was like that. Also, the non-parametric tests are not affected by outliers, so these points were kept to gain more insight about the data.

<u>3.1.2.1. Psychosocial Factor Effect in the Neutral Posture</u>

A non-parametric one-way Friedman test was used to determine whether any significant differences existed between the five levels of the psychosocial factor (absence of psychosocial stress, presence of mental math alone, presence of mental math with time pressure, presence of mental math with distraction, presence of mental math with time pressure and distraction) while holding the weight in a neutral posture. As so, there was no significant differences in the median EMG trapezius muscle activity between the five levels (Friedman p-value = 0.12) as shown in Figure 6.

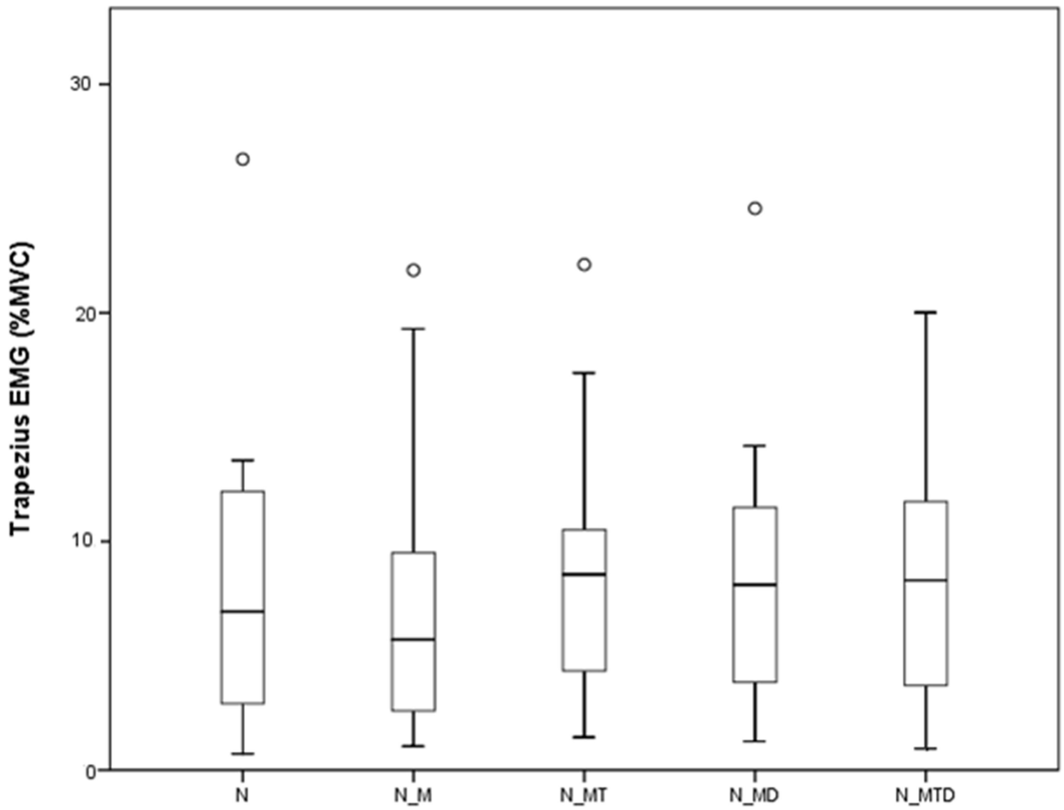



**Figure 6.** Boxplot of EMG trapezius muscle activity across all psychosocial factor levels in the neutral posture.

<u>3.1.2.2. Psychosocial Factor Effect in the Awkward Posture</u>

A non-parametric one-way Friedman test was used to determine whether any significant differences existed between the five levels of the psychosocial factor (absence of psychosocial stress, presence of mental math alone, presence of mental math with time pressure, presence of mental math with distraction, presence of mental math with time pressure and distraction) while holding the weight in an awkward posture. As so, there was a significant difference in medians between at least two factor levels when the weight was held in an awkward posture (Friedman p-value = 0.05).

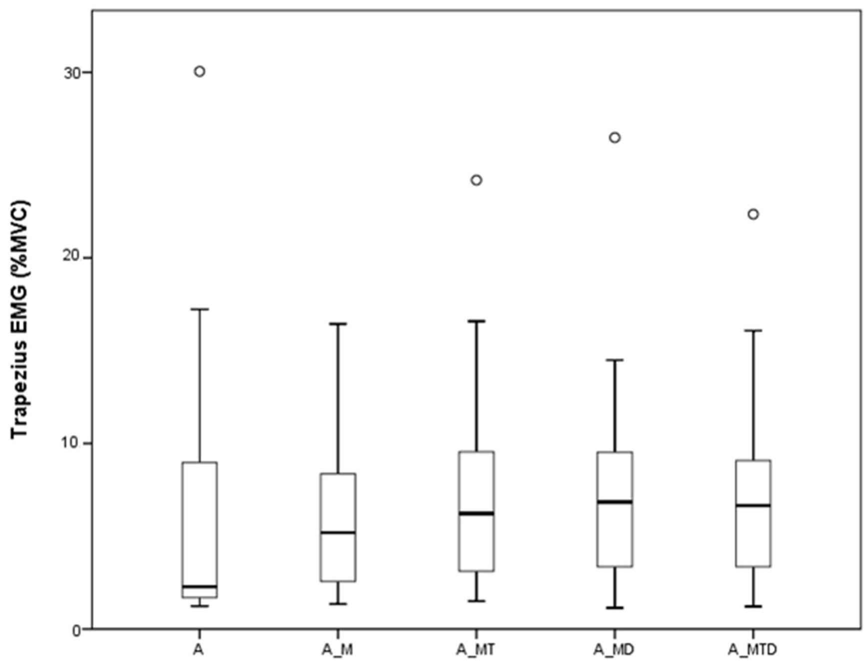



**Figure 7.** Boxplot of EMG trapezius muscle activity across all psychosocial factor levels in the awkward posture.

As shown in Figure 7, after the Bonferroni adjustment for multiple comparisons was applied, post hoc tests showed no significant differences between medians. But if the adjustment was not applied and the significance level was left at 0.05, the median EMG activity of the trapezius muscle during the mental math alone was significantly less than the median EMG activity during the mental math with time pressure (Wilcoxon p = 0.01; A_M versus A_MT). Also, the median EMG activity during the mental math alone was significantly less than the median EMG activity during the mental math with distraction (Wilcoxon p = 0.04; A_M versus A_MD).

3.1.2.3. Physical Factor's Effect

To test whether the physical factor had an effect on the EMG trapezius muscle activity, Wilcoxon was applied to compare between pairs having different postures but same psychosocial level.

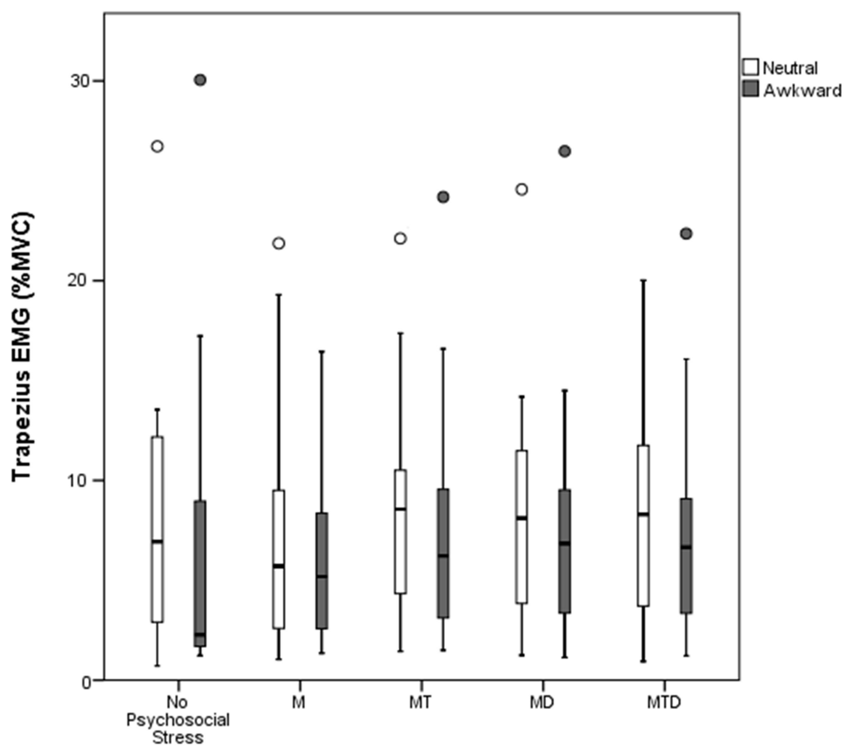



**Figure 8.** Boxplot of EMG trapezius muscle activity comparing the neutral and awkward postures under each psychosocial factor level

.

