

2009

## Neck muscles activity and upper body extremity angles in dynamic overhead lifting

Mohamed Wassim Mokrani

*Louisiana State University and Agricultural and Mechanical College*

Follow this and additional works at: [https://digitalcommons.lsu.edu/gradschool\\_theses](https://digitalcommons.lsu.edu/gradschool_theses)



Part of the [Construction Engineering and Management Commons](#)

---

### Recommended Citation

Mokrani, Mohamed Wassim, "Neck muscles activity and upper body extremity angles in dynamic overhead lifting" (2009). *LSU Master's Theses*. 370.

[https://digitalcommons.lsu.edu/gradschool\\_theses/370](https://digitalcommons.lsu.edu/gradschool_theses/370)

This Thesis is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Master's Theses by an authorized graduate school editor of LSU Digital Commons. For more information, please contact [gradetd@lsu.edu](mailto:gradetd@lsu.edu).

# **NECK MUSCLES ACTIVITY AND UPPER BODY EXTREMITY ANGLES IN DYNAMIC OVERHEAD LIFTING**

A Thesis

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Master of Science in Industrial Engineering  
in  
The Department of Construction Management & Industrial Engineering

by

Mohamed W Mokrani  
B.S., Industrial Engineering, Louisiana State University, 2006  
November, 2009

## **DEDICATION**

I dedicate this thesis to my mother, whose love, support and tenacious push for accompanied me all her life and who did not live to see the completion of this work. This is for you Mom, and I hope that you are proud of your son.

To my father, whose guidance and support were essential in this journey. He had to bear Mom's departure and teach me patience to overcome the time of hardship. His infinite love helped me to accomplish this work.

To my wife Imen, who supported me and never left my side during the past two years. To my son Mohamed Ameen, who brought joy and happiness to all the family. To my sisters Sana and Olfa, and my brother Karim, whose support and advice allowed me to accomplish this work.

## **ACKNOWLEDGMENTS**

First of all, I would like to thank God for the blessings he has given me and for the opportunity to accomplish this work.

I would like to thank my father Rachid, who was the most helpful and driving force for me during my academic years at LSU. I can never thank him enough for his love and for his role as the best father ever I could ask for.

I would like to thank my wife Imen, who supported me and never left my side. I thank her for her tolerance during the past year and a half. I also would like to give thanks to my family, Sana and Raouf; whom without them, I would not be where I am now. I give thanks to my sister, Dr. Olfa, who supported me all these years in every decision I have made, and to my brother Dr. Karim, whose financial support has helped me overcome hard times.

I would like to give special thanks to Dr. Fereydoun Aghazadeh, who saw in me many talents and helped them to flourish. Without his dedication and help, this work would not have become a reality. I would like to extend my sincere appreciation for the valuable advice he gave me as a student and as a friend.

I would like to thank the members of my committee, Dr Laura Ikuma and Dr Marwa Hassan, who provided me with all the help and encouragement to succeed in this work.

## Contents

DEDICATION .....	ii
ACKNOWLEDGMENTS .....	iii
ABSTRACT.....	viii
1. INTRODUCTION .....	1
2. BACKGROUND AND LITERATURE REVIEW .....	3
2.1 Introduction to the research in dynamic lifting above shoulder level. ....	3
2.1.1 Epidemiological study.....	3
2.1.2 Physiological study .....	5
2.1.3 Biomechanical Studies.....	6
3. STUDY .....	11
3.1 Rationale .....	11
3.2 Objectives .....	12
3.3 Hypothesis.....	13
4. METHODS AND PROCEDURE.....	15
4.1 Participants.....	15
4.2 Data Acquisition .....	16
4.2.1 Setting .....	16
4.2.2 Participant Preparation.....	18
4.2.3 Lifting Procedure .....	25
4.3 Experimental Design.....	27
4.3.1 Independent Variables.....	27
4.3.2 Dependent Variables .....	27
4.4 Data Analysis .....	28
4.4.1 Trimming .....	28
4.4.2 Digitizing .....	29
4.4.3 Transformation.....	29
4.4.4 Filtering.....	30
4.5 Upper Body Extremity Joint Angle Determination .....	30
4.6 EMG DATA Analysis.....	30
4.7 Statistical Analysis.....	31
5. RESULTS .....	33
5.1 Anthropometric and Strength Data .....	33

5.2	EMG Results .....	35
5.2.1	Effect of Weight on Neck Muscle EMG Activity .....	35
5.2.2	Effect of weight on EMG by gender .....	39
5.2.3	Relationship between joint angles and Neck EMG activity .....	40
5.2.4	Correlation analysis between joint angles and neck EMG activity .....	47
5.3	Effect of Weight on Shoulder and Elbow Joint Angles .....	48
6.	Discussion .....	49
6.1	Effect of weight on neck muscles EMG activity .....	49
6.2	Neck muscle behavior by gender .....	52
6.3	Effect of change in the joint angles on neck muscle activity .....	54
6.4	Effect of Weight on Maximum Angles of Elbow and Shoulder Joints .....	57
7.	Conclusion .....	59
7.1	Limitations .....	60
7.2	Recommendations for future studies .....	60
8.	BIBLIOGRAPHY .....	62
	APPENDIX – A Consent Form .....	65
	APPENDIX – B Personal Information Sheet .....	69
	APPENDIX – C Correlations analysis (Pearson) .....	70
	APPENDIX – D ANOVA Results .....	71
	APPENDIX – E Effect of weight increase on EMG activity .....	74
	VITA .....	89

## LIST OF TABLES

Table 1 - Participants' demographic data .....	16
Table 2 - Bagnoli™ Handheld EMG Systems.....	21
Table 3 - Random session order for all participants .....	27
Table 4 - Anthropometric and MVC data of participants at shoulder height .....	33
Table 5 - Anthropometric and MVC data of participants at elbow height .....	34
Table 6 - Comparison of weight lifted and shoulder height MVC .....	34
Table 7- Effect of weight variation on EMG MAV for sternocleidomastoid and upper Trapezius muscles.....	36
Table 8 - Effect of weight increase on EMG activity (Percentage) .....	37
Table 9 - ANOVA results .....	38
Table 10 - Tukey HSD All-Pair wise Comparisons Test.....	40
Table 11 - Correlation coefficient Analysis.....	47
Table 12 - Tukey HSD All-Pairwise Comparisons Test of SCM for (females) .....	51
Table 13 - Tukey HSD All-Pairwise Comparisons Test of SCM for (males) .....	51
Table 14 - Tukey HSD All-Pairwise Comparisons Test of TPZ for (Females).....	52
Table 15 - Tukey HSD All-Pairwise Comparisons Test of TPZ for (males).....	52
Table 16 - Tukey HSD All-Pairwise Comparisons Test of TPZ & SCM for Male Vs Female....	53
Table 17 - Effect of weight increase on MAX Shoulder and Elbow Angles (Percentage) .....	57

## LIST OF FIGURES

Figure 1 - Treadmill “Nautilus® T914 Commercial Series Treadmill” .	19
Figure 2 – Dillon Advanced Force Gauge “ AFG-500N” .	20
Figure 3 - Bagnoli EMG System. ....	21
Figure 4 - Electrode dimensions. ....	22
Figure 5 - Electrode placements on the sternocleidomastoid. ....	23
Figure 6 - Electrode placements on the Trapezius muscle. ....	23
Figure 7 - Lifting Platform.....	24
Figure 8 - Illustration of markers placement.....	25
Figure 9 - Effect of weight increase on EMG activity (AVG of all participants). ....	37
Figure 10 - Effect of joint angles on neck EMG activity during lifting for % MVC. ....	43
Figure 11 - Effect of joint angles on neck EMG activity during lifting for 30% MVC. ....	44
Figure 12 - Effect of joint angles on neck EMG activity during lifting for 45% MVC. ....	45
Figure 13 - Effect of joint angles on neck EMG activity during overhead lifting for one participant. ....	46
Figure 14 - Effect of weight increase on MAX shoulder and elbow joints. ....	48



## **ABSTRACT**

Injuries of the neck and shoulders are common among workers who perform overhead tasks. In order to develop an injury-free working environment with regards to occupational musculoskeletal stress, it is pivotal to understand the pathophysiology of mechanical stress on the musculoskeletal system.

The objective of this research was to study the effect of overhead lifting on the sternocleidomastoid and upper Trapezius muscles. Upper body joint angles were also analyzed using APAS during the overhead lifting.

This study was conducted using two devices. The set of equipment incorporates an electromyography device, and the APAS. Two electrodes were placed at the muscle belly of the sternocleidomastoid and the upper Trapezius muscles to record the muscle activity. Each participant was asked to lift 15%, 30% and 45% of his/her MVC, The MVC was determined by a non dynamic lifting task. ANOVA was performed to test the effect of different loads on the muscle activity. Correlation analysis was performed to observe the effect of increasing the lifted weight on the joint angles of the upper body extremities.

Results of this research show a strong relationship between neck muscle activities and overhead lifting. The level of sternocleidomastoid activity increased 11.8% from a 15% MVC load to a 30% MVC load and increased 16.53% from a 30%MVC to a 45% MVC. All these values were statistically significant. At the trapezius: a 10.64% increase from 15% MVC to 30% MVC, and a 7.76 % increase from 30% MVC to 45% MVC. The significance level of  $\alpha = 0.05$  reveals that weight increase has a significant effect on the MAV EMG of the neck muscles. A slight increase in the elbow joint angle of 0.1% was recorded from 15% MVC to 30% MVC. A 2.88% increase in elbow joint angle was recorded from 30% MVC to 45% MVC, with an

overall 2.98% increase from 15% MVC to 45% MVC. There was no effect of changing elbow angles on the sternocleidomastoid muscle. On the other hand, flexion of the shoulder angle in the sagittal plane had a significant effect on both the Trapezius and the sternocleidomastoid muscles.

## **1. INTRODUCTION**

Work related shoulder and neck disorders have been a major problem, contributing to the high level of morbidity in most of the working populations. According to the National Institute of Occupational Health and Safety (NIOSH, 2001), individuals who perform overhead work become a target for developing musculoskeletal disorders (MSD). Since the launch of NIOSH in 1982, it has been possible to classify injuries, and most importantly, obtain a fairly accurate assessment of work related injuries.

According to the U.S Bureau of Labor Statistics of 2006, there were 1.2 million cases requiring days away from work in private industry, which represented a decrease of 51,180 cases (4%). Median days away from work, a key measure of the severity of the injury or illness, was seven days. According to Fredriksson et al. (1999), MSDs of the neck and upper extremities result in longer sick leaves, due to the severity of the injury and a high level of discomfort, which in turn reflects a substantial cost for recovery and treatment.

The overall rate for all MSD cases was 39 per 10,000 workers in 2006. Surprisingly, repetitive motion resulted in the longest absences from work, consisting of 19 days away from work.

The majority of overexertion injuries among workers involve the neck and shoulder, and the direct cost of medical bills for masons are the highest among all construction occupations (Holmström et al. 1995, Cook et al. 1996, and Sturmer et al. 1997). In 2000, according to the Kansas Department of Human Resources, manual lifting recorded the highest percentage of incidents (19.6%) and the highest source of injury on the job (31%).

NIOSH Publication No. 97-141 (1997) on Musculoskeletal Disorders and Workplace Factors showed that there is strong evidence that a working environment with elevated levels of static contraction, or awkward working postures linking the neck and shoulder muscles are at augmented risk for neck and shoulder MSDs. There is also reasonable evidence for a strong relationship between repetitive work and neck/shoulder MSDs if the repetitive work is defined as continuous arm or hand movements affecting the neck and shoulder area.

NIOSH Publication No. 97-141 (1997) on Musculoskeletal Disorders and Workplace Factors also stated that there is not enough evidence for a positive association between force and weight lifted and shoulder MSDs based on currently available epidemiologic studies.

Akinomayowa (1987) conducted a study of bricklayers which involves overhead work. More than 6500 records were examined and out of those records, 97% were indeed suffering from musculoskeletal disorders. A significant percentage of younger bricklayers had problems related to upper limb, neck and the legs.

Neck musculoskeletal disorders have a big impact on the daily workers taskforce, which drives researchers to develop new methods to explore the mechanism of manual material handling and every aspect involved with the lifting tasks. Researchers focused on occupational tasks that involved repetitive forceful tasks.

The aim of this study was to obtain a better understanding of the upper Trapezius muscle and the sternocleidomastoid's behavior, with various amounts of loads while performing overhead lifting. The experiment performed would determine the contribution of these muscles in overhead lifting using electromyography. The angular displacement of the upper extremity joints were measured with the Ariel Performance Analysis System (APAS) which provided important data about the behavior of upper extremity joint angles during the overhwad lifting.

## **2. BACKGROUND AND LITERATURE REVIEW**

### **2.1 Introduction to the research in dynamic lifting above shoulder level.**

Muscle pain originating from the neck-shoulder region is a frequent injury in many work-related disorders. Previous studies stated that more than a quarter of the total workforce reported painful or tiring positions and continuously short, repetitive tasks at work. Little has been done in the research field to understand the actual link between neck pain, shoulder pain, and lifting heavy loads above the shoulder level.

Previously, neck and shoulder disorders have been evaluated using the following four common approaches: biomechanical, epidemiological, physiological, and psychophysical. With the rise of new technology and sophisticated software that can produce accurate results, biomechanical studies started to flood the research in this field. Each scientist had a different approach to analyze the involvement of neck and shoulder muscles in overhead lifting. In some cases, researchers have been analyzing simply the effect of raising the arm over shoulder level without lifting any load.

#### **2.1.1 Epidemiological study.**

The epidemiological study of work-related neck and upper limb pain has been primarily done in specific professional groups. So far, very little has been revealed about its effect in the general working population. The Epidemiological study consists of understanding and estimating the prevalence and population impact of work-related neck and upper limb pain.

Sim et al. (2006) concluded that neck and upper limb pain is indeed associated with working at or above shoulder level, repetitive lifting of heavy loads, and awkward neck position for a prolonged period. Silverstein et al. (2002) conducted a statistical analysis of compensation

claims in the state of Washington in order to evaluate the gravity of work related musculoskeletal disorders by using the prevention index (PI) to identify which industries are causing this stream of claims. The state of Washington alone compensated 392,925 workers at a price tag of \$2.6 billion and at least 20.5 million lost workdays. The identified top five industries at the highest risk work-related MSDs of neck and upper limb are nursing, trucking and courier services, masonry, residential construction, and air transportation.

Chen et al. (2006) estimated population incidence rates for work-related musculoskeletal disorders that were examined by rheumatologists and occupational physicians and categorized them by work type. This study concentrated on analyzing incidence rates for eight industrial groups. From 1997 to 2001, more than 2599 new cases were reported yearly by rheumatologists, from January 1996, nearly 5300 cases yearly were reported by occupational physicians. Upper limb disorders, as well as neck and back problems were found to be associated with keyboard work, and heavy lifting, and with gripping or holding tools in craft-related occupations.

Feveile et al. (2002) conducted a follow-up study of employees in Denmark to investigate the correlation between physical and psychosocial exposures and musculoskeletal symptoms in the neck-shoulder and wrist-hand regions. Among the studied male population, stress, twisting, bending and social support were slightly associated with the development of symptoms in the neck-shoulder region. The association of physical and psychosocial factors is strongly linked to musculoskeletal symptoms in the study. Different relations between exposure and symptoms in the upper body area were found for men and women.

Fredriksson et al. (1999) found that risk factors differ between males and females. Females showed positive results for upper limb and neck injuries when working overtime, performing high mental workload, and experiencing insufficient relaxation time. Among blue

collar male workers, immediate occurrence of high mental workload and additional workload at home predicted injuries in the neck-shoulder region.

The study of Ciriello et al. (1999) revealed that 31% of the insurance costs paid by the insurance companies due to manual handling were in the construction industry, which involves massive workloads and longer periods with the arms raised.

Viikari-Juntura, et al. (1994) indicated that dynamic physical work was associated with the risk of persistently severe neck trouble. The same study also found age as a fundamental predictor for developing acute neck trouble along with dynamic physical work. These epidemiological studies present clear evidence of the connection between neck and shoulder MSDs and overhead lifting.

### **2.1.2 Physiological study**

The physiological studies concerned are aimed to study oxygen consumption, metabolic energy expenditure rate, and heart rate during a given task. These physiological measurements are suggested mostly to determine maximum work capacity, and intensity that can be performed continuously with no major signs of physical fatigue.

Kadefors et al. (1976) showed that static shoulder muscle workload is common in shipyard welders, and that in particular, the supraspinatus and infraspinatus muscles were affected by localized muscle fatigue during welding work at or above shoulder level.

Recordings of the myoelectric activity of shoulder muscles performed during welding showed considerable spectral variation in myoelectric signals obtained from the supraspinatus muscle through extended overhead work, proving that the muscle is under continuous heavy strain in this working position. It was found that among inexperienced welders, localized muscle fatigue was frequent, in the deltoid and the upper Trapezius portion.

Hagberg and Wegman (1987) aimed their research to evaluate the relationship between occupational exposure and shoulder and neck musculoskeletal disorders. They found that rotator cuff tendinitis was 11 to 13 times higher in jobs requiring lifting at or above shoulder level.

Holmström et al. (1992) confirmed through their study that handling material more often than once every five minutes, and working with the arms above shoulder level, were the most significant contributing factors in neck/shoulder trouble and neck/shoulder pain. Surprisingly, they also found a small, but insignificant relationship between smokers and neck-shoulder musculoskeletal disorders.

Jensen et al. (1993) conducted a study to investigate how Trapezius muscle load could be a risk indicator for occupational shoulder/neck complaints. In this study, 32 female office workers and 39 female production workers were subject to a series of electromyographic recordings. The muscle activity trends of the office workers showed more short pauses and a lower static load. Compared to female production workers, this was a large/significant change. After reviewing the EMG recordings, Jensen et al. (1993) found a weak correlation between the EMG parameters recorded and symptoms of pain in the shoulder/neck region. Nevertheless, the intensity of the muscle load attracted much attention as a potential risk factor for shoulder muscle pain.

### **2.1.3 Biomechanical Studies**

Occupational biomechanical studies are aimed to determine precisely what a person can physically do within personal limits. This aspect matches the physical capability of a person within the physical demands of a prospective job. Occupational biomechanics focuses on physical attributes of the worker as related to occupations that are proved to cause harm to the musculoskeletal system, resulting in MSDs and trauma. Biomechanical studies are also aimed at



matching workers to the right job and then modifying the job tasks to meet the physical capability of the individual. Using biomechanical measurements such as force, moments, ground force, velocity, acceleration, and torques, we can adjust the job demand to meet the physical capabilities of the workers.

Nimbarte et al. (2009) evaluated the risk factors for cervical spine disorders due to manual material handling tasks. Eighteen healthy participants performed isometric static lifting at three different heights. EMG data was collected at the elbow height, shoulder height, and overhead height. Two muscles were observed in this study; the upper Trapezius muscle and the sternocleidomastoid muscle. During the task, three different neck postures were studied: extended, neutral and flexed. Results of the study showed significant evidence that upper Trapezius muscles were the most active at flexed neck position. The sternocleidomastoid is activated the most when the neck is extended. Results show that as the arm elevation increases from elbow to shoulder to overhead, the EMG activity of both muscles increased. There was no significant change in the EMG recordings of the Trapezius muscle from the shoulder height to the overhead height. This study concluded that neck muscles are involved in overhead lifting, and it is a major contributor for developing neck MSD.

Nimbarte et al. (2008) conducted a research study to understand the role of the major neck muscles during isometric lifting tasks at the elbow height, using EMG data collected from the upper Trapezius muscle and the sternocleidomastoid. There were four participants involved in this research with performed static lifting tasks. The aim of this study was to understand how different neck postures could affect the EMG activity of the muscles during static lifting. Three postures were studied: flexed, neutral, and extended neck posture. This experiment showed that EMG activity of both neck muscles increased by increasing the weight. The EMG activity of the

Trapezius showed more activity in the flexed position than in the neutral or the extended position at 50% and 75% of the participant's MVC. However, the results of the sternocleidomastoid showed higher EMG activity when the neck posture is extended compared to the flexed and neutral neck positions.

Burgess-Limerick et al. (1991, 1993) conducted research to analyze how movement is controlled and applied it to understand lifting. They compared the angular-position-time method of presenting the lifting kinematic data to a new method of presenting the data on a phase plane. They chose lumbar vertebral, hip, knee and ankle joints. In this approach, the movement of joints was expressed on a phase plane and coordination was quantified by calculating the relative phase angles between the joints. An 18-year old male participant lifted 8.5 kg weight from the floor level to an upright position with the mass held in a carrying position at waist height, using a self-selected technique. They performed two experiments, one with changing loads and another with changing the starting heights.

Freivalds et al. (1984) assumed that the body is made up of rigid segments and joined at known articulation locations. Six participants were chosen to be part of the research; all were healthy and suffered from no back pain or neck pain. The participants were asked to lift four different boxes with various weights, six times each. As a result of this study, the researchers confirmed several logical principles dealing with the effect of task variables on lifting dynamics. First, heavier loads act to increase vertical ground reaction forces, and more importantly, compressive forces. Second, larger boxes tend to create larger moment arms and increase compressive forces. To conclude this study, the results confirmed the predictive capabilities of a dynamic biomechanical model. It proved that ground reaction forces are correlated significantly. EMG recordings showed the significance in correlation for different loads.

Sigholm et al. (1984) studied the upper part of the Trapezius by performing five different static positions arm flexion at (0, 45, 90) degrees and upper arm abduction at (45 and 90) degrees. Nine volunteers participated in this research with a range of age (25 – 42). EMG data was recorded from the deltoid and the upper part of the Trapezius. As a result, the main findings for this research are that elbow flexion angles are of little importance for shoulder muscle load.

Bonato et al. (2002) were studying the changes in the surface EMG signals and the biomechanics of motion during a repetitive task. Nine male participants were recruited to be part of this research. All are healthy and young with a mean age of 26.3 and were generally fit. Each participant performed a five minute lifting task. The lifting task consisted of lifting a box from midshank position to waist-high position with a rate of 12 lifting cycles per minute. All participants were asked to adapt a free lifting method of performing the lifting task in the sagittal plane. During the five minutes of lifting, the EMG data was recorded at the beginning of the cycle, and at the end of the five minutes for 30 seconds. After analyzing all the biomechanical parameters measured, the researchers used the trajectory of the box to estimate the velocity and the acceleration of the box. The EMG and biomechanical data described in the analysis section were extracted from 30 second epochs. The result of this study has confirmed that fatigue-related EMG and biomechanical changes may be identified in healthy participants during a repetitive lifting task.

Nussbaum et al. (2000) developed a heuristic for locating upper extremity joint centers from a reduced set of surface markers. Four participants, all right-handed, volunteered to participate in this research. The experimental protocol stated that each participant would perform three voluntary full-range motion tasks: elbow flexion, shoulder flexion, and shoulder abduction/adduction. The recording time was five seconds, which consists of 125 frames during

which the participants are able to perform two full cycles of specified movement. Analysis of variance (ANOVA) was used to determine any significant ( $p < 0.05$ ) effects of the independent variables. Using the developed new algorithm to locate center of joints at the shoulder, elbow, and wrist, the yielded average error was reduced from 7.5 mm to 3.7 mm using the optimized heuristics. The main goal was achieved by reducing surface markers, thereby obtaining more accurately estimated upper-extremity joint centers.

### **3. STUDY**

#### **3.1 Rationale**

Studies in the literature review show evidence that neck and shoulder MSDs are strongly linked to over exertion, elevated upper extremity postures, and repetitive motions. Hattori et al. (2000) confirmed in their study that initiating lifting from elbow level to shoulder level would exert a load on the upper limbs as the load is lifted up to the shoulder level. This suggests that lifting to the shoulder level significantly increases the load on the upper limbs and shoulder muscles, as compared with lifting from the ground, which would place a heavier load on the leg and lower back muscles.

Hattori et al. (2000) studied the effect of weight on the heart rate. The results show that a 15 kg weight created a greater load on the body than a 10 kg load. The effect of increasing weight had a great impact on the average upward acceleration and peak velocity, signifying the intricacy in lifting a 15 kg load dynamically. Mital and Kromodihardjo (1986), Kee (1996) reported that an increase in lifting weight dramatically increased lumbar compression, as a result of a broad intensification in the muscular activities of the trunk. All these previous studies are mainly aimed to understand the mechanism of overhead dynamic lifting and its effect on the body, specifically the neck muscles. There are many aspects of dynamic lifting that could be investigated.

This study differentiated from other studies by using the APAS system to measure angular displacement and variation; together with EMG recordings to understand where the muscles work the most and at what angles the muscles hire more motor units to execute the task. This study did not only observe how the change in weight lifted can affect the amount of muscle

activity involved, but also to understand the type of relationship between weight and muscle activity using a curve fit test.

Burgess-Limerick et al. (1991, 1993) chose lumbar vertebral, hip, knee, and ankle joints. In this approach, the movement of joints is expressed on a phase plane, and coordination is quantified by calculating the relative phase angles between the joints. In this research, we chose a different approach than Burgess-Limerick et al. (1991, 1993). Instead of hip, knee and ankle joints, we analyzed shoulder, and elbow joints.

The placement of the markers adapted the same location as Bonato et al. (2002). We did not measure the lower body motion, which excluded the markers from the hip down. The results of this research would help redesign overhead lifting tasks, as the impact of increasing different loads causes awkward lifting postures and could develop MSDs.

No other studies have analyzed upper body extremity angular displacement in combination with EMG recordings and a variation of three different loads. This research was a furtherance of the extensive effort by current researchers in this field, and further analyzes the effect of overhead lifting on the neck muscles. The outcome of this research would be helpful in understanding the impact of various loads on the neck muscles and upper body extremities' joint angles, while lifting at the shoulder level.

### **3.2 Objectives**

The goal of this research was to evaluate the effect of lifting various loads on upper extremity joint angles and on the neck muscles while performing overhead lifting. It was achieved through the following objectives:

- Evaluation of the electrical activity of the two major neck muscles, the sternocleidomastoid and upper Trapezius, using electromyography during an overhead lift.
- Evaluation of the angular displacement of the upper body extremity joints due to increasing weight, during an overhead lift using APAS system.

### 3.3 Hypothesis

The type of hypothesis selected for this study was two tailed hypothesis tests.

- Hypothesis 1:
  - ✓ H<sub>0</sub>: EMG activity of the neck muscles would not change with an increase in the arm elevation angles.
  - ✓ H<sub>1</sub>: EMG activity of the neck muscles would change with an increase in the arm elevation angles.
- Hypothesis 2:
  - ✓ H<sub>0</sub>: The muscle activity of the neck muscles would not change, corresponding to the increase of the load lifted.
  - ✓ H<sub>1</sub>: The muscle activity of the neck muscles would change, corresponding to the increase of the load lifted.
- Hypothesis 3:
  - ✓ H<sub>0</sub>: During the dynamic overhead lifting, the EMG trend of the neck muscles in men is equal to the EMG of neck muscles in women.
  - ✓ H<sub>1</sub>: During the dynamic overhead lifting, the EMG trend of the neck muscles in men is not equal from the EMG of neck muscles in women.

- Hypothesis 4:
  - ✓ H<sub>0</sub>: Increase in lifted weight would not change the maximum shoulder and elbow joint angles.
  - ✓ H<sub>1</sub>: Increase in lifted weight would change the maximum shoulder and elbow joint angles.



## **4. METHODS AND PROCEDURE**

The aim of this research was to understand the mechanism of overhead lifting and to observe the involvement of neck muscles in dynamic overhead lifting. Using markers placed on the upper body extremity, neck, and back, we were able to study posture and interjoint angle variation during the lifting task. In order to make this possible, ten healthy participants were part of this research; each one had to be injury-free, and with no complaints about neck or back pain. Some participants were excluded from this research due to their health history, which increase possibilities of getting injured during the lifting task. Participants performed a free, self-selected lifting style.

### **4.1 Participants**

Five males and five females volunteered to participate in this study, with an age range from 18 to 35. All selected participants were healthy and suffered from no musculoskeletal disorders. The participants were chosen from the LSU population. A mandatory written consent form was signed by each participant after careful reading and understanding every aspect of the procedure involved in the lifting task. The procedure was approved by the Institutional Review Board (IRB), Louisiana State University. Failure to respond to any of the safety questions would automatically exclude the participant from participating in the study. Table 1 shows the demography of the participants.

**Table 1 – Participants’ demographic data.**

<b>Participant ID</b>	<b>Gender</b>	<b>Weight (Kg)</b>	<b>Height (Cm)</b>	<b>Age (years)</b>
<b>1</b>	<b>M</b>	<b>65</b>	<b>178</b>	<b>22</b>
<b>2</b>	<b>M</b>	<b>72</b>	<b>180</b>	<b>24</b>
<b>3</b>	<b>M</b>	<b>85</b>	<b>192</b>	<b>29</b>
<b>4</b>	<b>M</b>	<b>71</b>	<b>175</b>	<b>28</b>
<b>5</b>	<b>M</b>	<b>65</b>	<b>179</b>	<b>24</b>
<b>Average</b>		<b>71.6</b>	<b>180.8</b>	<b>25.4</b>
<b>SD</b>		<b>8.17</b>	<b>6.53</b>	<b>2.96</b>
<b>6</b>	<b>F</b>	<b>48</b>	<b>162</b>	<b>20</b>
<b>7</b>	<b>F</b>	<b>52</b>	<b>171</b>	<b>19</b>
<b>8</b>	<b>F</b>	<b>55</b>	<b>164</b>	<b>22</b>
<b>9</b>	<b>F</b>	<b>60</b>	<b>180</b>	<b>20</b>
<b>10</b>	<b>F</b>	<b>56</b>	<b>163</b>	<b>25</b>
<b>Average</b>		<b>54.2</b>	<b>168</b>	<b>21.2</b>
<b>SD</b>		<b>4.49</b>	<b>7.58</b>	<b>2.38</b>

Participants were asked to wear athletic clothing, such as tight shirts, so that the placement of the markers would not be affected by the movement of the shirt. For male participants, it was preferred to perform the task shirtless or to wear tight shirts that would not move during the lifting task. For female participants, it was mandatory to wear tight t-shirts or running tank tops.

## **4.2 Data Acquisition**

A series of steps took place to prepare the participants for overhead lifting. Set up of the equipment and preparation of the laboratory took place one day before participants were allowed to come to the laboratory.

### **4.2.1 Setting**

Setting the right environment for the experiment was very important for the study. The laboratory was air-conditioned and kept at room temperature, 22 degree Celsius. An adjustable

shelving system was put in place to allow the participants to lift from their knuckle height to their shoulder height. The Ariel Performance Analysis System (APAS) is a video-based 3D motion analysis system that can capture video from multiple cameras and perform a biomechanical analysis automatically. The APAS operated with one JVC high speed 240 Hz camera for two-dimensional recording. The camera was placed perpendicular to the sagittal plane of the participant at about three meters away and placed on the top of a tripod for stability. Kinematic data was recorded by implementing the studio DV software that came with the APAS package. The quality of the video was full quality for better reviewing and accurate data. This type of quality capture needed at least 200 MB of computer memory space for 60 seconds of data. An external hard drive of 1Terabite capacity was used for data storage.

The legs were adjusted using the liquid-dot meter to make sure that the camera was perfectly horizontal to the ground. A projector light was placed perpendicular to the participant. This technique is used to make the markers shine, and is easy to digitize with the APAS Digitizing Module. A plastic box of dimensions 40cm x 32cm x 5cm and weighing 0.5 Kg, was used to place the necessary weight inside. Two computers were used to display the EMG activity and the two-dimensional data from the video camera. A wooden platform was placed in front of the shelving system, to be used as a standard standing location for all participants.