As shown in Figure 8, Wilcoxon showed no significant difference at $\alpha=0.05$ between groups having same psychosocial level but different level of posture so there was no effect for physical factor on trapezius EMG muscle activity.

## 3.2. NASA TLX

This section presents the results for all measures related to the NASA-TLX. In checking for outliers, there were outliers identified in the different data sets. However, the outliers were kept because these were the actual responses of the participants. Also, the non-parametric tests are not affected by outliers, so these points were kept to gain more insight about the data.

### *3.2.1. Psychosocial Factor's Effect When Posture Is Neutral*

To test if there were any significant difference between five levels of psychosocial factors (absence of psychosocial stress, presence of mental math alone, presence of mental math with time pressure, presence of mental math with distraction, presence of mental math with time pressure and distraction) while holding physical (normal) posture as a constant, non parametric one-way Friedman test was used for all NASA TLX dependent variables (Table 9). Table 9 shows the median (interquartile range) of NASA TLX scales during the specific trials. As so, there was no significant difference in physical demand between the five levels of psychosocial factors while holding the weights in a neutral posture. However, there was a significant difference in medians of mental and temporal demand, performance, effort, frustration, and overall NASA between at least two factor levels when the weight was held in a neutral posture.

**Table 9.** Median (interquartile range) NASA TLX ratings across all psychosocial factor levels in the neutral posture. Within each NASA TLX scale, medians without at least one letter in common are considered significantly different from each other. P-values with asterisks (*) represent significant p-values.

| NASA TLX | N | N_M | N_MT | N_MD | N_MTD | Friedman p-value |
|---|---|---|---|---|---|---|
| Mental Demand | 0.0(0.0)[a] | 40.0(22.5)[b] | 55.0(32.5)[bc] | 50.0(17.5)[bc] | 60.0(27.5)[c] | <0.0005* |
| Physical Demand | 25.0(35.0)[a] | 25.0(15.0)[a] | 25.0(32.5)[a] | 25.0(32.5)[a] | 35.0(32.5)[a] | 0.52 |
| Temporal Demand | 0.0(10.0)[a] | 40.0(30.0)[b] | 50.0(22.5)[bc] | 50.0(30.0)[b] | 60.0(20.0)[c] | <0.0005* |
| Performance | 5.0(7.5)[a] | 30.0(25.0)[b] | 35.0(15.0)[b] | 25.0(22.5)[b] | 30.0(22.5)[b] | <0.0005* |
| Effort | 20.0(30.0)[a] | 50.0(22.5)[ab] | 55.0(27.5)[b] | 50.0(27.5)[b] | 50.0(22.5)[b] | <0.0005* |
| Frustration | 10.0(17.5)[a] | 20.0(37.5)[ab] | 40.0(40.0)[b] | 35.0(50.0)[ab] | 30.0(47.5)[ab] | 0.004* |
| Overall NASA | 10.0 (17.9)[a] | 33.3 (17.5)[b] | 40.8 (20.4)[bc] | 36.7 (18.8)[bc] | 45.8 (13.8)[c] | <0.0005* |

As shown in Table 9 for the mental demand scale, all participants agreed that holding the weights alone without solving any mental math equations (trial N) required no mental demand, so this experimental condition always had a significantly less mental demand median when compared with other experimental conditions (N_M,N_MT,N_MD,N_MTD). Moreover, the median of the mental demand in the N_M trial was significantly less than the median of mental math in the N_MTD trial. While for the temporal demand, the median of trial N was significantly less than the medians of trials N_M, N_MT, N_MD, and N_MTD. Moreover, the temporal demand median of N_MTD was significantly more than the medians of the N_M and N_MD trials. Regarding performance, all participants agreed that they performed very well when only a physical task was involved (holding the weights). Therefore, the median of the performance of N trial was less than (a lower score is an indication of a better performance) the median of performance of all the other trials For effort, the median for N trial was significantly less than the median of effort for N_MT, N_MD, and N_MTD trials. For frustration, the median was significantly less in N trial than N_MT trial. Regarding the overall NASA score, the median was significantly less in N trial than the median of overall NASA in each of N_M, N_MT, N_MD, and N_MTD trials. Moreover, the median of the overall NASA of N_M trial was significantly less than the median of overall NASA in N_MTD trial.

### *3.2.2. Psychosocial Factor's Effect When Posture Is Awkward*

To test if there were any significant difference between five levels of psychosocial factors (absence of psychosocial stress, presence of mental math alone, presence of mental math with time pressure, presence of mental math with distraction, presence of mental math with time pressure and distraction) while holding physical (awkward) posture as a constant, non parametric one-way Friedman test was used (Table 10). Table 10 shows the median (interquartile range) of NASA TLX scales during the specific trials. As so, there was no significant difference in physical demand between the five levels of psychosocial factors while holding the weights in an awkward posture. However, there was a significant difference in medians of mental and temporal demand, performance, effort, frustration, and overall NASA between at least two factor levels when the weight was held in an awkward posture.

**Table 10.** Median (interquartile range) NASA TLX ratings across all psychosocial factor levels in the awkward posture. Within each NASA TLX scale, medians without at least one letter in common are considered significantly different from each other. P-values with asterisks (*) represent significant p-values.

| NASA TLX | A | A_M | A_MT | A_MD | A_MTD | Friedman p-value |
|---|---|---|---|---|---|---|
| Mental Demand | 0.0(0.0)$^{a}$ | 40.0(30.0)$^{b}$ | 50.0(30.0)$^{bc}$ | 50.0(17.5)$^{bc}$ | 70.0(27.5)$^{c}$ | <0.0005* |
| Physical Demand | 40.0(27.5)$^{a}$ | 50.0(32.5)$^{a}$ | 50.0(42.5)$^{a}$ | 50.0(40.0)$^{a}$ | 50.0(35.0)$^{a}$ | 0.88 |
| Temporal Demand | 10.0(25.0)$^{a}$ | 30.0(17.5)$^{b}$ | 65.0(22.5)$^{c}$ | 50.0(25.0)$^{b}$ | 70.0(17.5)$^{c}$ | <0.0005* |
| Performance | 5.0(12.5)$^{a}$ | 25.0(12.5)$^{b}$ | 40.0(15.0)$^{c}$ | 35.0(22.5)$^{bc}$ | 40.0(30.0)$^{c}$ | <0.0005* |
| Effort | 20.0(35.0)$^{a}$ | 40.0(30.0)$^{ac}$ | 65.0(27.5)$^{b}$ | 60.0(32.5)$^{bc}$ | 60.0(25.0)$^{bc}$ | <0.0005* |
| Frustration | 5.0(20.0)$^{a}$ | 25.0(25.0)$^{ab}$ | 35.0(47.5)$^{b}$ | 35.0(37.5)$^{b}$ | 50.0(45.0)$^{b}$ | <0.0005* |
| Overall NASA | 16.7 (13.8)$^{a}$ | 34.2 (17.9)$^{b}$ | 50.8 (15.0)$^{cd}$ | 42.5 (15.0)$^{bc}$ | 53.3 (23.3)$^{d}$ | <0.0005* |