A list of the equipment used in this study is displayed in the list below:

- APAS- 2D motion analysis software
- JVC - High Speed (240 Hz) cameras
- Adjustable shelving system
- Plastic box (40cm x 32cm x 5 cm) without cutout handles.
- Cylindrical metal pieces of various masses

- Reflective markers (10 mm diameter).
- Delsys EMG system (2 channels)
- DELL LATITUDE D-620
- DILLON AFG-500N Force Gauge
- Isometric strength testing equipment
- Treadmill
- Projector
- Tripod
- One DELL laptop
- One APAS Desktop computer
- External hard drive 1TB

#### **4.2.2 Participant Preparation**

The first session was to familiarize the participants with the lifting task. After reading the consent form and signing it, a warm up session of five minutes took place in the ergonomics laboratory using a treadmill “Nautilus T914 Commercial series” (Nautilus, Inc. Global Headquarters 16400 SE Nautilus Drive Vancouver, WA 98683). The speed of the treadmill was adjusted among participants and ranged between three and five miles per hour. Speed of the treadmill was set by the participant to meet their comfort level.



**Figure 1 - Treadmill “Nautilus® T914 Commercial Series Treadmill”.**

Once the participants warmed up and were ready for the experiment, a static force measurement device was set up to measure each participant’s maximum voluntary contraction. This force test took place in the Ergonomics laboratory using the Advanced Force Gauge (AFG-500N, Dillon/Quality Plus, Inc. 3501 N.E. Kimball Dr. Kansas City, MO. 64161 Phone: 800-493-2263). This device is attached to a metal chain on the bottom side and a metal handle on the top side. The metal chain is linked to a flat wooden plate placed on the floor. Participants stood upright with legs and back straight and with feet flat. The participants held the sides of the handle bar connected to the load cell and exerted the force upward and vertically in the sagittal plane. The participants were informed to pull the handle gradually with increasing strength and strictly without jerking. This procedure insured the accuracy of the data, and reduced the chances

of causing injuries to participants. They were asked to stand on top of the wooden plate and perform a static lift at elbow height, with the shoulder angle at zero degrees and the elbow angle at 90 degrees, and another static lift at shoulder level while the shoulder joint angle is at 90 degrees and the elbow joint angle is at 180 degrees. For reliability and accuracy of the data, the test was repeated three times, and then averaged. The results of these static lifts were used to determine the amount of weight lifted by each participant. Each participant's MVC was recorded to determine the weights to be lifted.



**Figure 2 – Dillon Advanced Force Gauge “ AFG-500N”.**

In this same session, we set up the participant for the lifting procedure. To do so, two electrodes were placed on the upper Trapezius and sternocleidomastoid muscles. The EMG data acquisition and analysis was performed by Delsys, Inc.'s Bagnoli-2 EMG System (650 Beacon St., Boston MA. 02215, [www.DelSys.com](http://www.DelSys.com)). The characteristics of this EMG system are:

- 2 channels
- Selectable gains (1K)
- Accepts DE-2.1 and DE-3.1 sensors
- Unobtrusive, low profile design
- IEC601-1 Medical Standards

- CE Mark, 510 K Clearance

**Table 2 - Bagnoli™ Handheld EMG Systems.**

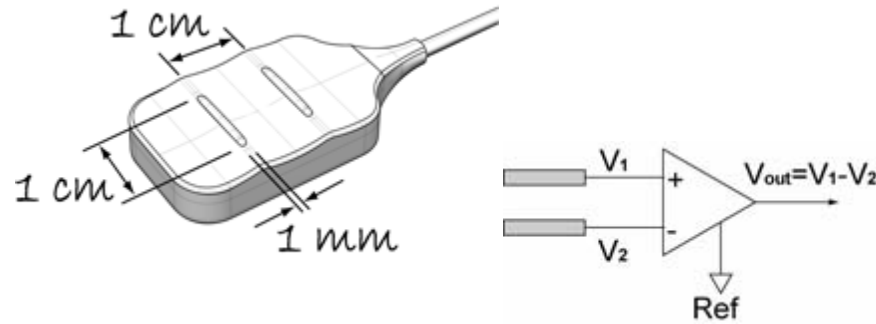
Item	Bagnoli™ Handheld
Main Amplifier Dimensions	100 x 65 x 40 mm
Main Amplifier Mass	0.3 kg
Output Cable Length	7.5 m
Overall Amplification	100, 1000, 10,000, $\pm 1\%$
Overall Bandwidth	20 - 450 Hz $\pm 10\%$ ,
Bandwidth Roll off	80 dB/decade
Overall Noise	$\leq 1.2 \mu\text{V(RMS, R.T.I)}$
Power Supply	9 V Battery
Voltage Isolation	3750 VAC (RMS)

This system is a two-channel system that allows the recording of two different muscle activities simultaneously.



**Figure 3 - Bagnoli EMG System.**

The electrodes used in this study had a parallel bar active surface electrode that is a single differential. Sensor contacts were made of pure silver, measuring 10mm in length, 1mm in diameter, and spaced 10mm away from each other.

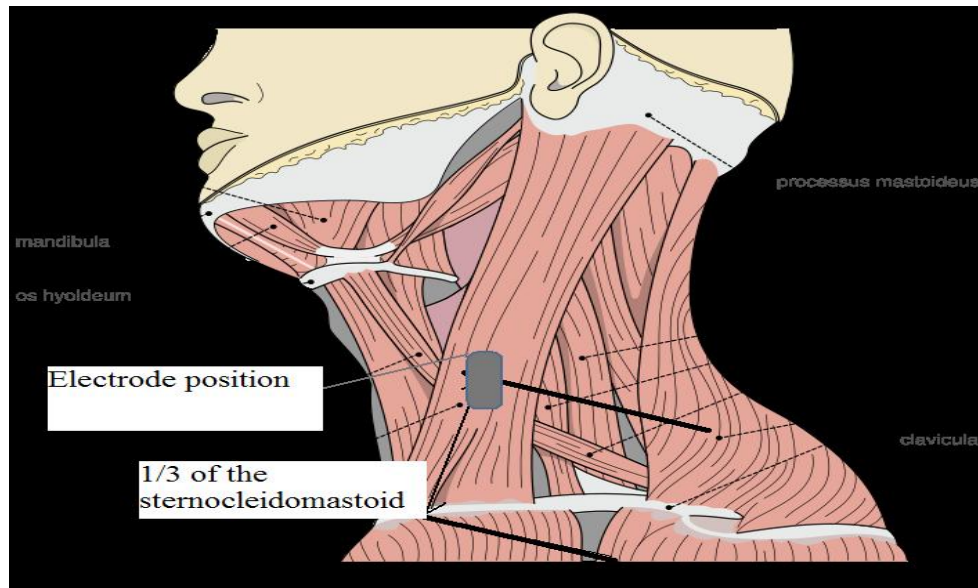


**Figure 4 - Electrode dimensions.**

The EMG system was set to collect data at a frequency equal to 1000Hz. Since the video was set at 60 Hz, we had to convert the frequency of the EMG data collected. To do so, we sampled the data to reduce it from 1000 to 60, using the Microsoft EXCEL sampling module. Sampling was done periodically, we divided the data into groups, and each group contains 16 values. We took the average of each group. The outcome of this procedure was sampling of the data from 1000 data points to 60 data points periodically

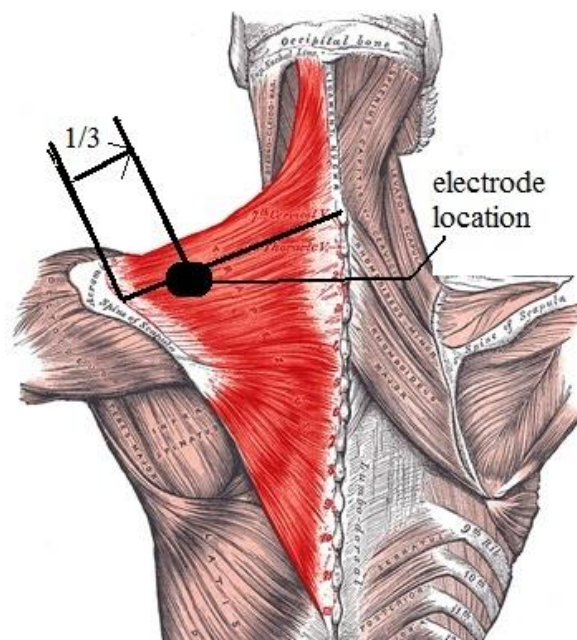
The two electrodes were placed on the sternocleidomastoid and the upper Trapezius muscle. Figure 5 shows in detail the placement of the electrode on the sternocleidomastoid, and Figure 6 shows in detail the placement of the electrode on the Trapezius muscle.





**Figure 5 - Electrode placements on the sternocleidomastoid.**

[“http://dic.academic.ru/dic.nsf/enwiki/259973”](http://dic.academic.ru/dic.nsf/enwiki/259973)



**Figure 6 - Electrode placements on the Trapezius muscle.**

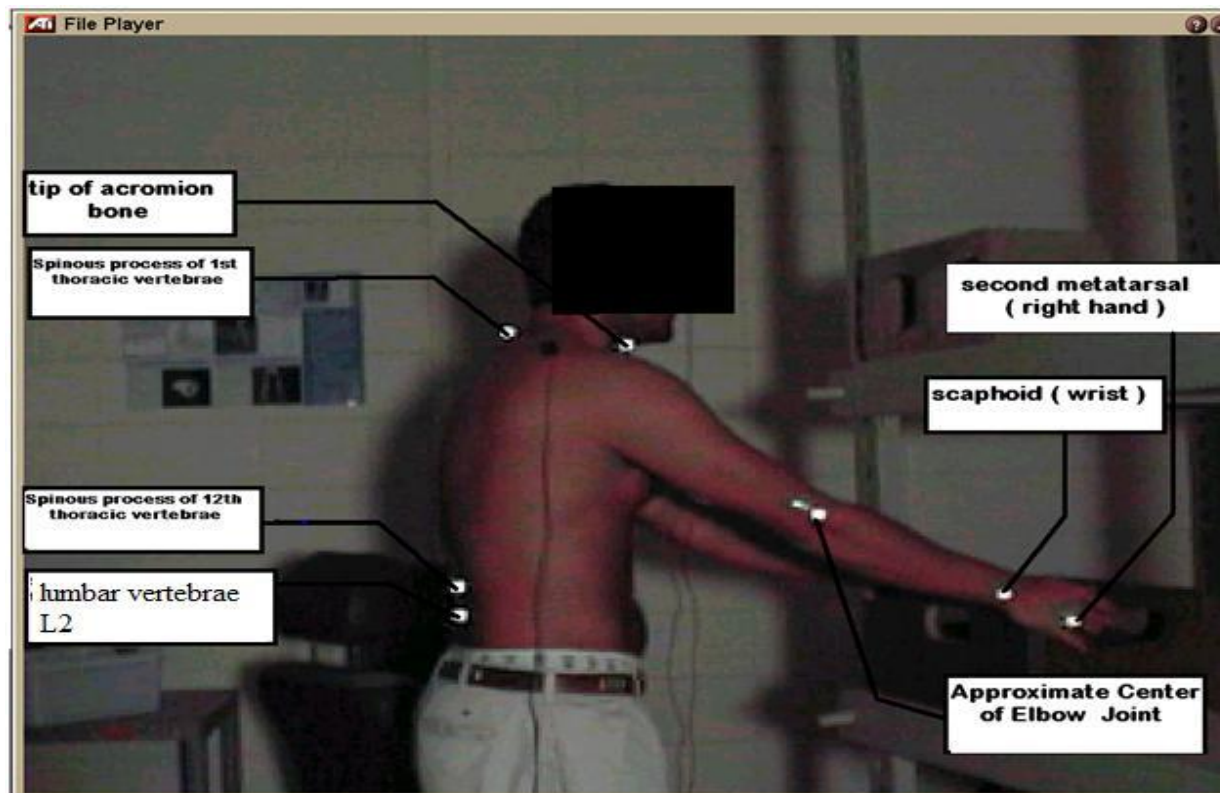
[“http://nicktumminello.com/wp-content/uploads/2009/07/Trapezius.jpg”](http://nicktumminello.com/wp-content/uploads/2009/07/Trapezius.jpg)

Once all the wiring was set up, a seven marker position system was adopted, as it has been suggested by Bonato et al. (2002), with adding one marker in the second metatarsal position and excluding the lower body extremity markers.

- i. second metatarsal ( right hand )
- ii. scaphoid ( wrist )
- iii. approximate center of rotation of elbow joint
- iv. acromion
- v. Spinous process of 1st thoracic vertebrae
- vi. Spinous process of 12st thoracic vertebrae
- vii. Lumbar vertebrae L2



**Figure 7 - Lifting Platform.**



**Figure 8 - Illustration of markers placement.**

#### **4.2.3 Lifting Procedure**

During session (II, III, IV), participants performed a lifting task of 15%, 30% and 45% of their MVC respectively. Participants stood on the platform in front of the wooden shelving system and lifted a plastic box that contained the right weight for each session from the bottom shelf to the upper shelf. These shelves were adjusted to meet the participant's knuckle height and shoulder height. The distance between the platform and the participant was about 20 cm to 35 cm. This clearance ensured that there was enough room for the arms to move freely while lifting. This range depended primarily on the anthropometry of the participant's arms. All ten participants lifted according to their best self-selected technique. Self-selected lifting techniques are less likely to cause injury to the participant (Ayoub et al. (1989); Garg et al. (1979)). During the lift, the participant had to be at the upright position.

A two-dimensional kinematic data were collected during these three sessions, as well as muscle activity data collected from two different muscles. EMG data was synchronized digitally with the kinematic data, in order to unify the starting point of the lifting task. Display of the EMG monitor and the participant's movements were shown in the same frame, which was extremely important for the synchronization of the data. This way we could see the exact start of the task and the matching time start for the EMG data recording. In order to setup the camera in full synchronization with the EMG system, we established a procedure to make certain that the starting point of the video recording was the same as the starting point of the EMG data recording. The idea was to be able to observe both starts in the same frame. If the EMG recording was in the same field view of the camera, we could see at what moment the EMG started and couple it to the motion of the participant. Once we obtained the exact frame when the motion started, using the trimmer Module in APAS, we were able to trim the video and locate the exact start point for both motion and EMG data. Once we located the starting point, we could trim the EMG data to the same starting point, and this way we could get a synchronized data in function of time. Using the same trimmer module, we calculated the duration of the lifting task. Once we trimmed the video at the end of the lift, we had the actual video that represented the lifting task frame by frame. Knowing the duration of the lifting task in milliseconds, we added it to the starting point of the EMG data. Using this method, we achieved synchronization between the video recording and the EMG data recording, which started at the same time and ended at the same time. This procedure was repeated for each participant, due to the variation of the lifting task duration.

The order of the lifting sessions was randomized to eliminate the learning factor of the collected data. Randomizing the data was a simple probability distribution. Let session 1, session

2, and session 3 be three variables. The outcome would be nine different possibilities to randomize the order of the sessions.

**Table 3 - Random session order for all participants.**

<b>Participant ID</b>	<b>Session order</b>
1	II,III,IV
2	II,IV,III
3	III,II,IV
4	III,IV,II
5	IV,II,III
6	IV,III,II
7	III,IV,II
8	IV,II,III
9	II,III,IV
10	III,II,IV

In order to make the experiment more uniform, we placed a shoe mark on the ground platform so that participants would start from the same point and their leg positions would be both straight and uniform for all participants. This technique would also eliminate side lifting.

### **4.3 Experimental Design**

#### **4.3.1 Independent Variables**

There is one independent variable considered in the study:

- 1) Weight of the box.
- 2) gender

#### **4.3.2 Dependent Variables**

There are three dependent variables considered in the study:

- 1) Angular displacement
- 2) EMG Data

## **4.4 Data Analysis**

The main software to be used to capture and analyze the data recorded from the JVC camera was the APAS software. The APAS package came with a multitude of different settings. The video was recorded at a frequency of 60 Hz. To convert the video captured by the JVC recording camera, a series of steps were needed.

- Studio DV software
- Trimming
- Digitization
- Transformation
- Filtering

### **4.4.1 Trimming**

It is very common that more data is collected than needed. Most of the researchers aim for more time to record. This way, they can choose which portion to analyze and which portion includes the most accurate data. Trimming comes in place after capturing all the movements aimed for analysis and converted into a stream of pictures in the DV Capture software. The software offers several options to cut out just the right portion from all the data collected. There are two methods to do so. The first method is to type in the range of time desired to analyze. The second method is to select the starting picture, which is the start of the lifting cycle, and the last picture of the end of the cycle. The second method is more accurate, because visual recognition is involved with this process. Visual recognition method was adapted in the trimming of the data for this study.

#### **4.4.2 Digitizing**

After saving the trimmed video into an AVI file, the second step uses APAS 4 SCREEN DIGITIZING APPLICATION (DIGI4) software. It is a Windows based program for digitizing images to be analyzed, using (APAS). Using the mouse, the location of each marker on the body joints is selected and stored into the computer. Each marker goes through the same cycle of entry to the system. As the points move with the movements of the joints, the markers would change the location of each frame. The computer connects the dots which each frame, taking in to consideration that the marker's position is changing each frame. At the end of this connecting cycle, the computer displays the trajectory that all the markers did, and thus be ready for analysis. There is a manual and an automatic method to connect the markers and create an imaginary segment from one joint to another. The manual method is used in this study to emphasize accuracy and to correct the miscalculated assumptions that the software tends to calculate.

The digitizing module was set at 60 Hz. This means that for every second captured, there are 60 frames. Each second of video is broken into 60 frames for more accuracy of the data. All the frames were digitized, using a proximal to distal pattern, i.e., markers are digitized beginning from the marker at the 2<sup>nd</sup> metacarpal bone and ending with the marker at lower back marker L2. The total number of digitizing points was calculated by the number of markers and the length of time the lifting procedure is taking place. In this study, one lift takes approximately 2 sec. +/- 0.7 sec

#### **4.4.3 Transformation**

The transformation module is the third step into analyzing the data. In this study, the computer converted a single two-dimensional digitized view into a two-dimensional image

sequence with two-dimensional coordinates. This process is aimed at digitizing all the digitized points into an absolute space coordinate. Fortunately, this process is executed by the computer and there is no further manual involvement in the transformation process.

#### **4.4.4 Filtering**

Due to the repeated measurement nature of digitizing joint location, the location of each joint was measured. These measurements consisted of the true joint location, plus a random digitizing error due to the inability to pinpoint the cursor of the mouse on the exact joint location. Using the APAS filter module, the two-dimensional coordinate data was filtered, using a cubic spline filter with a smoothing value of 1 cm.

#### **4.5 Upper Body Extremity Joint Angle Determination**

The purpose of this study was to measure the change of upper extremity joint angles during overhead lifting. Each marker was placed to create a series of segment that made up the imaginary lines between the joints to provide us a clear understanding of joint angles behavior during overhead lifting, and with an increased load. This study was aimed at understanding the effect of loads on joint angles. In order to do this, the primary data used for all the calculations is the angular displacement of different upper extremity body joints. APAS software determined all the joint angles automatically, using the Display Module.

#### **4.6 EMG DATA Analysis**

EMG data was analyzed as follows:

- EMG signal is demeaned
- Obtain linear envelope
- Normalization



- Calculate the average EMG signal values to determine the mean absolute value (MAV).

Once the EMG (MAV) was obtained, I superimposed the video sequence and the change of the angular displacement of the angles to get a clear visual prospective on the change of data and its effect on the rest of the variables at any time.

#### **4.7 Statistical Analysis**

In this study, a statistical analysis was very important to analyze the data collected. The tests performed are to test hypotheses that examine the difference between three means. Analysis of Variance or ANOVA allowed us to test the difference between two or more means. ANOVA did this by examining the ratio of variability between three conditions and variability within each condition. Another aspect of this statistical analysis was to evaluate the relationship between the three sets of data collected. This analysis gave us an idea about the affiliation between increasing the loads in the overhead lifting and the recorded EMG, as well as the angular displacement of the elbow joint and shoulder joint.

Statistical analysis was performed using independent and dependent variables.

- ✓ Independent variable was the weight lifted (15%, 30% and 45% of the individual's MVC) and gender (male and female).
- ✓ Dependent variables were (1) EMG MAV of sternocleidomastoid and EMG MAV of upper Trapezius muscles and (2) the angular displacement at each joint.
- ✓ The analysis of variance (ANOVA) was used to compare the EMG MAV between muscles at different weight levels. The significance level is  $\alpha=0.05$
- ✓ The correlation analysis was used to determine the statistical significance of the effect of change in weight lifted on the neck muscles electromyographic activity.

The type of correlation analysis used in this research was the Pearson method. We chose this method because our assumption was that the effect of weight on the neck muscles activity was linear.

## 5. RESULTS

### 5.1 Anthropometric and Strength Data

The aim of this research was to study the effect of overhead lifting on the Trapezius and the sternocleidomastoid muscles. The two joints that were studied and analyzed were shoulder and elbow angles. These two angles represent the two major joints of the upper body extremity. Along with the variation of joint angles, we also studied the effect of increasing the lifted weight on the neck muscles while performing overhead activity. In this case, the overhead activity was to lift one box from one shelf to another at the knuckle height and shoulder height, respectively.

Results of this overhead lift analysis are presented under the following sections:

- Determination of MVC
- EMG Results
- Effect of weight on neck muscles
- Effect of neck joint angles on neck muscles
- Effect of weight on elbow and shoulder joint angles

**Table 4 - Anthropometric and MVC data of participants at shoulder height.**

	Gender	Age (yr)	Height (cm)	Weight (kg)	MVC Trial 1 (kg)	MVC Trial 2 (kg)	MVC Trial 3 (kg)	Avg MVC (kg)	SD
Participant 1	Male	29	186	90	24.5	24.8	23.9	<b>24.40</b>	+/-0.54
Participant 2	Male	23	182	85	22.6	23.1	24.6	<b>23.43</b>	+/-1.04
Participant 3	Male	31	175	72	27.1	26.5	26.9	<b>26.83</b>	+/-0.30
Participant 4	Male	25	177	81	24.1	25.6	24.3	<b>24.67</b>	+/-0.81
Participant 5	Male	19	180	75	27.5	27.9	28.4	<b>27.93</b>	+/-0.45
Participant 6	Female	31	170	48	13.2	11.5	12.4	<b>12.37</b>	+/-0.85
Participant 7	Female	26	172	51	12.1	11.5	12.8	<b>12.13</b>	+/-0.65
Participant 8	Female	19	180	62	10.3	10.9	10.2	<b>10.47</b>	+/-0.37
Participant 9	Female	25	157	57	9.5	8.9	8.8	<b>9.07</b>	+/-0.37
Participant 10	Female	19	162	53	12.6	10.2	11.1	<b>11.30</b>	+/-1.21

Average		24.7	174.1	67.4	18.35	18.09	18.34	<b>18.26</b>	0.65
SD		4.7	9.0	15.1	7.3	8.0	7.8	<b>7.7</b>	3.49

**Table 5 - Anthropometric and MVC data of participants at elbow height.**

	Gender	Age (yr)	Height ( cm)	Weight (kg)	MVC Trial 1 (kg)	MVC Trial 2 (kg)	MVC Trial 3 (kg)	Avg MVC (kg)	SD
Participant 1	Male	29	186	90	34.45	32.25	31.25	<b>32.65</b>	1.63
Participant 2	Male	23	182	85	38.85	39.9	39.45	<b>39.40</b>	0.52
Participant 3	Male	31	175	72	34.05	37.75	38.55	<b>36.78</b>	2.40
Participant 4	Male	25	177	81	36.9	38.4	39.1	<b>38.13</b>	1.12
Participant 5	Male	19	180	75	32.5	33.5	32.9	<b>32.97</b>	0.50
Average		25.4	180	80.6	35.35	36.36	36.25	<b>35.98</b>	1.23
SD		4.7	4.3	7.3	2.5	3.3	3.8	<b>3.04</b>	0.8
Participant 6	Female	31	170	48	20.15	20.3	20.65	<b>20.37</b>	0.25
Participant 7	Female	26	172	51	19.2	18.8	20.8	<b>19.60</b>	0.65
Participant 8	Female	19	180	62	24.65	23.4	20.05	<b>22.70</b>	0.37
Participant 9	Female	25	157	57	18.85	18.2	19.6	<b>18.88</b>	0.37
Participant 10	Female	19	162	53	23.5	24.7	20.2	<b>22.80</b>	1.21
Average		24	168.2	54.2	21.2	21.1	20.2	<b>20.87</b>	0.57
SD		5.1	8.9	5.4	2.6	2.8	0.4	<b>1.79</b>	0.3

**Table 6 - comparison of weight lifted and shoulder height MVC.**

	15% of MVC (Kg)	30% of MVC (Kg)	45% of MVC (kg)	Shoulder MVC (kg)
participant 1	4.8975	9.795	14.6925	<b>&lt; 24.40</b>
participant 2	5.91	11.82	17.73	<b>&lt; 23.43</b>
participant 3	5.5175	11.035	16.5525	<b>&lt; 26.83</b>
participant 4	5.72	11.44	17.16	<b>&lt; 24.67</b>
participant 5	4.945	9.89	14.835	<b>&lt; 27.93</b>
participant 6	3.055	6.11	9.165	<b>&lt; 12.37</b>
participant 7	2.94	5.88	8.82	<b>&lt; 12.13</b>
participant 8	3.405	6.81	10.215	<b>&lt; 10.47</b>
participant 9	2.8325	5.665	8.4975	<b>&lt; 9.07</b>

participant 10	3.42	6.84	10.26	< 11.30
----------------	------	------	-------	---------

Table 6 represents the participant's MVC at the shoulder height. The values obtained serve as a weight limit to be lifted by the participants. The weight lifted by each participant at 45% MVC at the elbow height did not exceed the 100% MVC of the shoulder height to each corresponding participant. This method was mainly aimed to minimize the occurrence of injuries and to make the lifting task as easy as possible and free of overexertion.

## 5.2 EMG Results

### 5.2.1 Effect of Weight on Neck Muscle EMG Activity

Table 8 represents the effect of lifted weight increase on the change in EMG activity in percentage. By increasing the weight from 15% MVC to 30% MVC, we recorded an increase in the MAV EMG of the sternocleidomastoid by 11.8%. An increase of 10.6% increase in the MAV EMG of the Trapezius muscle was recorded. From 30% MVC to 45% MVC weight increase, we recorded 16.5 % increase at the sternocleidomastoid muscle and 7.7% increase at the Trapezius muscle. The overall percentage increase recorded was 26.3% increase for the sternocleidomastoid muscle and 17.5% increase for the Trapezius muscle.

Figure 9 represents the effect of weight lifted during the overhead lift on neck muscles. The data is arranged in bar chart format to compare in the behavior of mean absolute value (MAV) between 15%MVC, 30%MVC and 45%MVC. The trend recognized, regarding the bar charts, is the MAV of both neck muscles increase as the weight increases. We noticed also that the amplitude of MAV of the Trapezius muscle is greater than MAV of the sternocleidomastoid muscle.

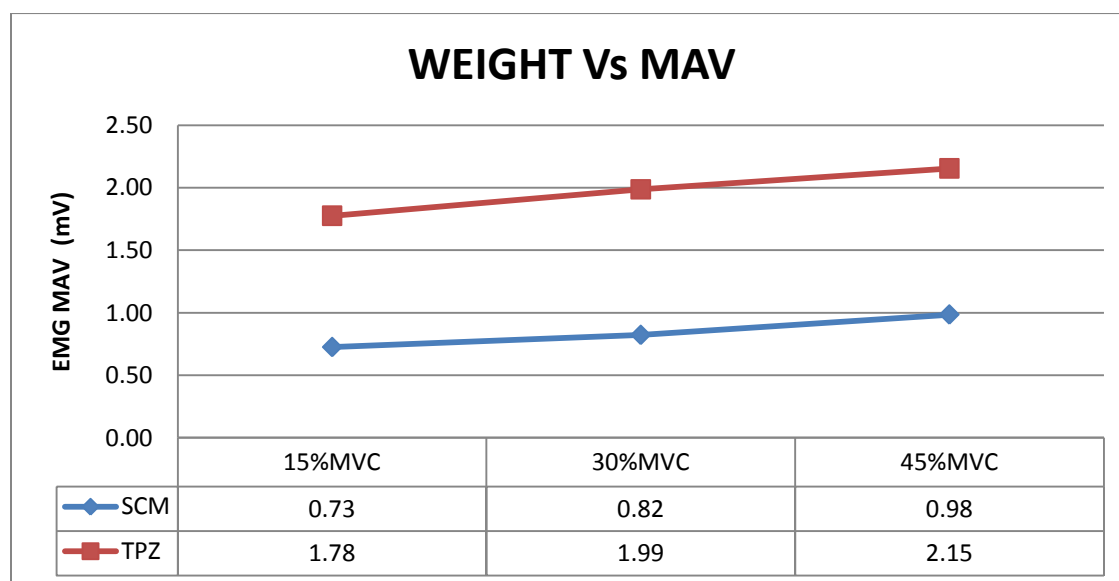
**Table 7- Effect of weight variation on EMG MAV for sternocleidomastoid and upper Trapezius muscles.**

<b>Gender</b>	<b>Subject</b>	<b>Weight</b>	<b>Sternocleidomastoid MAV (mV)</b>	<b>TPZ MAV (mV)</b>
M	1	15% MVC	0.52	1.03
M	1	30% MVC	0.78	1.90
M	1	45% MVC	1.52	2.64
M	2	15%MVC	0.53	1.27
M	2	30%MVC	0.96	2.28
M	2	45%MVC	1.94	2.94
M	3	15% MVC	0.46	1.24
M	3	30% MVC	1.25	2.40
M	3	45% MVC	1.95	3.42
M	4	15% MVC	0.57	1.17
M	4	30% MVC	0.82	1.93
M	4	45% MVC	1.52	2.63
M	5	15% MVC	0.34	1.23
M	5	30% MVC	0.82	1.83
M	5	45% MVC	1.33	2.34
F	1	15%MVC	0.36	1.82
F	1	30%MVC	0.82	2.62
F	1	45%MVC	1.48	3.55
F	2	15%MVC	0.27	1.09
F	2	30%MVC	0.57	1.63
F	2	45%MVC	0.99	2.24
F	3	15%MVC	0.26	1.18
F	3	30%MVC	0.62	1.63
F	3	45%MVC	1.08	1.95
F	4	15%MVC	0.19	0.91
F	4	30%MVC	0.36	1.79
F	4	45%MVC	0.91	2.34
F	5	15%MVC	0.29	1.31
F	5	30%MVC	0.48	1.95

F	5	45%MVC	1.21	2.52
---	---	--------	------	------

**Table 8 - Effect of weight increase on EMG activity (Percentage).**

	Sternocleidomastoid MAV	TPZ MAV
15%-30%	11.80%	10.64%
30%-45%	16.53%	7.76%
15%-45%	26.38%	17.57%



**Figure 9 - Effect of weight increase on EMG activity (AVG of all participants).**

Figure 10 shows a clear relationship between increases in weight from 15% MVC, 30% MVC, 45% MVC, and the mean absolute value of the EMG collected. The observation of the graph reveals a consistent with all participants. This trend shows a steady increase as the weight increases.