As shown in Table 10, for mental demand, all participants agreed that holding the weights alone without solving any mental math equations (trial A) required no mental demand, so the A trial always had significantly less mental demand median when compared with other trials (A_M,A_MT,A_MD,A_MTD) . Moreover, the median of the mental demand in the A_M trial was significantly less than the median of mental math in the A_MTD trial. Regarding temporal demand, the median in A trial was significantly less than median of temporal demand of each of A_M, A_MT, A_MD, and A_MTD trials. Moreover, the median of temporal demand of A_MTD trial was significantly more than the median of the temporal demand of each of A_M and A_MD trials. Likewise, the median of temporal demand of A_MTD trial was significantly more than the median of the temporal demand of each of A_M and A_MD trials. Also, the median of temporal demand of A_MT trial was significantly more than the median of the temporal demand of each of A_MD and A_M trials. For performance scale, all participants agreed that they performed very well when only a physical task was involved (holding the weights). Therefore, the median of the performance of A trial was less than (a lower score is an indication of a better performance) the median of performance of all the other trials (A_M, A_MT, A_MD, and A_MTD). Also the median of the performance of A_M trial was less than the median of performance of each of A_MT and A_MTD trials. For effort scale, the median of effort in A trial was significantly less than the median of effort in each of A_MT, A_MD and A_MTD trials. Also the median of effort in A_MT trial was significantly more than the median of effort in A_M trial. For frustration scale, the median in A trial was significantly less than the median of frustration in each of A_MT, A_MD and A_MTD trials. Regarding overall NASA, the median was significantly less in A trial than the median of overall NASA in each of A_M, A_MT, A_MD, and A_MTD trials. Moreover, the median of overall NASA of A_MTD trial was significantly more than the median of overall NASA in A_MD and A_M trials. Also, the median of overall NASA of A_MT trial was significantly more than the median of overall NASA in A_M trial.

### *3.2.3. Physical Factor's Effect*

To test whether the physical factor had an effect on NASA TLX scales, Wilcoxon was applied to compare between pairs having different postures but same psychosocial level as shown in Table 11.

**Table 11.** Median (interquartile range) NASA TLX ratings comparing the neutral and awkward postures under each psychosocial factor level. Within each NASA TLX scale and psychosocial factor level, medians without at least one letter in common are considered significantly different from each other.

| | No Psychosocial Stress | | M | | MT | | MD | | MTD | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | A | N | A | N | A | N | A | N | A |
| Mental Demand | 0.0 (0.0)[a] | 0.0 (0.0)[a] | 40.0 (22.5)[a] | 40.0 (30.0)[a] | 55.0 (32.5)[a] | 50.0 (30.0)[a] | 50.0 (17.5)[a] | 50.0 (17.5)[a] | 60.0 (27.5)[a] | 70.0 (27.5)[a] |
| Physical Demand | 25.0 (35.0)[a] | 40.0 (27.5)[b] | 25.0 (15.0)[a] | 50.0 (32.5)[b] | 25.0 (32.5)[a] | 50.0 (42.5)[b] | 25.0 (32.5)[a] | 50.0 (40.0)[b] | 35.0 (32.5)[a] | 50.0 (35.0)[b] |
| Temporal Demand | 0.0 (10.0)[a] | 10.0 (25.0)[b] | 40.0 (30.0)[a] | 30.0 (17.5)[a] | 50.0 (22.5)[a] | 65.0 (22.5)[a] | 50.0 (30.0)[a] | 50.0 (25.0)[a] | 60.0 (20.0)[a] | 70.0 (17.5)[b] |
| Performance | 5.0 (7.5)[a] | 5.0 (12.5)[a] | 30.0 (25.0)[a] | 25.0 (12.5)[a] | 35.0 (15.0)[a] | 40.0 (15.0)[b] | 25.0 (22.5)[a] | 35.0 (22.5)[a] | 30.0 (22.5)[a] | 40.0 (30.0)[a] |
| Effort | 20.0 (30.0)[a] | 20.0 (35.0)[a] | 50.0 (22.5)[a] | 40.0 (30.0)[a] | 55.0 (27.5)[a] | 65.0 (27.5)[a] | 50.0 (27.5)[a] | 60.0 (32.5)[a] | 50.0 (22.5)[a] | 60.0 (25.0)[a] |
| Frustration | 10.0 (17.5)[a] | 5.0 (20.0)[a] | 20.0 (37.5)[a] | 25.0 (25.0)[a] | 40.0 (40.0)[a] | 35.0 (47.5)[a] | 35.0 (50.0)[a] | 35.0 (37.5)[a] | 30.0 (47.5)[a] | 50.0 (45.0)[b] |
| Overall | 10.0 (17.9)[a] | 16.7 (13.8)[b] | 33.3 (17.5)[a] | 34.2 (17.9)[a] | 40.8 (20.4)[a] | 50.8 (15.0)[b] | 36.7 (18.8)[a] | 42.5 (15.0)[b] | 45.8 (13.8)[a] | 53.3 (23.3)[b] |

As shown in Table 11, for mental demand, Wilcoxon showed no significant difference at α=0.05 between groups having same psychosocial level but different level of posture so there was no effect for physical factor on mental demand. While for physical demand, Wilcoxon showed significant difference at α=0.05 between all groups having same psychosocial level but different levels of posture so there was an effect for awkward physical factor on increasing physical demand on all psychosocial levels. For temporal demand, awkward posture increased temporal demand significantly for two psychosocial levels only (absence of psychosocial stress and MTD). For performance, awkward posture increased performance median (the higher the score, the worse the performance) significantly for one psychosocial level only (MT). For effort, Wilcoxon showed no significant difference at α=0.05 between groups having same psychosocial level but different level of posture so there was no effect for physical factor on effort. For frustration, awkward posture increased frustration significantly for one psychosocial level only (MTD). For overall NASA, awkward posture increased overall NASA significantly for all psychosocial levels except for one level only (M).

## 3.3. Math Performance Measures

This section presents the results of the analysis of the math performance measures. In checking for outliers, there were outliers identified in these measures. However, the outliers were kept because the actual data was like that. Also, the non-parametric tests are not affected by outliers, so these points were kept to gain more insight about the data.

### *3.3.1. Psychosocial Factor's Effect When Posture Is Neutral*

To test if there were any significant difference between five levels of psychosocial factors (absence of psychosocial stress, presence of mental math alone, presence of mental math with time pressure, presence of mental math with distraction, presence of mental math with time pressure and distraction) while holding physical (normal) posture as a constant, non parametric one-way Friedman test was used. As so, there was a significant difference in the median of math performance measures between at least two factor levels when the weight was held in a neutral posture (Friedman p-values for number of correct and % error were 0.01 and 0.003, respectively). As shown in Figure 9, the median of the number of correct in N_MT trial was significantly less than the median of the number of correct in each of N_M and N_MD trials. As shown in Figure 10, the median of % error in N_MT trial was significantly higher than the median of % error in the N_MD trial.

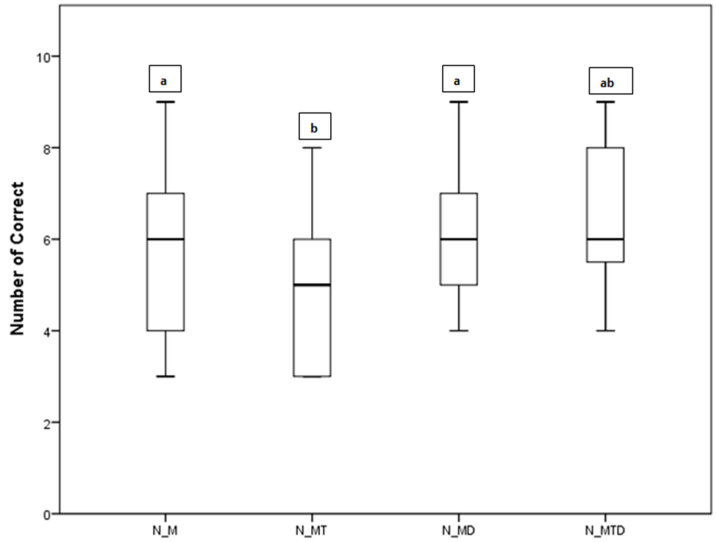



**Figure 9.** Boxplot of the number of correct responses for all psychosocial factor levels in the neutral posture. Medians without at least one letter in common are considered significantly different from each other.