**Table 9 - ANOVA results.**

Statistix 9.0

7/5/2009, 9:51:37 PM

**Analysis of Variance Table for Sternocleidomastoid**

<b>Source</b>	<b>DF</b>	<b>SS</b>	<b>MS</b>	<b>F</b>	<b>P</b>
gender	1	9.766E-07	9.766E-07	14.24	0.0054
Error gender*participant	8	5.486E-07	6.858E-08		
weight	2	5.279E-06	2.639E-06	154.90	<u><b>0.0000* (P-VALUE)</b></u>
gender*weight	2	1.206E-07	6.031E-08	3.54	0.0534
Error gender*participant*weight	16	2.726E-07	1.704E-08		
Total	29	7.197E-06			

Grand Mean 8.40E-04

CV(gender\*participant) 31.17

CV(gender\*participant\*weight) 15.54

**Analysis of Variance Table for TPZ**

<b>Source</b>	<b>DF</b>	<b>SS</b>	<b>MS</b>	<b>F</b>	<b>P</b>
gender	1	9.605E-08	9.605E-08	0.25	0.6274
Error gender*participant	8	3.018E-06	3.772E-07		
weight	2	1.026E-05	5.132E-06	141.46	<u><b>0.0000* (P-VALUE)</b></u>
gender*weight	2	1.556E-07	7.780E-08	2.14	0.1496
Error gender*participant*weight	16	5.805E-07	3.628E-08		
Total	29	1.411E-05			

Grand Mean 1.96E-03

CV(gender\*participant) 31.34

CV(gender\*participant\*weight) 9.72



The ANOVA table results represented the analysis of variance of the EMG activity of neck muscles affected by the increase in weight. This table represented the significance of the variation of the upper Trapezius and sternocleidomastoid muscles showing EMG behavior when using three different weights. The underlined value represents the P-value which shows the level of significance in the effect of weight on neck muscles with EMG. ANOVA table results showed a statistically significant change of neck muscle activities by increasing the weight with P-value = 0.000 < 0.05. As we increased the weight from 15%MVC to 30% MVC to 45% MVC, The neck muscles EMG MAV increased as well. This test addressed hypothesis two and rejects the null hypothesis.

### **5.2.2 Effect of weight on EMG by gender**

This section of the results displays the differing EMG response, during overhead lifting between male and female. A Tukey comparison test was conducted to evaluate the difference between each trial of the lift at 15%MVC, 30%MVC, and 45%MVC, using Statistix 9.0 software. This statistical analysis was done assuming that gender is an independent variable.

Table 10 represents the Tukey HSD all-Pair wise comparisons test. This test addressed the gender difference in their response to the increase in lifted weight. The change in means for both genders from 15% MVC to 30% MVC to 45% MVC was not statistically significant. Table 10 shows the difference in means at each weight level and for each gender. The values that are accompanied with a (\*) sign are statistically significant. The values that are not accompanied with a (\*) value are not statistically significant. From this table we conclude that the change in EMG MAV for both genders was not statistically significant. The results of this table support the rejection of the null hypothesis for hypothesis four.

**Table 10 - Tukey HSD All-Pair wise Comparisons Test.**

<b><i>Tukey HSD All-Pair wise Comparisons Test of SCM for gender*weight</i></b>							
<b>GENDER</b>	<b>WEIGHT</b>	<b>MEAN</b>	<b>M,15%</b>	<b>M,30%</b>	<b>M,45%</b>	<b>F,15%</b>	<b>F,30%</b>
<b>M</b>	<b>15</b>	9.28E-04					
<b>M</b>	<b>30</b>	1.71E-03	7.80E-04*				
<b>M</b>	<b>45</b>	2.39E-03	1.45E-03*	6.79E-04*			
<b>F</b>	<b>15</b>	3.15E-04	6.12E-04	1.39E-03	2.07E-03*		
<b>F</b>	<b>30</b>	5.77E-04	3.51E-04	1.13E-03	1.81E-03	2.62E-04*	
<b>F</b>	<b>45</b>	9.75E-04	4.72E-05	7.33E-04	1.41E-03	6.60E-04*	3.98E-04*
<b><i>Tukey HSD All-Pair wise Comparisons Test of TPZ for gender*weight</i></b>							
<b>GENDER</b>	<b>WEIGHT</b>	<b>MEAN</b>	<b>M,15%</b>	<b>M,30%</b>	<b>M,45%</b>	<b>F,15%</b>	<b>F,30%</b>
<b>M</b>	<b>15</b>	1.43E-03					
<b>M</b>	<b>30</b>	2.99E-03	1.55E-03*				
<b>M</b>	<b>45</b>	4.69E-03	3.25E-03*	1.70E-03*			
<b>F</b>	<b>15</b>	1.21E-03	2.17E-04	1.77E-03*	3.47E-03*		
<b>F</b>	<b>30</b>	2.90E-03	1.46E-03*	8.64E-05	1.78E-03*	1.69E-03*	
<b>F</b>	<b>45</b>	4.65E-03	3.21E-03*	1.66E-03*	3.56E-05	3.43E-03*	1.75E-03*

### **5.2.3 Relationship between joint angles and Neck EMG activity**

Joint angles are calculated with the APASVIEW module. It calculates joint angles throughout the lifting task at any given point at a rate of 60Hz. The results in this chapter are represented in form of graphs that juxtapose the angle variation and the EMG activity of the sternocleidomastoid and Trapezius muscle in function of time (seconds).

There are three sets of data that are displayed. The elbow and shoulder angles share the same axis (left side), displaying angles in (degrees), and the EMG data axis is on the right side, measuring MAV.

Figures 11, 12, and 13 represent the effect of change in joint angles on the neck muscles. The graphs show a consistency in the change of elbow angles in both males and females. During the overhead lift, the trend is the same for all participants. The same consistency is observed in shoulder joint angles. The behavior of elbow joint angles during the task is somewhat similar to shoulder joint angles. We clearly distinguished that shoulder and elbow joints move in harmony. From the graphs we see that these two joints move simultaneously and in the same direction. In this overhead task, the shoulder and elbow joints flex and extend simultaneously.

EMG data in Figures 10, 11, and 12 reflect the muscle activity of the Trapezius and the sternocleidomastoid during the overhead lift. Both muscles show significant activity, which confirms their activation during the overhead lifting task. Unlike the joint angles discussed earlier, the EMG data for these two neck muscle do not behave simultaneously. We clearly see that the Trapezius muscle is active along the lift from start to end; however, the sternocleidomastoid is activated in the middle of lift.

The EMG graphs are divided into three phases. The first phase is the start phase, which shows a small peak right at the beginning of the lifting. The second phase is the behavior of the muscle during the lifting. The Trapezius muscle is active from start to end, and for some participants, it shows a higher peak when the elbow and shoulder angles are extended. The sternocleidomastoid shows no activity for the first half of the lift and peaks right when the elbow and shoulder angles are extended. The third phase is a decline in the activity of the muscles simultaneously, due to the nature of the lift.

Figure 10-12 represent the effect of change in joint angles on the neck muscles at various loads. Figure 10 represents 15% MVC load, figure 11 represents 30% load, and figure 12 represent 45% load. All three figures have the same color coded graphs axis and units. The blue line in the graphs represents the change in elbow angles, the red line in the graphs represents the change in shoulder angles, and the green line represents the MAV EMG activity of the selected neck muscles. All figures 10-12 have the same units and axis. The x-axis represents the change in time. The y-axis on the right side represents the MAV EMG variation with units (V), and the second y-axis on the left side represents the change in angle values with units (degrees).

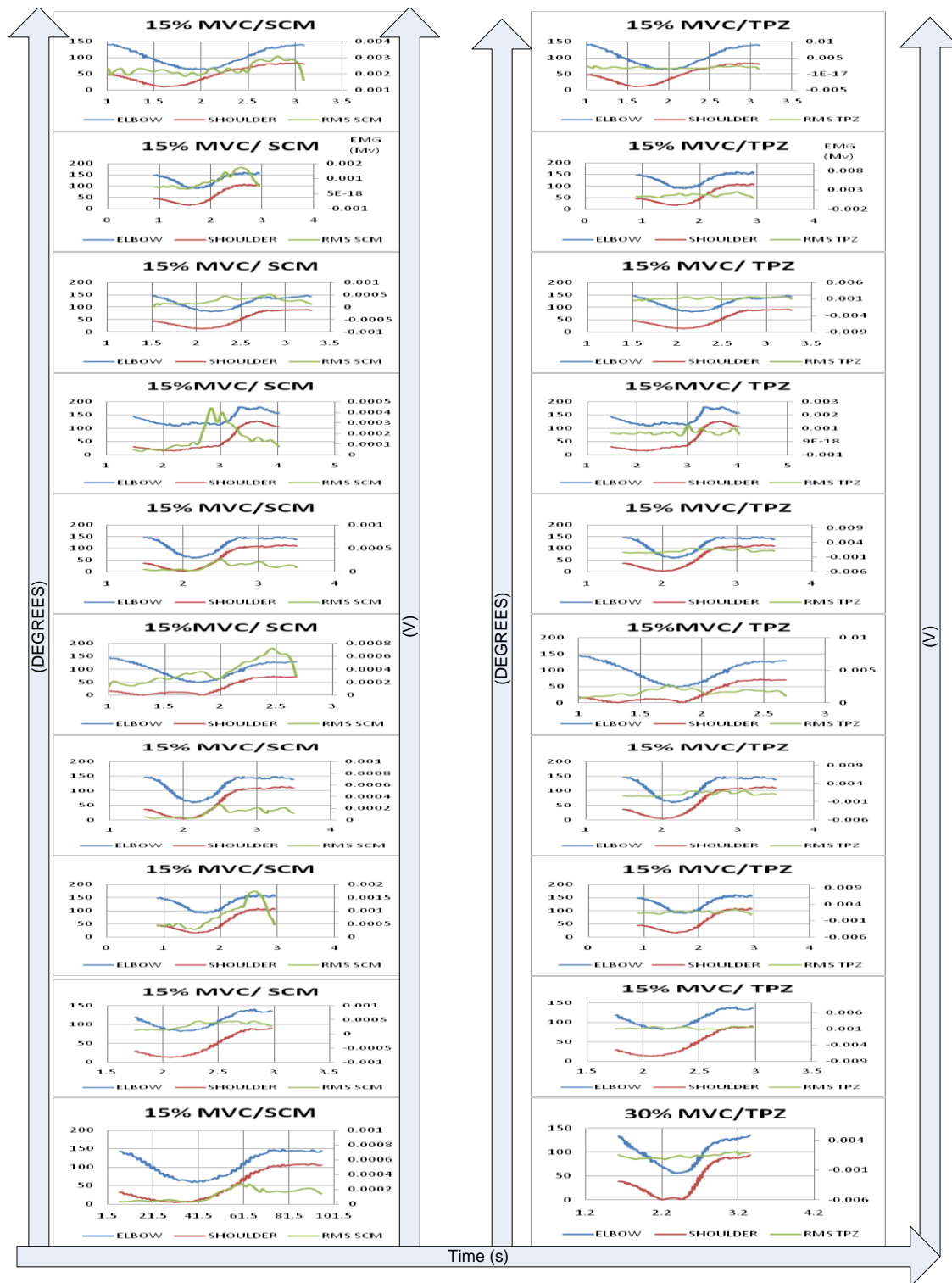


Figure 10 - Effect of joint angles on neck EMG activity during lifting for % MVC.

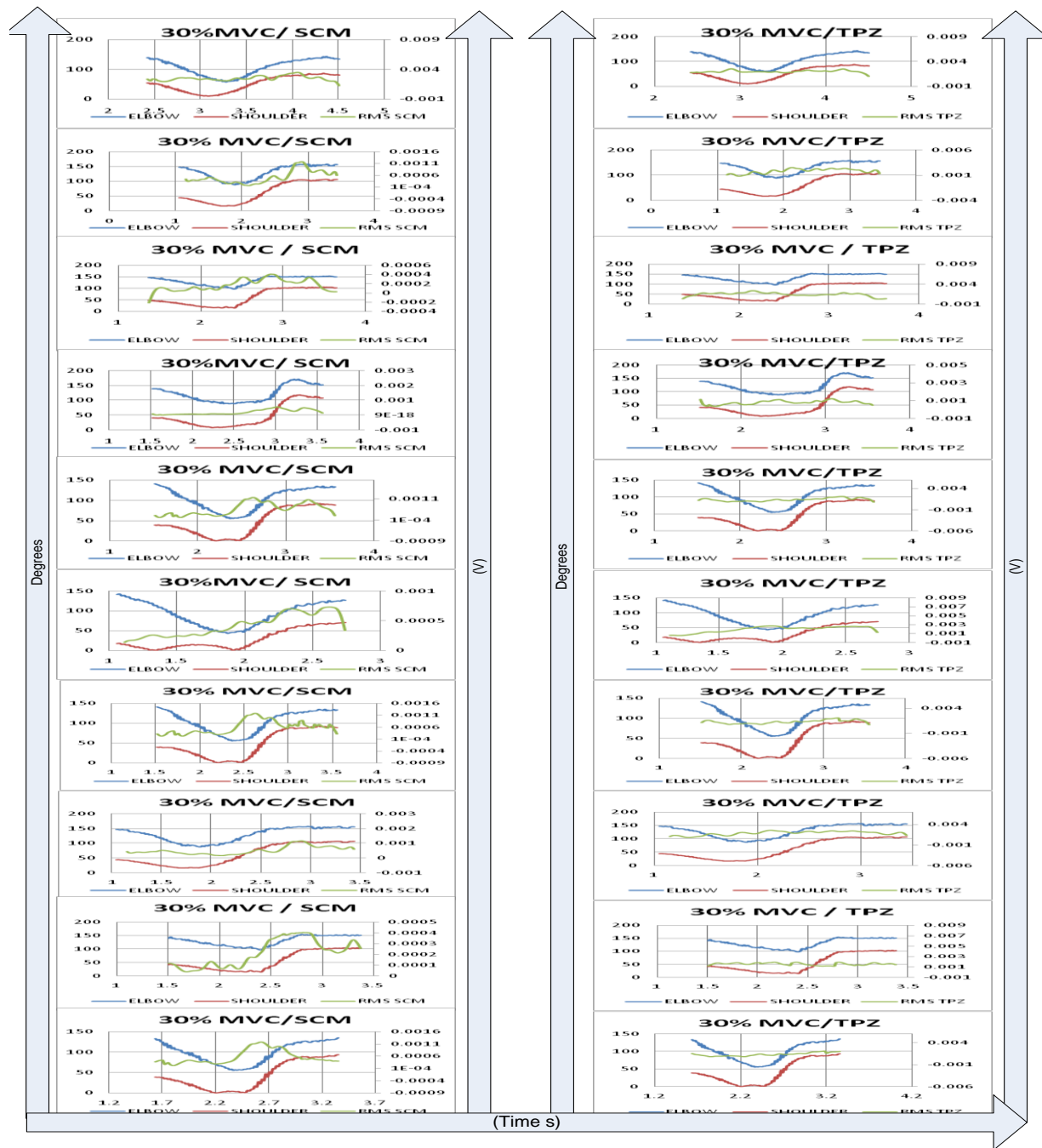


Figure 11 - Effect of joint angles on neck EMG activity during lifting for 30% MVC.