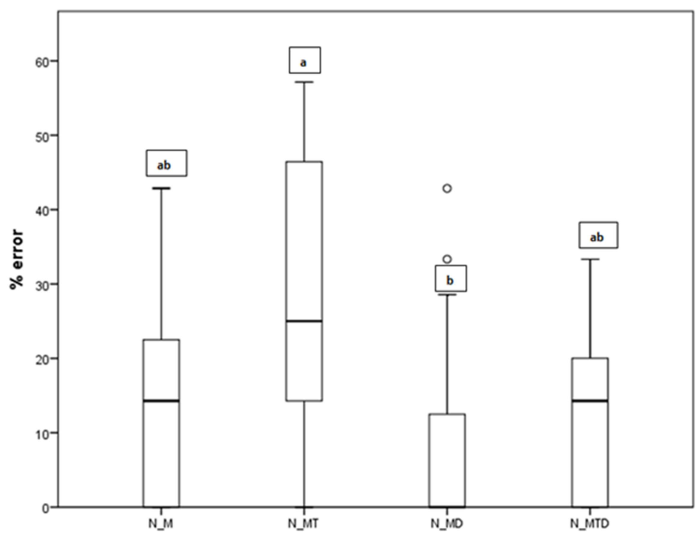



**Figure 10.** Boxplot of the %error for all psychosocial factor levels in the neutral posture. Medians without at least one letter in common are considered significantly different from each other.

### *3.3.2. Psychosocial Factor's Effect When Posture Is Awkward*

To test if there were any significant difference between five levels of psychosocial factors (absence of psychosocial stress, presence of mental math alone, presence of mental math with time pressure, presence of mental math with distraction, presence of mental math with time pressure and distraction) while holding physical (awkward) posture as a constant, non parametric one-way Friedman test was used. As so, as shown in Figures 11 and 12 there was no significant difference in the math performance measures between the five levels of psychosocial factors while holding the weights in an awkward posture (Friedman p-value for number of correct=0.07 and 0.81 for % error).

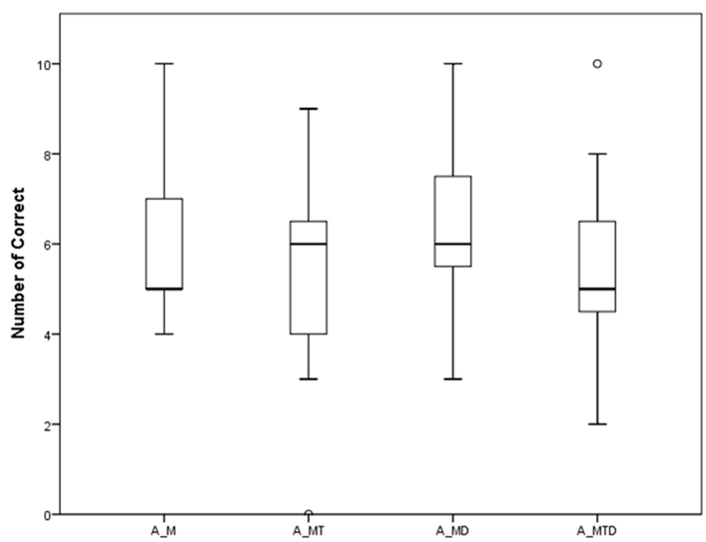



**Figure 11**. Boxplot of the number of correct responses for all psychosocial factor levels in the awkward posture.

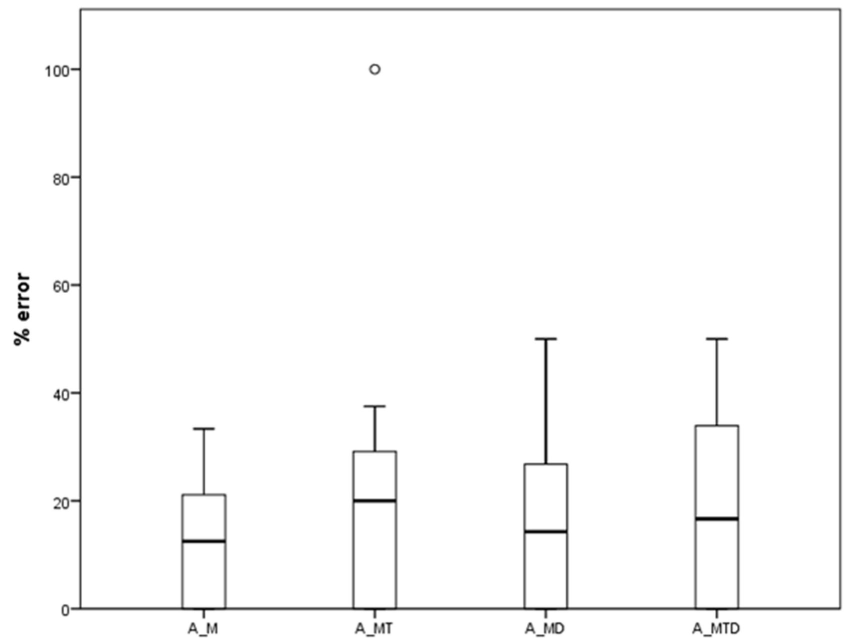



**Figure 12.** Boxplot of the %error for all psychosocial factor levels in the awkward posture.

### *3.3.3. Physical Factor's Effect*

To test whether the physical factor had an effect on math performance measures, Wilcoxon was applied to compare between pairs having different postures but same psychosocial level.

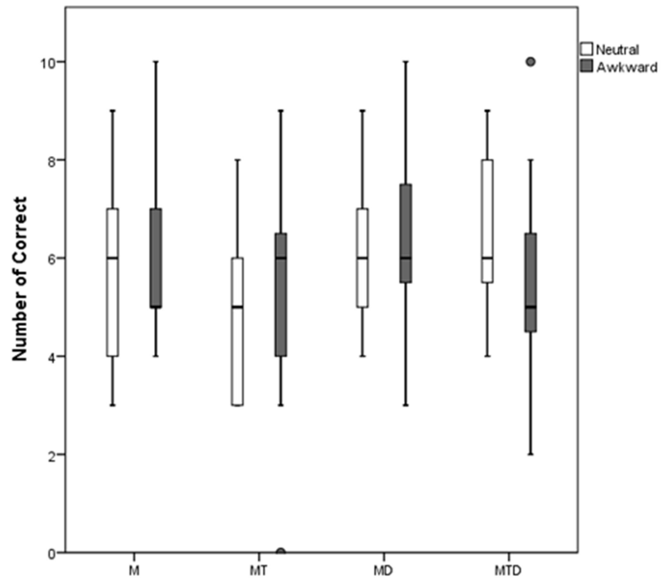



**Figure 13.** Boxplot of the number of correct responses comparing the neutral and awkward postures under each psychosocial factor level.

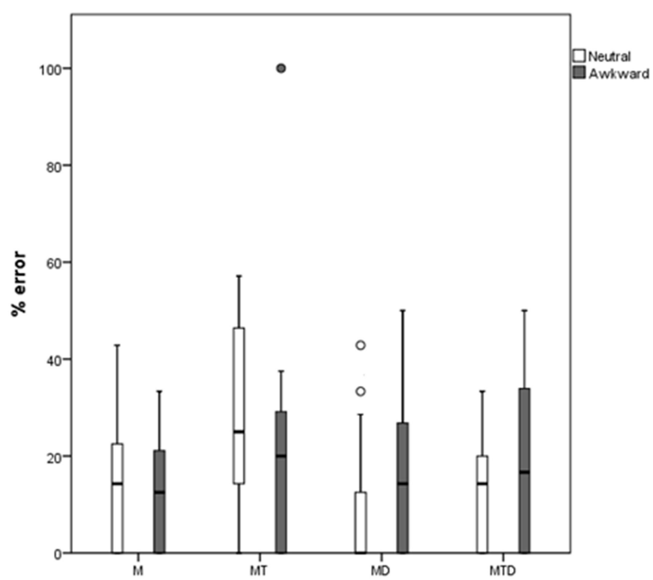



**Figure 14.** Boxplot of the %error comparing the neutral and awkward postures under each psychosocial factor level.

At each level of the psychosocial factor, the Wilcoxon signed rank test showed no significant differences between the medians of the neutral and awkward postures, in terms of the number correct (Figure 13) and % error (Figure 14).