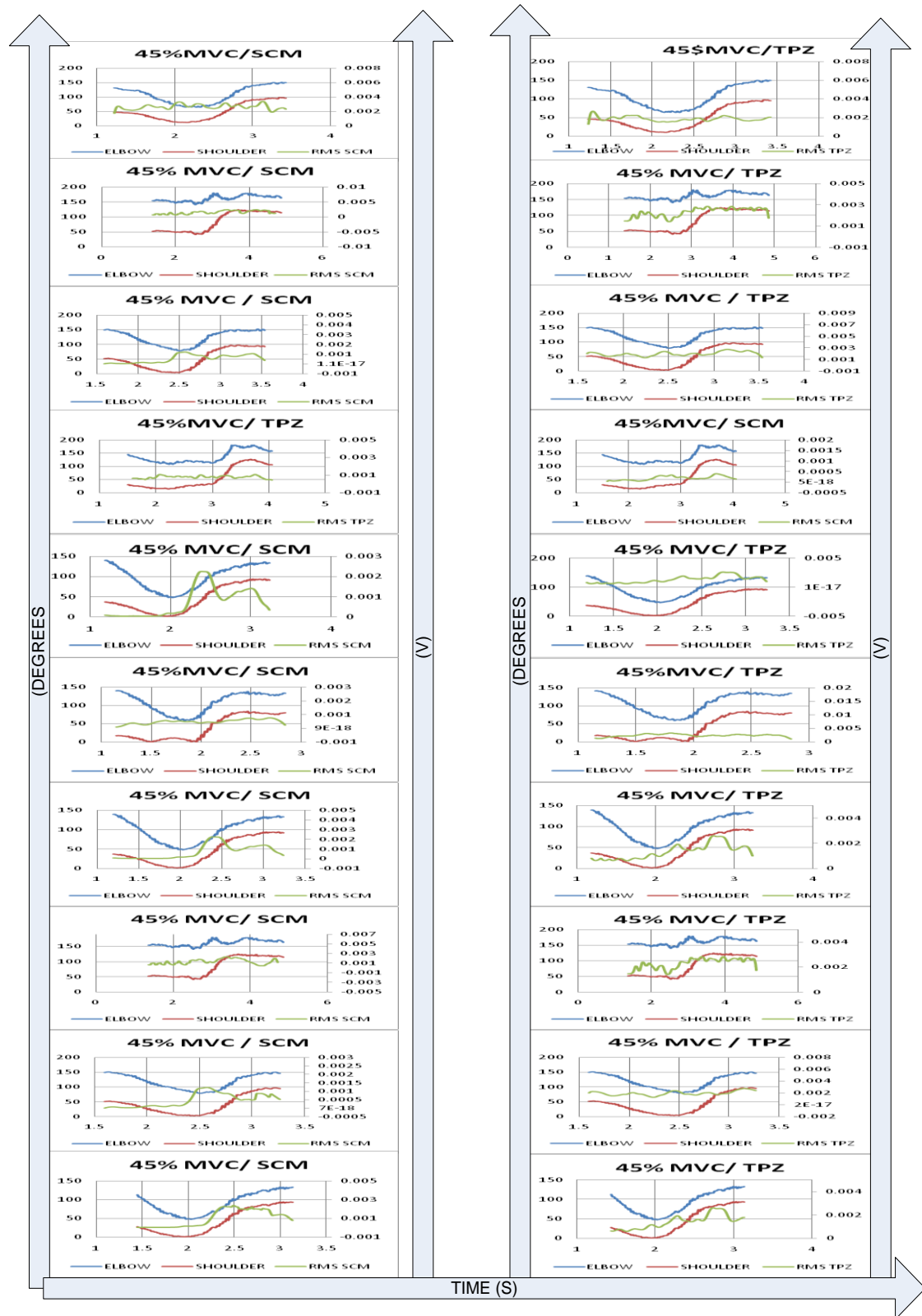
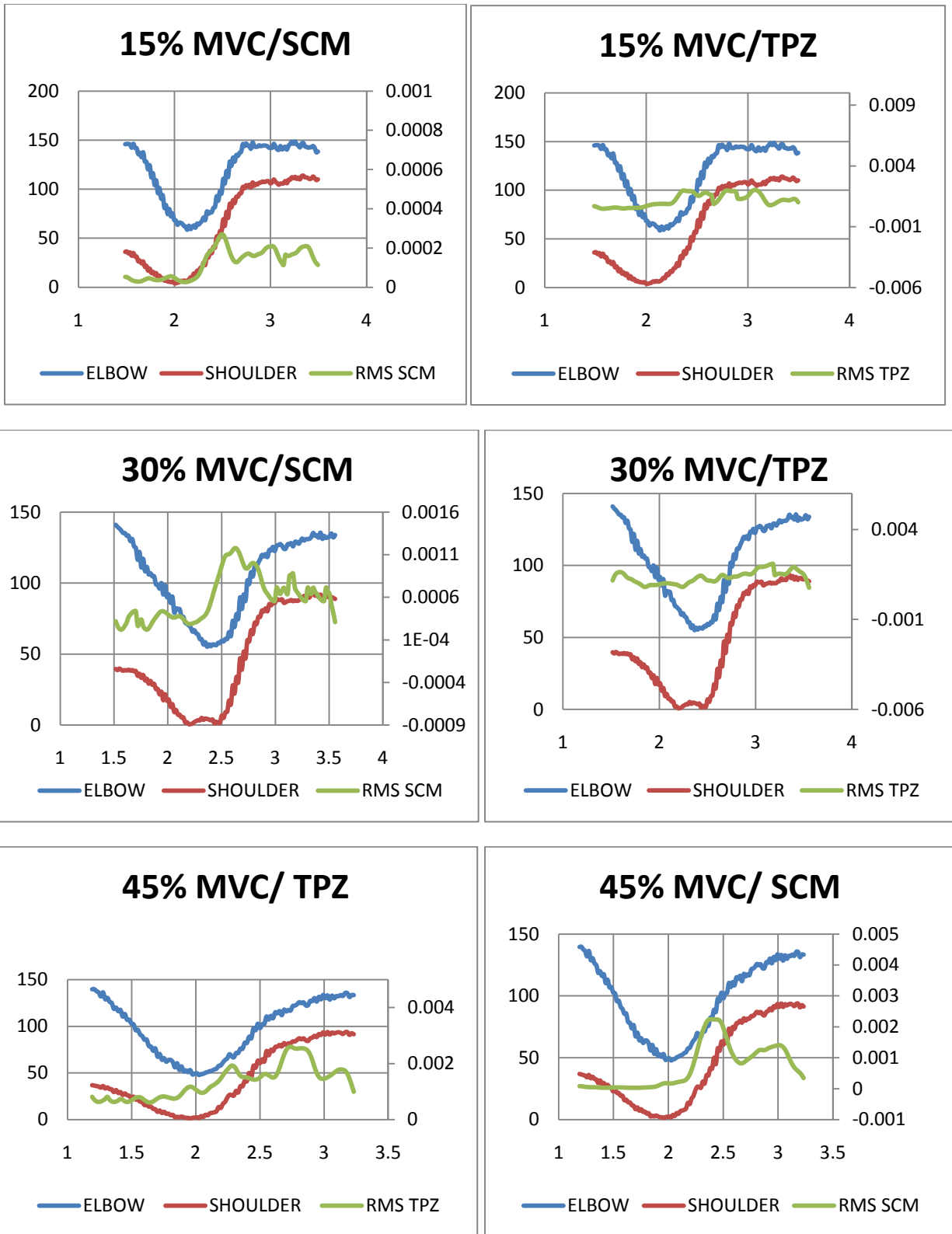


Figure 12 - Effect of joint angles on neck EMG activity during lifting for 45% MVC.



**Figure 13 - Effect of joint angles on neck EMG activity during overhead lifting for one participant.**



#### 5.2.4 Correlation analysis between joint angles and neck EMG activity

The results from the correlation analysis represent the type of bond between variation joint angles and neck muscle EMG. The outcome of the correlation analysis is the average of the correlation coefficient for all participants. It is very important to support the graphical data with statistical data. Table 9 represents the relationship between change of elbow angles and its effect on upper Trapezius and sternocleidomastoid muscle, and the relationship between the change of shoulder angles and its effect on upper Trapezius and sternocleidomastoid muscle. The yellow values represent a statistical significance of change, and the red values represent the non-significant relationships. The obtained results also show whether there is a difference in correlation between 15%MVC, 30% MVC, and 45% MVC.

**Table 11 -Correlation coefficient Analysis.**

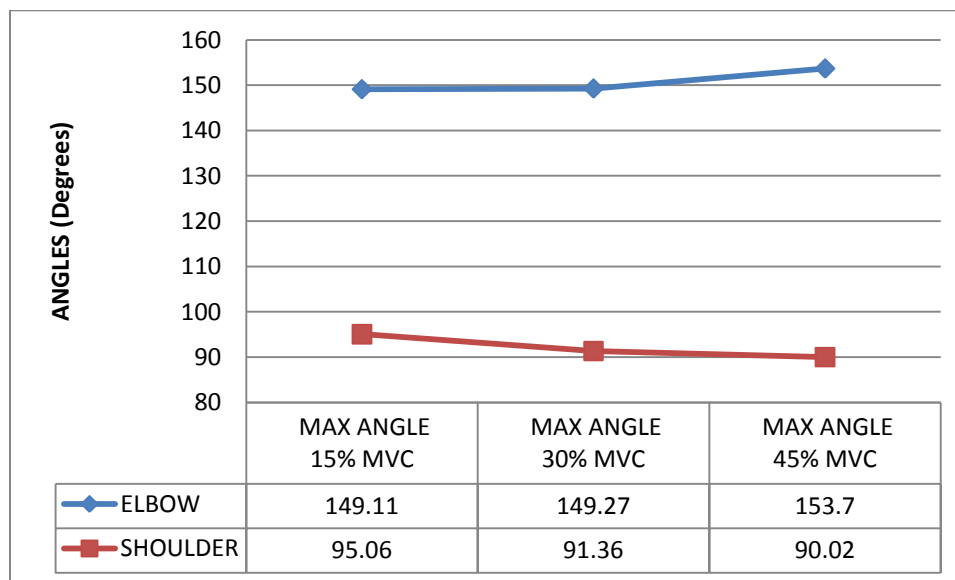
	Elbow Vs. TPZ		Shoulder Vs. TPZ		Elbow Vs. Sternocleidomastoid		Shoulder Vs. Sternocleidomastoid	
	Correlation coefficient	P-Value	Correlation coefficient	P-Value	Correlation coefficient	P-Value	Correlation coefficient	P-Value
15%MVC	0.23	0.02	0.39	0.01	0.26	<b>0.23</b>	0.42	0.00
30%MVC	0.11	0.05	0.46	0.03	0.21	<b>0.26</b>	0.38	0.03
45%VMC	0.39	0.00	0.75	0.03	-0.04	<b>0.17</b>	0.42	0.03

Each correlation coefficient is associated with a P-value. The P-value was to determine if the correlation between joint angles and EMG MAV of the neck muscles were statistically significant or not. The significance level alpha was set at 0.05. The P-value of elbow angles Vs sternocleidomastoid EMG was not statistically significant.

### 5.3 Effect of Weight on Shoulder and Elbow Joint Angles

We noticed a slight struggle for participants in trying to position the box on the top shelf as we increased the weight. This observation led us to evaluate the influence of increased weight on the maximum shoulder and elbow angles. It was logical to study the effect of weight on upper body joint angles, since weight was an independent variable, and joint angles were dependent variables. This section displayed the effect of weight on the average angle values at 15% MVC, 30% MVC, and 45% MVC during the overhead lift. This attempt was to analyze the behavior of average joint angles as we increased the weight.

Figure 14 represented a linear graph of maximum angles recorded during the overhead lift. The table in Figure 14 shows an increase in maximum values of the elbow joint and a decrease in maximum values of the shoulder joint.



**Figure 14 - Effect of weight increase on MAX shoulder and elbow joints.**

## **6. Discussion**

### **6.1 Effect of weight on neck muscles EMG activity**

The aim of this study was to observe the behavior of neck muscles during overhead lifting using a variation of weights, and to analyze the effect of increasing weight on upper body joint angles and neck EMG activity during dynamic, over-head lifting. Workers in many fields are subjected to overhead lifting, which causes neck pain, and sometimes neck injuries. As it has been suggested (Hagberg, 1984; Larsson et al., 1990), neck muscle exertion of more than 20% of the MVC is believed to be a possible risk factor, related with the occurrence of MSD. In this study, we chose a gradual increase of the lifting weight to study the effect of increasing the weight on the Trapezius and sternocleidomastoid muscle. This study shows a consistency in the level of neck muscles response. A bar chart was used to compare different lifted weights in both muscles and then averaging all participants into one chart. The results show an increase of EMG activity in both neck muscles. As the weight increases, the mean absolute value on the EMG data recorded also increases.

It is clear that the activity of both muscles increases by increasing the weight; however the EMG MAV of the Trapezius muscles is greater than the EMG MAV of the sternocleidomastoid muscle. In viewing the anatomy of these two neck muscles, they differ in shape, mass and volume. Since the Trapezius muscle has the biggest size, it requires more motor units and more energy to be activated, compared to the sternocleidomastoid muscle.

During all the forceful arm exertions, the lowest neck muscle activation was observed at 15% MVC. The highest neck muscle activity was recorded at 45% MVC for both sternocleidomastoid and upper Trapezius muscles, which supports our general hypothesis that an

increase in lifting weight would indeed increase the neck muscle activity. This observation is supported by the study of Astrom et al. (2007), which indicated a positive linear relationship between the upper Trapezius muscle activity and the weight lifted at knuckle height.

Table 7 represents the ANOVA results of the effect of weight on neck muscles. A simple observation of the P-Value “ $P=0.0000$ ” of the sternocleidomastoid and the Trapezius muscle indicates that the change in EMG activity from 15% to 30% to 45% is significant. This result indicates a positive relationship between EMG and weight, which indicates that as one increases, the other increases as well. This result for the first hypothesis is in agreement with the findings of Nimbarte et al., 2008, who confirmed neck muscle EMG activity increases correspondingly with the increase of weight or forces exerted. Furthermore, Anton et al. (2005) showed in their study that an increase in force applied to the hand resulted in an increase of the upper Trapezius muscle activity. Farina et al. (2002) claimed that a gradual increase from 0kg to 0.5 kg to 1kg lifted at the shoulder level with an angle on  $90^\circ$  at the shoulder joint shows an increase in the Trapezius muscle activity. As the initial value with a 1kg load, the two-way ANOVA showed a significant difference in the mean MMG and EMG values between the different loads ( $F=14.05$ ,  $P<0.001$  and  $F=8.84$ ,  $P=0.002$ ). Similar results were obtained with RMS values and for normalized data with 0 and 0.5 kg loads. This result supports our hypothesis that an increase in lifted weight results in an increase in EMG activity of the neck muscles.

Figure 6 represents the overall response of neck muscles during the overhead lifting task, of lifting three different weights. The upper Trapezius average EMG activity for all participants appears to be greater than the sternocleidomastoid average of EMG activity. The level of sternocleidomastoid activity increase was 11.8% from a 15% MVC load to a 30% MVC load and 16.53% from a 30%MVC to 45% MVC. This percentage increase may be low, due to the light

weight that was lifted. The same results were shown for upper Trapezius neck muscle activity: 10.64% increase from a 15% MVC to a 30% MVC, and 7.76 % increase from a 30% MVC to a 45% MVC. These results are consistent with several studies. Anton et al. (2005) showed elevated upper Trapezius EMG activity along with an increase in the load lifted. Farina et al. (2002) concluded in their study that a simple increase in the lifted weight at shoulder height from 0Kg to 0.5Kg to 1Kg resulted in an increase in activities for the upper Trapezius muscle. A much higher percentage of increase was expected between 15% MVC and 45% MVC; 26.38% was the percentage increase for the sternocleidomastoid muscle and 17.57% increase for the upper Trapezius muscle.

Tables 12-16 represent the results from the Tukey HSD ALL-Pairwise comparison test of neck muscles in male and female subjects. The values used in the tables represent the difference in mean of the EMG MAV of the muscles at difference weight levels. The (\*) sign represent the significance of the comparison. Each value that is accompanied with a star is statistically significant.

**Table 12 - Tukey HSD All-Pairwise Comparisons Test of SCM for (females).**

Gender	Female 15%	Female 30%	Female45%
Female 15%			
Female 30%	2.62E-04*		
Female 45%	6.60E-04 *	3.98E-04*	

**Table 13 - Tukey HSD All-Pairwise Comparisons Test of SCM for (males).**

Gender	Male 15%	Male 30%	Male45%
Male 15%			
Male 30%	7.80E-04*		
Male 45%	1.45E-03*	6.79E-04*	

**Table 14 - Tukey HSD All-Pairwise Comparisons Test of TPZ for (Females).**

Gender	Female 15%	Female 30%	Female45%
Female 15%			
Female 30%	1.69E-03*		
Female 45%	3.43E-03*	1.75E-03*	

**Table 15 - Tukey HSD All-Pairwise Comparisons Test of TPZ for (males).**

Gender	Male 15%	Male 30%	Male45%
Male 15%			
Male 30%	1.55E-03*		
Male 45%	3.25E-03*	1.70E-03*	

Tables 10 through 15 are in accordance with our findings that changes in the EMG activity of both upper Trapezius and sternocleidomastoid muscles are indeed influenced by the increase of the weight lifted. The (\*) sign shown next to each mean value represents the statistical significance of that difference. Upper Trapezius muscle behavior in this study show significant increase from 15% MVC to 30% MVC to 45% MVC. The Tukey HSD ALL-Pairwise comparison test is consistent with the findings in the ANOVA test.