# CHAPTER 4

# DISCUSSION

This study investigated the impact of concurrent physical (neutral and awkward postures in a static lift) and psychosocial factors (mental demands, time pressure, and distractions) on muscle activity of the low back and shoulder, NASA- TLX scores, and cognitive performance. The findings of this study showed that low back muscle activity during a physical task decreased when a mental task was introduced. A past study has shown an increase in muscular activity when participants had to focus on maintaining a fixed posture (postural stabilization) (Waersted, 2000). In the absence of a mental task, participants in this research may have focused on maintaining the postural requirements of the task, but the addition of the mental task perhaps served as a positive distraction from the physical task that led to a decrease in muscle activity. This result agreed with the findings of Mehta & Agnew (2011), who showed a decrease in shoulder muscle activity in the presence of a mental task. Such a decrease was more evident for high physical loads (45% MVC or more of upper extremity exertion during a task requiring participants to pull a handle). In the present study, however, varying physical loads was not investigated.

Comparing between mental task trials, it was shown that time pressure in a mental task contributed to an increase in low back muscle activity. Under the time pressure condition, participants were urged to answer as many questions as possible, increasing their arousal and thus their muscle activity. This finding agreed with Waersted et al.'s (1994) study, which showed that the higher the level of stress, the higher the muscle activity was. Also, Davis et al. (2002) and Marras et al. (2000) showed an increase in spine compression when a lift was done simultaneously with complex mental tasks. Although this study examined a static rather than a dynamic task, Davis et al. (2002) found that mental stress could be one possible mechanism for mental processing to initiate the biomechanical loading of the spine. On the other hand, the distraction factor during the mental task did not have a significant effect on low back muscle activation. This could be attributed to the fact that participants were aware that distractions would be presented before the trial began, allowing them to prepare ahead of time in focusing only on the math equations.

As for the effects of the physical factor (posture) on low back EMG, it was shown that muscle activity was higher in the awkward posture than in the neutral, erect posture. Although the increase in low back muscular activity due to mental stress was small when compared to the increase caused by awkward postures, mental tasks still play a role in jobs where mental demands are frequently required and for long durations.

For the trapezius muscle activity, there were no significant differences in EMG values between the physical task alone and the physical task with a mental task. Flodgren et al. (2009) also showed that mental loads of short durations did not induce an increase in muscle activity when superimposed with a low repetitive physical task, but the latter study cannot be compared with the present study because of the difference in the methods; in the latter study participants were seated and required to push in a piston alternatively. On the other hand, Lundberg et al. (1994) showed that trapezius muscle activation (tension) increased when participants were exposed to mental demands, while performing shoulder abduction in a seated position. Similarly, other studies showed that muscle tension increased when mental tasks were presented (Iwanaga et al., 2000; Westgaard & Bjørklund, 1987); however, these studies did not examine the concurrent effects of both physical and mental tasks. Participants were seated without performing any physical effort. Moreover, muscle activity generation was shown to be attributed to three possible sources - in addition to biomechanical physical stress - which were the mental demands, the participant's emotional state and attitude, and individual characteristics and their inclination to be aroused (Waersted, 1997). Thus, no significant differences in trapezius muscle activity was found possibly because the mental tasks were not stressful enough for the participants or because the task duration was not long enough to affect the trapezius muscle activity. Moreover, due to individual differences, some participants were stressed as a result of the mental task while others were unaffected. For example, frustration in the presence of the mental task was very low for some participants (0 to 5) while others rated it as high (60 to 65), so the mental task was not perceived as stressful by all the participants. In reviewing the overall NASA-TLX results to check whether the experimental tasks were considered demanding enough among the participants, it could be seen that even the highest overall NASA score was only 53.33 (in the A_MTD trial), which is not considered a high score but rather a moderate score.

The effect of the physical factor on the trapezius muscle activity was not significant. This finding was as expected because the deviation from the neutral posture was at the back region, not at the shoulders. The upper arms remained vertically positioned in the awkward posture.

For all the NASA-TLX scales except the "physical demand" and "frustration" scales, higher ratings were recorded for tasks with psychosocial demands (time pressure and/or distractions) versus tasks with no psychosocial stress. Frustration showed significant differences when comparing the neutral posture with and without time pressure. Unlike distraction, time pressure resulted in psychosocial stress, possibly because participants could filter out the distractions by focusing only on the math equations. Whereas, time pressure may have been difficult to disregard, considering that participants were pressured to answer as fast as possible. In the case of the awkward posture, frustration ratings were significantly higher with versus without time pressure and/or distraction. Both the effects of time pressure and distraction were more evident when an awkward or non-neutral posture was required. Effort in the absence of psychosocial stress when compared with trials with mental task alone was not significantly different. However, comparing effort for trials with no psychosocial stress with trials with distraction and/or time pressure was significant. This shows that participants did not find the mental task alone to need as much effort as trials having a mental task with time pressure or distraction. The physical demands were always perceived higher in the awkward posture than in the neutral posture, which are in agreement with the EMG results of the low back. Also, the mean overall NASA score was significantly higher in the awkward posture than in the neutral posture, in nearly all cases of the psychosocial factor. This finding indicates that the additional posture requirement adds to the overall perceived workload of the task.

No significant differences were found in the math performance measures across most of the experimental conditions, indicating that cognition was not significantly affected by psychosocial stress or the posture. The stress induced in the experiments was not too much for the participant to handle nor was it for a long period of time (only 30 sec). Thus, participants did not feel mentally tired by the psychosocial or postural demands. However, only in the case of the neutral posture, adding time pressure decreased the number of correct responses. This finding may suggest that participants under time pressure were more concerned with solving as many problems as possible than solving correctly. When comparing time pressure to distraction in the neutral posture, math performance measures in distraction were significantly better than under time pressure. Again, under time pressure, participants may have been more focused on answering as many problems as possible rather than answering correctly; whereas, with distractions, participants may have become extra careful to answer correctly.

# CHAPTER 5

# RESEARCH LIMITATIONS

When interpreting the results of this study, there were several limitations to be considered. Due to budget constraints and the length of the experiment, only 15 participants were recruited which lead to a low power of 39%. There may have been more significant differences in the results, but they may have been undetected due to the low power. Thus, a future study can recruit more participants, which may lead to the detection of more statistically significant results. Also, the participants recruited for this study were only male university students, disregarding the effects of age. A future study can recruit participants from both genders and of different age groups. Moreover, participants were exposed to psychosocial factors for short durations (30 seconds), which may underestimate the true effect of such factors in practice where workers are exposed to such demands for several hours a day. Thus, the findings are limited only to short term exposure to psychosocial stress. A future study may investigate the long term exposure effects of psychosocial stress. Furthermore, the psychosocial factors in this study due to their short durations were not mentally fatiguing in nature. More mentally-demanding tasks may have led to different results, which could be examined in a future study. Another limitation of this study was that it did not account for individual differences, such as the participants' personality type (e.g. feeling vs. thinking).

# CHAPTER 6

# CONCLUSIONS

In conclusion, this study's experimental design was the first of its kind as it explored the effects of postural demand and psychosocial factors on the low back and shoulder muscle activity, NASA-TLX scores, and math performance measures. Regarding low back muscle activity, the addition of a mental task to a static physical task can actually reduce tension in the low back muscle. However, adding time pressure to the task could significantly increase muscle tension. On the other hand, shoulder muscle activity was not significantly affected by the different physical and psychosocial factors. The lack of significant differences in the shoulder muscle activity could be attributed to the low statistical power, short durations of the experimental trials, and/or the fact that the mental tasks were not perceived as mentally demanding. For NASA-TLX scores, nearly all scales showed an increase in ratings when psychosocial factors were added with the physical task. Finally, math performance measures were not significantly different in nearly all the experimental conditions, indicating that minor or moderate increases in physical and/or psychosocial demands do not significantly affect mental performance.

# REFERENCES


- Ando, S., Ono, Y., Shimaoka, M., Hiruta, S., Hattori, Y., Hori, F., & Takeuchi, Y. (2000). Associations of self-estimated workloads with musculoskeletal symptoms among hospital nurses. *Occupational and environmental medicine*, *57*(3), 211-211.
- Bongers, P. M., de Winter, C. R., Kompier, M. A., & Hildebrandt, V. H. (1993). Psychosocial factors at work and musculoskeletal disease. *Scandinavian journal of work, environment & health*, 297-312.
- BQ Hafen, WWK Hoeger (1994), Wellness: Guidelines for a healthy lifestyle. Englewood, Colo.: Morton Pub. Co.
- Callister, R. O. B. I. N., Suwarno, N. O., & Seals, D. R. (1992). Sympathetic activity is influenced by task difficulty and stress perception during mental challenge in humans. *The Journal of physiology*, *454*(1), 373-387.
- Criswell, E. (2011). *Cram's introduction to surface electromyography*. Jones & Bartlett Publishers.
- Da Costa, B. R., & Vieira, E. R. (2010). Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. *American journal of industrial medicine*, *53*(3), 285-323.
- Davis, K. G., Marras, W. S., Heaney, C. A., Waters, T. R., & Gupta, P. (2002). The impact of mental processing and pacing on spine loading: 2002 Volvo Award in biomechanics. *Spine*, *27*(23), 2645-2653.
- De Luca, C.J. (1997) The Use of Surface Electromyography in Biomechanics. Journal of Applied Biomechanics, 13, 135-163.

- Ekstrom, R. A., Soderberg, G. L., & Donatelli, R. A. (2005). Normalization procedures using maximum voluntary isometric contractions for the serratus anterior and trapezius muscles during surface EMG analysis. *Journal of Electromyography and Kinesiology*, *15*(4), 418-428.
- Flodgren, G. M., Crenshaw, A. G., Gref, M., & Fahlström, M. (2009). Changes in interstitial noradrenaline, trapezius muscle activity and oxygen saturation during low-load work and recovery. *European journal of applied physiology*, *107*(1), 31.
- Frankenhaeuser, M., Lundberg, U., Fredrikson, M., Melin, B., Tuomisto, M., Myrsten, A. L., & Wallin, L. (1989). Stress on and off the job as related to sex and occupational status in white-collar workers. *Journal of Organizational Behavior*, *10*(4), 321-346.
- Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In *Advances in psychology* (Vol. 52, pp. 139-183). North-Holland.
- Iwanaga, K., Saito, S., Shimomura, Y., Harada, H., & Katsuura, T. (2000). The effect of mental loads on muscle tension, blood pressure and blink rate. *Journal of PHYSIOLOGICAL ANTHROPOLOGY and Applied Human Science, 19*(3), 135-141. doi:10.2114/jpa.19.135
- Knibbe, J. J., & Friele, R. D. (1996). Prevalence of back pain and characteristics of the physical workload of community nurses. *Ergonomics*, *39*(2), 186-198.
- Konrad, P. (2005). The ABC of EMG: A practical introduction to kinesiological electromyography. *version*, *1*, 29-33.

- Larsson, S. E., Larsson, R., Zhang, Q., Cai, H., & Öberg, P. Å. (1995). Effects of psychophysiological stress on trapezius muscles blood flow and electromyography during static load. *European journal of applied physiology and occupational physiology*, *71*(6), 493-498.
- Lundberg, U., Forsman, M., Zachau, G., Eklöf, M., Palmerud, G., Melin, B., & Kadefors, R. (2002). Effects of experimentally induced mental and physical stress on motor unit recruitment in the trapezius muscle. *Work & Stress*, *16*(2), 166-178.
- Lundberg, U., Kadefors, R., Melin, B., Palmerud, G., Hassmén, P., Engström, M., & Dohns, I. E. (1994). Psychophysiological stress and EMG activity of the trapezius muscle. *International journal of behavioral medicine*, *1*(4), 354-370.
- Lundberg, U. (2002). Psychophysiology of work: Stress, gender, endocrine response, and work-related upper extremity disorders. *American journal of industrial medicine*, *41*(5), 383-392.
- Marras, W. S., Davis, K. G., Heaney, C. A., Maronitis, A. B., & Allread, W. G. (2000). The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine. *Spine*, *25*(23), 3045-3054.
- McLean, L., Chislett, M., Keith, M., Murphy, M., & Walton, P. (2003). The effect of head position, electrode site, movement and smoothing window in the determination of a reliable maximum voluntary activation of the upper trapezius muscle. *Journal of Electromyography and Kinesiology*, *13*(2), 169-180.
- Mehta, R. K., & Agnew, M. J. (2011). Effects of concurrent physical and mental demands for a short duration static task. *International Journal of Industrial Ergonomics*, *41*(5), 488-493.

- Mehta, R. K., & Agnew, M. J. (2013). Exertion-dependent effects of physical and mental workload on physiological outcomes and task performance. *IIE Transactions on Occupational Ergonomics and Human Factors*, *1*(1), 3-15.
- Ng, J., & Richardson, C. (1994). EMG study of erector spinae and multifidus in two isometric back extension exercises. *Australian Journal of Physiotherapy*, *40*(2), 115-121.
- Nimbarte, A. D., Al Hassan, M. J., Guffey, S. E., & Myers, W. R. (2012). Influence of psychosocial stress and personality type on the biomechanical loading of neck and shoulder muscles. *International Journal of Industrial Ergonomics*, *42*(5), 397-405.
- Punnett, L., & Wegman, D. H. (2004). Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of electromyography and kinesiology*, *14*(1), 13-23.
- Tinubu, B. M., Mbada, C. E., Oyeyemi, A. L., & Fabunmi, A. A. (2010). Work-related musculoskeletal disorders among nurses in Ibadan, South-west Nigeria: a cross-sectional survey. *BMC Musculoskeletal disorders*, *11*(1), 12.
- U.S. Department of Labor, Bureau of Labor Statistics. (2016). Nonfatal Occupational Injuries and Illnesses Requiring Days Away From Work. Retrieved from https://www.bls.gov/news.release/osh2.toc.htm
- Waersted, M., Bjørklund, R. A., & Westgaard, R. H. (1991). Shoulder muscle tension induced by two VDU-based tasks of different complexity. *Ergonomics*, *34*(2), 137-150.

- Waersted, M., Bjørklund, R. A., & Westgaard, R. H. (1994). The effect of motivation on shoulder-muscle tension in attention-demanding tasks. *Ergonomics, 37*(2), 363-376. 10.1080/00140139408963652
- Wærsted, M. (1997).Attention- related muscle activity- a contributor to sustained occupational muscle load? An EMG study of the upper trapezius muscles during VDU- based work with minimal physical activity. Thesis, National Institute of Occupational Health/ Institute of General Practice and Community Medicine, University of Oslo, Oslo
- Wærsted, M. (2000). Human muscle activity related to non-biomechanical factors in the workplace. European Journal of Applied Physiology, 83(2), 151-158. doi:10.1007/s004210000273
- Waters, T. R., Dick, R. B., Davis-Barkley, J., & Krieg, E. F. (2007). A cross-sectional study of risk factors for musculoskeletal symptoms in the workplace using data from the General Social Survey (GSS). *Journal of Occupational and Environmental Medicine*, *49*(2), 172-184.
- WELFORD, A. T. (1973). Stress and performance. *Ergonomics*, *16*(5), 567-580.
- Westgaard, R. H., & Bjørklund, R. (1987). Generation of muscle tension additional to postural muscle load. *Ergonomics*, *30*(6), 911-923.
- World Health Organization. (2003). Protecting Workers' Health Series No. 5. *Preventing musculoskeletal disorders in the workplace*.
- Zanca, G. G., Oliveira, A. B., Ansanello, W., Barros, F. C., & Mattiello, S. M. (2014). EMG of upper trapezius− Electrode sites and association with clavicular kinematics. *Journal of Electromyography and Kinesiology*, *24*(6), 868-874.