## 6.2 Neck muscle behavior by gender

The difference in gender during overhead neck muscle behavior is supported by table 16. The results show a complete comparison between male and female participants during each weight category: 15% MVC, 30% MVC, and 45% MVC. Table 8 represents the Tukey HSD All-Pairwise Comparisons Test of the upper Trapezius and sternocleidomastoid muscles. Results show no significant difference at the upper Trapezius level between male and female participants

during 15% MVC, 30% MVC, and 45% MVC. These results are applicable for the sternocleidomastoid muscle for only 15% MVC and 30%MVC. However, at 45% MVC the difference between male and female participants becomes significant.

Table 16 was derived from Table 10; it showed no significant change between genders for the same level of weight. This was interpreted that response of weight increase on EMG activity for both genders behaved the same way.

**Table 16 - Tukey HSD All-Pairwise Comparisons Test of TPZ & SCM for Male Vs Female.**

<b>TPZ</b>	<b>Male 15% MVC</b>	<b>Male 30% MVC</b>	<b>Male 45% MVC</b>
Female 15% MVC	2.17E-04	-	-
Female 30% MVC	-	8.64E-05	-
Female 45% MVC	-	-	3.56E-05
<b>SCM</b>	<b>Male 15%</b>	<b>Male 30%</b>	<b>Male 45%</b>
Female 15% MVC	6.12E-04	-	-
Female 30% MVC	-	1.13E-03	-
Female 45% MVC	-	-	1.41E-03

Table 16 represents a comparison between male and female MAV EMG activity. These tables compared 15%MVC male to 15%MVC female, 30%MVC male to 30% MVC female, and 45%MVC male to 45% MVC female. None of the values show a significant change between both genders. Alpha was 0.05, and the standard error of comparison was 2.34E-04 for the same level of gender. The values represented the difference in mean between different weights at male and female participants.

### **6.3 Effect of change in the joint angles on neck muscle activity**

The effect of joint angles on neck muscle activity constitutes the main core of this study. A series of measurements took place to evaluate the change in joint angles continuously throughout the dynamic lifting task chosen for this study. Using our synchronization technique, a graph of the neck EMG activity and the upper extremity joint angle variation shows the relationship between these two variables. As a general observation, neck muscle activity increases as arm elevation increases. In this study, activities of the neck muscles were recorded continuously from knuckle height to overhead height. Nimbarte et al. (2009) reported that static forceful exertion at knuckle height, elbow height, shoulder height, and overhead height increases respectively. Results of this study show a steady trend for the upper Trapezius muscle. The trend was a steady activation of the upper Trapezius muscle during the lift, with a slight increase as the shoulder joint angle increases. Results of the graphs reveal more information that helps to understand neck muscle behavior during dynamic overhead lifting. In the majority of the participants, sternocleidomastoid muscle is activated at mid-range of the motion, which means that sternocleidomastoid muscle was not significantly active during the first half of the motion. In the first half, the sternocleidomastoid EMG shows an escalating activity as the shoulder joint angle increases to about 90-95 degrees. These observations are possible to spot only in a dynamic analysis. Most of the static studies relating to neck muscles show no results that support this observation.

The benefit of conducting a dynamic study is the ability to observe the continuous behavior of neck muscles during the entire lifting task. Static studies showed a steady increase at various static positions of the arm with different angle combinations and different postures. The



lifting task was divided into three sections. The first section was the start of the motion. By observing the EMG graphs for Trapezius and sternocleidomastoid, we noticed a peak, even while the joint angles were at their minimal values. This trend was explained by the fact that the participants needed to gather enough momentum to move the object lifted. Once the object was in motion, the muscle exerted less force than at the starting point. The second phase of the lifting is the mid-range of motion. At mid-range, all participants tended to lift the box closer to their trunk area. At this range, we observed a decline in the activity of neck muscles. Simple laws of physics explain this observation. By holding the box closer to the body, the box becomes closer to the body's center of gravity. The closer the weight gets to the center of gravity, the less activity we observed in neck EMG activity.

Correlation analysis was a major factor to statistically support our hypothesis. The hypothesis states that change in upper body extremity joint angles have some influence on upper Trapezius and sternocleidomastoid muscles. Table 11 displays both correlation coefficient and P-Values of neck muscles with elbow and shoulder joint angles at different weight categories. Results of the correlation analysis were divided into four sections. Each section displayed the correlation coefficient and the associated P-values of the three different lifted weights of 15% MVC, 30% MVC, and 45% MVC.

Table 11 shows a correlation relationship between elbow joint angles and the EMG activity of the upper Trapezius. Even though the correlation coefficient is 0.0233 which is low, the P- value ( $=0.02$ ) indicates that as the elbow joint angle changes during the motion, the upper Trapezius EMG activity also changes significantly. The same result is shown at all the weight levels. At 30% MVC the P-value is 0.004 and at 45% MVC the P-value is 0.0001.

The correlation coefficient between shoulder joint angles and the EMG activity of the upper Trapezius show the correlation coefficient at 15% MVC to be 0.01, which is considered a weak relationship. The P-value is 0.02, which indicates that the effect of a change of shoulder joint angles on the upper Trapezius EMG activity is significant. The same result is observed at all weight levels. At 30% MVC, the P-value is 0.003; and at 45% MVC, the P-value is 0.025. There is a strong relationship between the shoulder angle variation and upper Trapezius EMG activity. The results show that the highest relationship out of the four sections of the correlation analysis table is between the shoulder joint angles and the upper Trapezius muscles. This is due to the connection between the muscle and the joint. It also indicates the major role the upper Trapezius muscle plays in overhead lifting.

Elbow joint movement does not significantly influence the activation of the sternocleidomastoid muscle. The correlation analysis shows a neutral relationship between elbow joint angles and sternocleidomastoid EMG activity. The correlation coefficient is 0.25 at 15% MVC, 0.21 at 30% MVC, and -0.04 at 45% MVC. These values are close to zero, which indicates that there is a neutral relationship between the two variables. Therefore, this dynamic overhead study shows an important result, supported by Vigreux et al. (1979) who studied the elbow flexors in an isometric condition. The researchers determined that within the range of angles studied, there was no major effect of elbow joint angle in EMG activity of the area studied.

The fourth section of the correlation shows a significant P-value of 0.0002, 0.02, and 0.03 for 15% MVC, 30% MVC and 45% MVC, respectively. Even though the correlation coefficient is weak, the P-value indicated that the effect of shoulder joint angles significantly affects the sternocleidomastoid muscle activity during overhead lifting at three different weights.

Figures 11 through 15 represent the effect of increasing upper extremity joint angles on neck muscle activities. Results have shown an increase in upper Trapezius muscle as joint angles increase simultaneously. An interesting oscillating trend was observed in all graphs for all ten participants. This could be explained due to the repetitive angle position during the lift. At the start of the lift, a shoulder angle value of 20 degrees was repeated twice. One was at the start of the lift and the other was at mid-range. Both angles were the same, but different EMG recording was allocated to each angle. The same was observed at the elbow joint. At the start of the lift, the elbow angle was about 165 degrees, while the same angle was repeated at the end of the lift, where the shoulder joint angle was at its maximum. This explains that for the same value we could have a maximum value, and a minimum value. For this reason, the oscillating trend was observed.

#### **6.4 Effect of Weight on Maximum Angles of Elbow and Shoulder Joints**

The effect of weight on maximum shoulder and elbow joints was noticed visually and was supported by the data in Table 10, as well.

**Table 17 - Effect of weight increase on MAX Shoulder and Elbow Angles (Percentage).**

	Elbow	Shoulder
15%-30%	0.1%	-4.06%
30%-45%	2.88%	-1.50%
15%-45%	2.98%	-5.6%

An increase in the elbow joint angle of 0.1% was recorded from 15% MVC to 30% MVC. A 2.88% increase in elbow joint angle was recorded from 30% MVC to 45% MVC, with an overall 2.98% increase from 15% MVC to 45% MVC. This result was expected due to the increase of the lifted weight. The elbow joint would extend to reach almost 180 degrees

(completely flat), due to the gravity and weight factor. The shoulder joint angle decreased in value as we increased the weight from 15% MVC to 45% MVC.

## 7. Conclusion

The correlation analysis on the effect of change in joint angles on neck muscles reveals that joint angles change result in a statistically significant change in neck EMG muscles. The only exception is the correlation between elbow joint angles and sternocleidomastoid EMG is not statistically significant. Hypothesis 1 is partially rejected due to its four components. The change in shoulder flexion angles in the sagittal plane is correlated and statistically significant with the change in Trapezius MAV EMG activity.

According the ANOVA results, an increase in the load lifted during overhead tasks results in significant change in the muscular activity in both Trapezius and sternocleidomastoid muscles. The results lead us to reject the null hypothesis for hypothesis #2.

The Tukey HSD results reveal that the null hypothesis for hypothesis #3 is accepted. This means that male and females participants react similarly to the increase of weight. The change in EMG activity for both genders is not statistically significant.

The obtained results can play a major factor in redesigning overhead lifting in general, as well as overhead work in the construction industry. Brick layers suffer from neck pain and fatigue due to the repetitive nature of their job that involves overhead lifting Akinomayowa (1987). This study shows the approximate joint angle that produces maximum neck muscle activity. In order to eliminate the factor of lifting bricks above the shoulder, we can use ladders and pedestals so we can position the worker in a comfortable position to lift and lay bricks without reaching high shoulder joint angles. Less EMG activity produced means less muscle activity involved, and less muscle activity involved translates to less fatigue and muscle pain. By

reducing the muscle activity level, muscles will have enough time to recover and experience less fatigue.

## **7.1 Limitations**

Due to the time frame and budget limitations, we had to work with the existing equipment available in the Ergonomics laboratory. An aspect of the research was considered to be a limitation. The lifting procedure had many variations; for example, the duration of the lift varied from one participant to another. The lifting technique was chosen by the participants to match each person's best level of comfort. These minor details had a major impact on the analysis of the data. Due to of the dynamic nature of the lifting task, we were unable to make the lifting duration uniform for all participants. As a result we simply timed our lifting to two seconds or three seconds exactly. Since variation is part of the lifting process, we could not average the graphs in function of time, because each graph had different time duration. Another aspect of the study that proved to be a limitation was the motion of the neck.

## **7.2 Recommendations for future studies**

In this research, we focused on the two-dimensional aspect of overhead lifting. The notion was to simulate overhead lifting in the construction industry. Since real work involves three-dimensional movements, we can further investigate the involvement of the neck muscles and back muscles in the over head lifting procedure by adding a twisting movement. This reflects a closer simulation to actual construction workers. More video cameras would be involved in this analysis; at least six cameras should be installed to analyze this lifting task. We can also add biomechanical variables to be measured, such as torque, speed, velocity, and ground reaction. We can benefit of one system that can collect kinematic data and EMG activity that synchronizes

both data simultaneously. The concept behind these added factors would be to simulate the real life tasks and thereby extract a more accurate interpretation of the neck muscles behavior in overhead work.

## 8. BIBLIOGRAPHY

Aghazadeh, F. and Ayoub, M.M. 1985, A comparison of dynamic- and static-strength models for prediction of lifting capacity, *Ergonomics*, 28, 1409-1417.

Anton, D., Rosecrance, J. C., Gerr, F., Merlino, L. A. and Cook, T. M. (2005). Effect of concrete block weight and wall height on electromyographic activity and heart rate of masons. *Ergonomics* 48(10): 1314-1330.

Åström, C., Lindkvist, M., Burström, L., Sundelin, G. and Karlsson, J. (2007). Changes in EMG activity in the upper Trapezius muscle due to local vibration exposure. *Journal of Electromyography and Kinesiology*.

Ayoub, M.M. and Mital, A. 1989, *Manual Materials Handling*, Taylor & Francis: London.

Bente R. Jensen, Bente Schibye, Karen Sogaard, Erik B. Simonsen, and Gisela Sjogaard. Shoulder muscle load and muscle fatigue among industrial sewing-machine operators *European Journal of Applied Physiology* (1993)) 67:467-475

Burgess-Limerick, R., Abernethy, B., Neal, R. J., 1991. A natural-physical approach to understanding lifting. In V. Popovic and M. Walker (Eds.). *Ergonomics and Human Environments. Proceedings of the 27th Annual Conference of the Ergonomics Society of Australia*, December, Coolumb, 295-302.

Burgess-Limerick, R., Abernethy, B., Neal, R. J., 1993. Relative phase quantifies Inter-joint coordination. *Journal of Biomechanics* 26, 91-94.

Jensen C., Nilsen K. Hansen K., and Westgaard R. H. Trapezius muscle load as a risk indicator for occupational shoulder-neck complaints. *Int Arch Occup Environ Health* (1993) 64: 415-423

Ciriello, V.M., Snook, S.H., Hashemi, L. and Cotnam, J. (1999). Distributions of manual materials handling task parameters. *International Journal of Industrial Ergonomics*, 24, (4), 379-388.

Farina, D., Madeleine, P., Graven-Nielsen, T., Merletti, R. and Arendt-Nielsen, L. (2002). Standardising surface electromyogram recordings for assessment of activity and fatigue in the human upper Trapezius muscle. *European Journal of Applied Physiology* 86(6): 469-478.

Fredriksson, K; Alfredsson, L; Koster, M; Thorbjornsson, C.B; Toomingas, A; Torgen, M; Kilbom, A. Risk factors for neck and upper limb disorders: results from 24 years of follow up. *Occupational and Environmental Medicine: Volume 56(1) January 1999*pp 59-66

Garg, A. and Saxena, U. 1979, Effects of lifting frequency and fatigue with special reference to psychophysical methodology and metabolic rate, *American Industrial Hygiene Association Journal*, 40, 894-903



Hattori Y.; Ono Y.; Shimaoka M.; Hiruta S.; Shibata E.; Ando S.; Hori F.; Takeuchi Y. Effects of box weight, vertical location and symmetry on lifting capacities and ratings on category scale in Japanese female workers. *ERGONOMICS*, 2000, VOL. 43, NO. 12, 2031 ± 2042

Helene, F; Chris, J; Hermann, B. Risk factors for neck-shoulder and wrist-hand symptoms in a 5-year follow-up study of 3,990 employees in Denmark. *Int Arch Occup Environ Health* (2002) 75: 243–251

Holmstrom, E.B., Lindell, J. and Moritz, U. (1992). Low back and neck/shoulder pain in construction workers: Occupational workload and psychosocial risk factors. Part 1: Relationship to low back pain. *Spine*, 17, (6), 663-671.

Holmstrom, E.B., Lindell, J. and Moritz, U. (1992). Low back and neck/shoulder pain in construction workers: Occupational workload and psychosocial risk factors. Part 2: Relationship to neck and shoulder pain. *Spine*, 17, (6), 672-677

Hagberg, M. (1984). Occupational musculoskeletal stress and disorders of the neck and shoulder: A review of possible pathophysiology. *International Archives of Occupational and Environmental Health* 53(3): 269-278.

Julius, S; Rosie, J.L; and Martyn, L. The impact of workplace risk factors on the occurrence of neck and upper limb pain: a general population study. *Public Health* 2006, 6:234

Larsson, S. E., Bodegård, L., Henriksson, K. G. and Oberg, P. (1990). Chronic Trapezius myalgia: Morphology and blood flow studied in 17 patients. *Acta Orthopaedica* 61(5): 394-398

Hagberg, M; Wegman, D.H. Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. *British Journal of Industrial Medicine* 1987; 44:602-610

Nussbaum, M; Zhang, X. Heuristics for locating upper extremity joint centers from a reduced set of markers. *Human Movement Science* 19 (200) 797-816.