**APPENDIX A**

## PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

| YES | NO | |
|---|---|---|
| ☐ | ☐ | 1. Has your doctor ever said you have a heart trouble? should only do physical activity recommended by a doctor? |
| ☐ | ☐ | 2. Do you frequently suffer from chest pain? |
| ☐ | ☐ | 3. Do you often faint or have spells of severe dizziness? |
| ☐ | ☐ | 4. Has your doctor ever said your blood pressure was too high? |
| ☐ | ☐ | 5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by, or might be made worse with exercise. |
| ☐ | ☐ | 6. Is there any good physical reason why you should not follow an activity program even if you want to? |
| ☐ | ☐ | 7. Are you 65 and not accustomed to vigorous exercise? |

If you answer "yes" to any question, vigorous exercise or exercise testing should be postponed. Medical clearance may be necessary.

I have read this questionnaire, I understand it does not provide medical assessment in lieu of a physical examination by a physician.

Participant's signature: __________________ Date: __________________

Investigator's signature: __________________ Date: __________________

---

Adopted from PAR-Q validation report, British Columbia department of Health, June 1975.

Reference: BQ Hafen, WWK Hoeger (1994), Wellness: Guidelines for a healthy

lifestyle. Englewood, Colo.: Morton Pub. Co.

## APPENDIX B

### American University of Beirut

### Consent to Participate in a Research Study

**Study Title:** The Effects of Concurrent Physical and Psychosocial Demands on Muscle Activation, Subjective Workload, and Performance

You are invited to participate in a biomedical research study conducted by the principle investigator of this study Dr. Saif Al-Qaisi, an Assistant Professor at the Faculty of Engineering and Architecture at the American University of Beirut, Rania Ghalayini, a Master student at the Industrial Engineering and Management Department at AUB (as part of her Master thesis), and Dr. Lina Younan, an Assistant Clinical Professor at the Hariri School of Nursing at the American University of Beirut.

Please read the information below and feel free to ask any questions that you may have.

**Recruitment Strategy**
Recruitment will be done through emails sent to all AUB students. The recruitment process will begin after obtaining IRB approval. The email will contain detailed information about the study (objective, duration, monetary compensation, risks, inclusion and exclusion criteria, and location). Participants will be provided with the experimenter's email address and will be advised to contact him if they want additional information. The participants will be males (since EMG sensor attachment requires the participants to be topless), AUB students with health insurance, between the ages of 18 and 29, and healthy with no history of back pain. Then the participants need to fill the PAR-Q questionnaire, only participants who pass the PAR-Q will be able to participate and asked for their written consent. Consent forms will be collected by Ms. Rania Ghalayini, and the consent form and the questionnaire administration will take place at the ergonomics lab located in AUB's SRB building where the experiment will take place. If participants have any questions, the experimenter is going make the adequate clarifications. Participants will conduct experimental trials, in a randomized manner.

**Description of the research and your participation**
The objective of this research will be to analyze the interaction effect of both physical and mental demands on workers' perceived workload, performance, and muscle tension, using an electromyography (EMG) device.

In this study, you will be asked as a part of 15 other participants to:

1. Attend a brief orientation session about the data collection procedures, and specifics of the experimental tasks.
2. Fill a questionnaire about your Physical Activity Readiness and some basic demographic information.
3. Subsequent to the warm-up session, EMG surface electrodes will be attached to the muscles of your back and shoulders after shaving any hair on the skin at either side of the upper trapezius and erector spinae muscles.
The electromyography device:

The EMG device measures muscle activation via electrodes placed over the muscle, providing information about the internal forces and load acting on the body.

4. After attaching the electrodes, you will be asked to perform the following tasks:
   a. Holding a 7 kg weight (while standing in an erect posture).
   b. Holding a 7 kg weight while answering math equations at a comfortable pace.
   c. Holding a 7 kg weight while answering math equations under time pressure.
   d. Holding a 7 kg weight while answering math equations while being distracted visually and verbally with incorrect answers.
   e. Holding a 7 kg weight while answering math equations under time pressure with distractions.
   f. Standing in an awkward posture with your back flexed at $20^{\circ}$ and repeating the above tasks.
   g. The order of the experimental tasks will be randomized.
5. EMG activity will be recorded throughout each trial.
6. After each trial, you will be asked to rate your perceived workload exertion by completing the NASA-TLX questionnaire.
7. The estimated time to complete this study is approximately two hours.

**Compensation**
Participants will be compensated with $10 for every hour of participation.

**Risks and discomforts**
There are minimal risks associated with this research. Prior to the data collection, the Physical Activity Readiness Questionnaire (PAR-Q, British Columbia Ministry of Health) will be used to screen participants for cardiac and other health problems, such as dizziness, chest pain, or heart trouble (Hafen and Hoeger, 1994). Any participant who answers yes to any of the questions on the PAR-Q will be excluded from the study.
The tasks have been designed to fall within the normal job performance, so the potential of physical discomfort is not expected to be any greater than that after a difficult work session. Thus, there may be some discomfort during performance of the tasks which may lead to fatigue and/or aching of the muscles. At least one minute of rest will be provided between trials, and if requested, you will be given more time to rest. In case discomfort or pain occurs, kindly inform the experimenter. You have the right to withdraw your consent or discontinue participation at any time for any reason. There may be further risks that are unforeseeable in this research study.

**Potential benefits**
You receive no direct benefits from participating in this research; however, your participation will help researchers understand the effects of concurrent physical and psychosocial demands on workers' mental performance and muscle activity. The findings may lead to recommendations to change the design of the workplace to make it safer and more efficient. The research may be published in academic journals and presented at international conferences.

**Protection of confidentiality**
There are no confidentiality risks associated with participating in the study. Your identity will remain confidential. The data will be stored on a password-protected computer that no one can access except for the PI and co-investigator. All data will be destroyed responsibly after the

required retention period (usually three years). Your identity will not be revealed in any report or publication resulting from this study.

**If you agree to participate in this research study, the information will be kept confidential. Unless required by law, only the study doctor and designee, the ethics committee and inspectors from the government agencies will have direct access to your medical records.**

**Voluntary participation**
Participation in this study is voluntary. You have the right to withdraw your consent or discontinue participation at any time for any reason. Your decision to withdraw will not involve any penalty or loss of benefits to which you are entitled. Discontinuing participation in no way affects your relationship with AUB. Also, refusal or withdrawal from the study will not affect your grades or academic standing.

**Investigator's Statement**
I have reviewed, in detail, the informed consent document for this research study with _________________ (name of participant, legal representative, or parent/guardian) the purpose of the study and its risks and benefits. I have answered to all the participant's questions clearly. I will inform the participant in case of any changes to the research study.

________________________ ____________________
Name of Investigator or designee Signature

___________________________
Date & Time

**Volunteer's Participation**
If you have any questions or concerns about the research you may contact Dr. Saif Al-Qaisi, email sa189@aub.edu.lb, Bechtel Building Room 533 at AUB, Phone Extension: 3479.

If you have any questions, concerns or complains about your rights as a participant in this research, you can contact the following office at AUB:
Biomedical Institutional Review Board
American University of Beirut
PO BOX: 11-0236 F15
Riad El Solh, Beirut 1107 2020
Lebanon
**Tel**: 00961 1 374374, ext: 5445, **Fax**: 000961 1 738025, **Email**: irb@aub.edu.lb

I have read and understood all aspects of the research study and all my questions have been answered. I voluntarily agree to be a part of this research study and I know that I can contact Dr. Saif Al Qaisi at ext 3479 or any of his/her designee involved in the study in case of any questions. If I feel that my questions have not been answered, I can contact the Institutional Review Board for human rights at ext 5445. I understand that I am free to withdraw this consent and discontinue participation in this project at any time, even after signing this form, and it will not affect my care or benefits. I know that I will receive a copy of this signed informed consent.

___________________________ ________________________________________
Name of Participant Signature

__________________________________
Date & Time

A copy of this consent form should be given to you.

# APPENDIX C

**American University of Beirut**

**Data Collection Sheet: Demographic Questionnaire, Subjective Ratings, and Math Equation Responses**

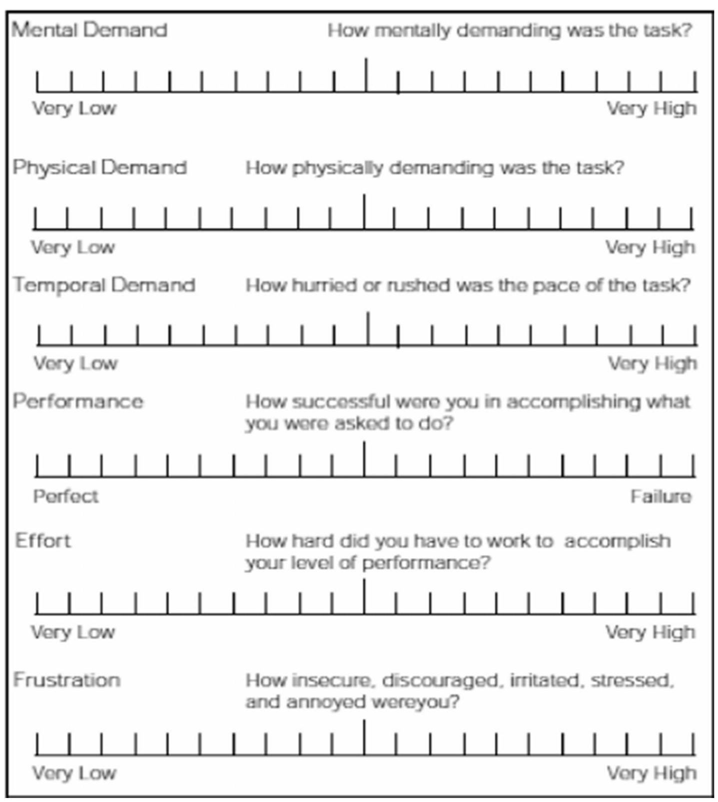
Name: __________________

Age: ____

Weight (kg): ____

Height (cm): ____

Mark your rating on each of the below scales (mental demand, physical demand, temporal demand, performance, effort, and frustration). Read the questions of each scale, and provide a rating that represents your perception of the task, which can be any value between 0 (very low) and 100 (very high). Note that each scale is divided in increments of 5. To mark your ratings, draw a vertical line that crosses the scale at your corresponding rating. Base your ratings solely on how you personally perceived the task to be, without considering the thoughts of others.


Mental Demand How mentally demanding was the task?
Very Low Very High
Physical Demand How physically demanding was the task?
Very Low Very High
Temporal Demand How hurried or rushed was the pace of the task?
Very Low Very High
Performance How successful were you in accomplishing what you were asked to do?
Perfect Failure
Effort How hard did you have to work to accomplish your level of performance?
Very Low Very High
Frustration How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low Very High

**Data Collection Sheet (to be filled by experimenter): NASA-TLX**

| Order of Trial | Trial | Mental Demand | Physical Demand | Temporal Demand | Performance | Effort | Frustration |
|---|---|---|---|---|---|---|---|
| | Neutral posture | | | | | | |
| | Awkward posture | | | | | | |
| | Neutral posture and math | | | | | | |
| | Awkward posture and math | | | | | | |
| | Neutral posture and math under time pressure | | | | | | |
| | Awkward posture and math under time pressure | | | | | | |
| | Neutral posture and math with distraction | | | | | | |
| | Awkward posture and math with distraction | | | | | | |
| | Neutral posture and math under time pressure and with distraction | | | | | | |
| | Awkward posture and math under time pressure and with distraction | | | | | | |

## Data Collection Sheet (For Experimenter): Math Responses

| math alone | | | | | |
|---|---|---|---|---|---|
| Neutral Posture | | | Awkward Posture | | |
| | Math Equations | Participant's Response | | Math Equations | Participant's Response |
| 1. | 97-42 | | 1. | 33-26 | |
| 2. | 31-24 | | 2. | 89-36 | |
| 3. | 86-55 | | 3. | 96-54 | |
| 4. | 62-14 | | 4. | 86-22 | |
| 5. | 97-32 | | 5. | 77-25 | |
| 6. | 87-12 | | 6. | 56-23 | |
| 7. | 77-35 | | 7. | 96-87 | |
| 8. | 89-64 | | 8. | 88-27 | |
| 9. | 53-12 | | 9. | 97-34 | |
| 10. | 49-23 | | 10. | 72-15 | |
| 11. | 85-36 | | 11. | 97-34 | |
| 12. | 99-54 | | 12. | 72-65 | |
| 13. | 43-15 | | 13. | 96-13 | |
| 14. | 75-13 | | 14. | 84-27 | |
| 15. | 93-58 | | 15. | 76-28 | |

| math under time pressure | | | | | |
|---|---|---|---|---|---|
| Neutral Posture | | | Awkward Posture | | |
| | Math Equations | Participant's Response | | Math Equations | Participant's Response |
| 1. | 89-31 | | 1. | 57-15 | |
| 2. | 73-56 | | 2. | 81-53 | |
| 3. | 52-19 | | 3. | 96-87 | |
| 4. | 98-15 | | 4. | 82-24 | |
| 5. | 65-24 | | 5. | 63-24 | |
| 6. | 85-72 | | 6. | 96-89 | |
| 7. | 93-45 | | 7. | 86-52 | |
| 8. | 74-32 | | 8. | 57-42 | |
| 9. | 52-13 | | 9. | 91-15 | |
| 10. | 63-25 | | 10. | 76-42 | |
| 11. | 78-21 | | 11. | 68-33 | |
| 12. | 86-44 | | 12. | 53-37 | |
| 13. | 78-12 | | 13. | 97-26 | |
| 14. | 87-32 | | 14. | 61-25 | |
| 15. | 76-57 | | 15. | 43-15 | |

| math with distraction | | | | | |
|---|---|---|---|---|---|
| Neutral Posture | | | Awkward Posture | | |
| | Math Equations | Participant's Response | | Math Equations | Participant's Response |
| 1. | 65-14 | | 1. | 88-23 | |
| 2. | 96-43 | | 2. | 91-52 | |
| 3. | 68-45 | | 3. | 85-34 | |
| 4. | 97-12 | | 4. | 96-85 | |
| 5. | 87-42 | | 5. | 25-13 | |
| 6. | 97-53 | | 6. | 96-87 | |
| 7. | 88-53 | | 7. | 95-32 | |
| 8. | 65-29 | | 8. | 96-71 | |
| 9. | 58-24 | | 9. | 76-55 | |
| 10. | 67-24 | | 10. | 52-22 | |
| 11. | 89-76 | | 11. | 98-33 | |
| 12. | 92-71 | | 12. | 33-22 | |
| 13. | 65-42 | | 13. | 54-26 | |
| 14. | 96-45 | | 14. | 86-77 | |
| 15. | 75-23 | | 15. | 89-75 | |

| math under time pressure and with distraction | | | | | |
|---|---|---|---|---|---|
| Neutral Posture | | | Awkward Posture | | |
| | Math Equations | Participant's Response | | Math Equations | Participant's Response |
| 1. | 94-32 | | 1. | 84-27 | |
| 2. | 75-43 | | 2. | 72-54 | |
| 3. | 96-84 | | 3. | 67-53 | |
| 4. | 95-33 | | 4. | 86-33 | |
| 5. | 85-42 | | 5. | 95-78 | |
| 6. | 53-21 | | 6. | 27-15 | |
| 7. | 87-55 | | 7. | 86-23 | |
| 8. | 41-23 | | 8. | 53-18 | |
| 9. | 81-25 | | 9. | 96-42 | |
| 10. | 76-34 | | 10. | 87-24 | |
| 11. | 51-43 | | 11. | 74-25 | |
| 12. | 96-78 | | 12. | 95-43 | |
| 13. | 87-42 | | 13. | 87-23 | |
| 14. | 98-25 | | 14. | 55-23 | |
| 15. | 76-54 | | 15. | 57-29 | |

______________________ ____________________________________

Name of Participant Signature

______________________________

Date & Time