Mital, A. and Kromodihardjo, S. 1986, Kinetic analysis of manual lifting activities: Part II. Biomechanical analysis of task variables, *International Journal of Industrial Ergonomics*, 91 ± 101.

Nimbarte, A. D., Aghazadeh, F., Ikuma, L.H. (2008). Understanding the contribution of neck muscles during isometric lifting tasks. Paper presented at the International Occupational Ergonomics and Safety Annual Conference. June 12-13, Chicago, USA.

Nimbarte, A. D., Aghazadeh, F., Ikuma, L.H. (2009). Evaluation of risk factors for cervical spine disorders due to manual material handling tasks. Paper accepted for presentation at the IEA Triennial Congress. August 9-14, Beijing, China.

NIOSH, July, 1997. Musculoskeletal Disorders and Workplace Factors: A Critical Review of epidemiological Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. DHHS (NIOSH) Publication No. 97-141

Bonato, P; Boissy, P; Della Croce, U; and Roy, S.H;. Changes in the surface EMG Signal and the Biomechanics of Motion during a Repetitive Lifting Task. IEEE Transactions on neural systems and rehabilitation engineering, VOL. 10, NO. 1, MARCH 2002

Herbert, P; Kadefor, S.R;. A study of painful shoulder in welders. Acta-orthop-scand. 47, 381-387, 1976

Van den Heuvel, S.G., Van der Beek, A.J., Blatter, B.M., Hoogendoorn, W.E., Bongers, P.M. Psychosocial work characteristics in relation to neck and upper limb symptoms. Pain 114 (2005) 47–53

U.S. Bureau of Labor Statistics. 1999a, BLS releases new 1998–2008 employment projections. Washington, DC. <http://www.stats.bls.gov/emphome.htm>

Vigreux B., Cnockaert J.C., Pertuzon E (1979) Factors influencing quantified surface EMGs. Eur J Appl Physiol 41:119-129

Viikari-Juntura, E., Riihimäki, H., Tola, S., Videman, T. and Mutanen, P. (1994). Neck trouble in machine operating, dynamic physical work and sedentary work: a prospective study on occupational and individual risk factors. J Clin Epidemiol, 47, (12), 1411-1422.

Chen, Y., McDonald, J.C., and Cherry, N.M. Incidence and suspected cause of work-related musculoskeletal disorders, United Kingdom, 1996–2001 Occupational Medicine 2006; 56:406–413

## **APPENDIX – A**

### **CONSENT FORM**

- 1. Study Title:** Neck Muscles Activity and Upper Body Extremity Angles in Dynamic Overhead Lifting
- 2. Performance Site:** 3413, Occupational Biomechanics Laboratory, Department of Construction Management and Industrial Engineering. Louisiana State University and Agricultural and Mechanical College.
- 3. Investigators:** The following investigators are available for questions about this study: Dr. F Aghazadeh Department of Construction Management and Industrial Engineering, 3132B CEBA, Louisiana State University, Baton Rouge, LA 70803  
Telephone Number: (225)578-5367  
Mohamed Wassim Mokrani  
Department of Construction Management and Industrial Engineering.  
Telephone Number: (225)588-4330
- 4. Purpose of the Study:** The purpose of this research is to see how lifting heavy objects such as concrete blocks for an eight hour shift can cause work related musculoskeletal disorder to neck muscles. The focus of this research is on the Trapezius muscle and sternocleidomastoid muscle.
- 5. Participant Inclusion:** Healthy graduate or undergraduate students at Louisiana State University between the ages of 20 and 35 who are free from back and neck pain and have no musculoskeletal abnormalities will participate

in the study. Participants who answer YES to any of the following questions will be excluded from the research.

- |                             |     |    |
|-----------------------------|-----|----|
| 1) Heart trouble:           | yes | no |
| 2) Neck pain:               | yes | no |
| 3) Severe dizziness:        | yes | no |
| 4) Blood pressure problems: | yes | no |
| 5) Arthritis:               | yes | no |
| 6) Pregnant:                | yes | no |
| 7) Back surgery?            | Yes | no |

**6. Number of participants:** 10

**7. Study Procedures:** The study procedure will be completely explained to the participant and all the questions regarding the research will be answered. Participants will be asked to read and sign the consent form before the start of experiment. During session I the functional mass that participants are going to lift during session II will be determined using a static pull test. Session I will also serve as practice session and will be used to familiarize the participant with the lifting task. Participants will lift from knuckle height to shoulder height, using a self-selected lifting technique at the rate of 4lifts/min. At the beginning of session I, the participants will be given an empty plastic box (0.3 kg mass) and add 15% of their MVC. During session II, they will lift the functional mass of 30% of their MVC. During session III, participants will perform the lifting task, using 45% of the weight

determined in session I and a two channel EMG system will be installed. One electrode will be placed on the Trapezius muscle and another electrode will be placed on the sternocleidomastoid muscle to record muscle activity during the lift.

**8. Measurements:** Neck muscle activity will be collected using surface electromyography (EMG), and joint angles will be derived from the Ariel Performance analysis system (APAS).

**9. Benefits:** There are no direct benefits to the participants. However, information gained from the study will provide significant data on redesigning lifting methods and may prevent future neck pain.

**10. Risks:** The possible risks of participating in the study are dizziness, muscle fatigue, and vertebrae disc damage.

**11. Injury/Illness:** The risk involved in the study is minimized by excluding all the participants who don't meet physical requirements or answer YES to the health-screening questionnaire. In case of any physical injury to participants during this research project, treatment is not available at Louisiana State University, nor is there any insurance carried by the University or its personnel applicable to cover any such injury. Treatment and financial compensation for such injury must be provided through the participant's own insurance program. In case of emergency, the local emergency service (911) will be contacted.

**12. Right to Refuse:** Participants may choose not to participate or if at any time during the study, participant feels uncomfortable with any method or in

performing the requirements, formal withdrawal from the study will commence at any time with no penalty.

**13. Privacy:**

The LSU Institutional Review Board (which oversees university research with human participants) may inspect and/or copy the study records.

Results of the study may be published, but no names or identifying information will be included in the publication.

Other than as set forth above, participant identity will remain confidential unless disclosure is legally compelled.

**14. Financial Information:** No costs are incurred by participants in this study.

**15. Signature:**

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about participants' rights or other concerns, I can contact Robert C. Mathews, Institutional Review Board, (225) 578-8692. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of the consent form.

Participant Signature

Date

## APPENDIX – B Personal Information Sheet

Date: \_\_\_\_\_ Time: \_\_\_\_\_

Name: \_\_\_\_\_

Age: \_\_\_\_\_

Gender: M / F

Weight: \_\_\_\_\_ Kg

Height: \_\_\_\_\_ CM

Participant ID #

Phone number: (    )       -

### **Data Collection Table:**

	Trial1	Trial2	Trial3	AVG
Elbow MVC				
	<b>15%</b>	<b>30%</b>	<b>45%</b>	
Lifting Weight				
	<b>Trial1</b>	<b>Trial2</b>	<b>Trial3</b>	<b>AVG</b>
Shoulder MVC				

Participant Signature: \_\_\_\_\_

## APPENDIX – C Correlations analysis (Pearson)

Correlation Analysis									
Location		Elbow / TPZ		Shoulder / TPZ		Elbow / Sternocleidomastoid		Shoulder / Sternocleidomastoid	
Participant		Correlation coefficient	P-Value	Correlation coefficient	P-Value	Correlation coefficient	P-Value	Correlation coefficient	P-Value
1	15%	0.6605	0	0.4355	0	0.5657	0.0647	0.6951	0
1	30%	0.104	0.0522	0.104	0.2522	0.2568	0.0756	0.3467	0.0001
1	45%	0.456	0.000157	0.7954	0.1245	-0.3379	0.0618	0.824	0.0378
2	15%	0.5105	0	0.4355	0	0.5657	0.09974	0.6951	0
2	30%	0.118	0.2754	0.0967	0.02875	0.348	0.002	0.3467	0.0001
2	45%	0.315	0.0003	0.8354	0.1245	-0.3379	0.0001	-0.1824	0.0378
3	15%	-0.0046	0.00102	0.3259	0	0.6172	0.129	0.8514	0
3	30%	0.1297	0.0613	0.4654	0	0.785	0.09167	0.782	0
3	45%	0.7292	0	0.7924	0	0.2646	0.019	0.3905	0
4	15%	0.1765	0.05	0.5738	0	-0.2356	0.07183	-0.4921	0
4	30%	0.5817	0	0.7553	0	-0.0088	0.9241	0.3976	0
4	45%	0.2955	0.001	0.6963	0	-0.1007	0.3652	-0.2216	0.044
5	15%	0.0144	0.0884	0.3657	0.0001	0.1154	0.2481	0.4572	0
5	30%	-0.6188	0	0.5584	0	-0.0269	0.7987	-0.1557	0.1383
5	45%	0.4	0	0.561	0	0.1093	0.2917	0.58312	0.07492
1	15%	-0.6782	0	0.1309	0.01941	0.1789	0.075	0.8901	0
1	30%	-0.4512	0	0.4809	0	0.1732	0.0898	0.8552	0
1	45%	-0.5792	0	0.931	0.01068	0.1186	0.2401	0.6498	0
2	15%	0.3358	0.0012	0.7261	0	-0.2058	0.1432	-0.4921	0.0002
2	30%	0.626	0	0.8457	0	-0.2426	0.014	0.0692	0.04897
2	45%	0.569	0	0.7529	0	-0.1285	0.2685	0.48479	0.0818
3	15%	0.6126	0	0.3259	0.0003	-0.0046	0.9602	0.8515	0
3	30%	0.1297	0.0613	0.4654	0	0.785	0.068245	0.782	0
3	45%	0.7292	0	0.7924	0	0.2646	0.05789	0.3905	0
4	15%	0.0416	0.07269	0.1428	0.0945	0.4212	0.1504	0.6631	0
4	30%	-0.2523	0.0075	0.72922	0.0019	-0.0818	0.4652	-0.1584	0.1552
4	45%	0.3707	0.0002	0.5632	0	0.1679	0.1391	0.4564	0.00916
5	15%	0.6705	0	0.4355	0	0.5657	0.34954	0.04572	0
5	30%	0.7164	0	0.0967	0.02875	0.1568	0.0833	0.51487	0
5	45%	0.569	0	0.7529	0	-0.1285	0.2685	0.8569	0
		Elbow / TPZ		Shoulder / TPZ		elbow / Sternocleidomastoid		Shoulder / Sternocleidomastoid	
		Correlation coefficient	P-Value	Correlation coefficient	P-Value	Correlation coefficient	P-Value	Correlation coefficient	P-Value
15%		0.23	0.02	0.38	0.01	0.25	0.22	0.41	0.00
30%		0.10	0.04	0.45	0.03	0.21	0.26	0.37	0.03
45%		0.38	0.001	0.74	0.02	-0.04	0.17	0.42	0.02



## APPENDIX –D ANOVA Results

Statistix 9.0

7/5/2009, 9:51:37 PM

### Analysis of Variance Table for Sternocleidomastoid

Source	DF	SS	MS	F	P
gender	1	9.766E-07	9.766E-07	14.24	0.0054
Error gender*participant	8	5.486E-07	6.858E-08		
weight	2	5.279E-06	2.639E-06	154.90	<u>0.0000*</u>
gender*weight	2	1.206E-07	6.031E-08	3.54	0.0534
Error gender*participant*weight	16	2.726E-07	1.704E-08		
Total	29	7.197E-06			

Grand Mean 8.40E-04

CV(gender\*participant) 31.17

CV(gender\*participant\*weight) 15.54

### Analysis of Variance Table for TPZ

Source	DF	SS	MS	F	P
gender	1	9.605E-08	9.605E-08	0.25	0.6274
Error gender*participant	8	3.018E-06	3.772E-07		
weight	2	1.026E-05	5.132E-06	141.46	<u>0.0000*</u>
gender*weight	2	1.556E-07	7.780E-08	2.14	0.1496
Error gender*participant*weight	16	5.805E-07	3.628E-08		
Total	29	1.411E-05			

Grand Mean 1.96E-03

CV(gender\*participant) 31.34

CV(gender\*participant\*weight) 9.72

### *Tukey HSD All-Pairwise Comparisons Test of SCM for gender\*weight*

Statistix 9.0

7/13/2009, 12:30:00 AM

gender	weight	Mean	1,15	1,30	1,45	2,15	2,30
1	15	9.28E-04					
1	30	1.71E-03	7.80E-04*				
1	45	2.39E-03	1.45E-03*	6.79E-04*			
2	15	3.15E-04	6.12E-04	1.39E-03	2.07E-03*		
2	30	5.77E-04	3.51E-04	1.13E-03	1.81E-03	2.62E-04*	
2	45	9.75E-04	4.72E-05	7.33E-04	1.41E-03	6.60E-04*	3.98E-04*

Comparisons of means for the same level of gender

Alpha 0.05 Standard Error for Comparison 1.961E-04  
Critical Q Value 4.557 Critical Value for Comparison 6.318E-04  
Error term used: gender\*participant\*weight, 16 DF  
Comparisons of means for different levels of gender  
Alpha 0.05 Standard Error for Comparison 5.666E-04  
Critical Q Value 5.119 Critical Value for Comparison 2.051E-03  
Error terms used: gender\*participant and gender\*participant\*weight

#### **Tukey HSD All-Pairwise Comparisons Test of TPZ for gender\*weight**

gender	weight	Mean	1,15	1,30	1,45	2,15	2,30
1	15	1.43E-03					
1	30	2.99E-03	1.55E-03*				
1	45	4.69E-03	3.25E-03*	1.70E-03*			
2	15	1.21E-03	2.17E-04	1.77E-03*	3.47E-03*		
2	30	2.90E-03	1.46E-03*	8.64E-05	1.78E-03*	1.69E-03*	
2	45	4.65E-03	3.21E-03*	1.66E-03*	3.56E-05	3.43E-03*	1.75E-03*

Comparisons of means for the same level of gender  
Alpha 0.05 Standard Error for Comparison 2.349E-04  
Critical Q Value 4.557 Critical Value for Comparison 7.571E-04  
Error term used: gender\*participant\*weight, 16 DF  
Comparisons of means for different levels of gender  
Alpha 0.05 Standard Error for Comparison 3.264E-04  
Critical Q Value 4.957 Critical Value for Comparison 1.143E-03  
Error terms used: gender\*participant and gender\*participant\*weight

Statistix 9.0  
PM

7/30/2009, 1:39:27

#### **Tukey HSD All-Pairwise Comparisons Test of Elbow for gender\*weight**

gender	weight	Mean	1,15	1,30	1,45	2,15	2,30
1	15	113.30					
1	30	117.65	4.35				
1	45	118.99	5.69	1.33			
2	15	109.37	3.93	8.28	9.61		
2	30	103.84	9.46	13.81	15.15	5.53	
2	45	104.48	8.82	13.18	14.51	4.90	0.64

Comparisons of means for the same level of gender  
Alpha 0.05 Standard Error for Comparison 5.1676  
Critical Q Value 4.557 Critical Value for Comparison 16.652  
Error term used: gender\*trial\*weight, 16 DF  
Comparisons of means for different levels of gender  
Alpha 0.05 Standard Error for Comparison 9.6280  
Critical Q Value 5.050 Critical Value for Comparison 34.382  
Error terms used: gender\*trial and gender\*trial\*weight

#### **Tukey HSD All-Pairwise Comparisons Test of Shoulder for gender\*weight**

gender	weight	Mean	1,15	1,30	1,45	2,15	2,30
1	15	50.436					
1	30	48.072	2.365				
1	45	50.618	0.182	2.547			
2	15	43.090	7.347	4.982	7.529		
2	30	44.841	5.595	3.231	5.777	1.751	
2	45	44.456	5.980	3.616	6.162	1.366	0.385

Comparisons of means for the same level of gender

Alpha 0.05 Standard Error for Comparison 4.5587

Critical Q Value 4.557 Critical Value for Comparison 14.690

Error term used: gender\*trial\*weight, 16 DF

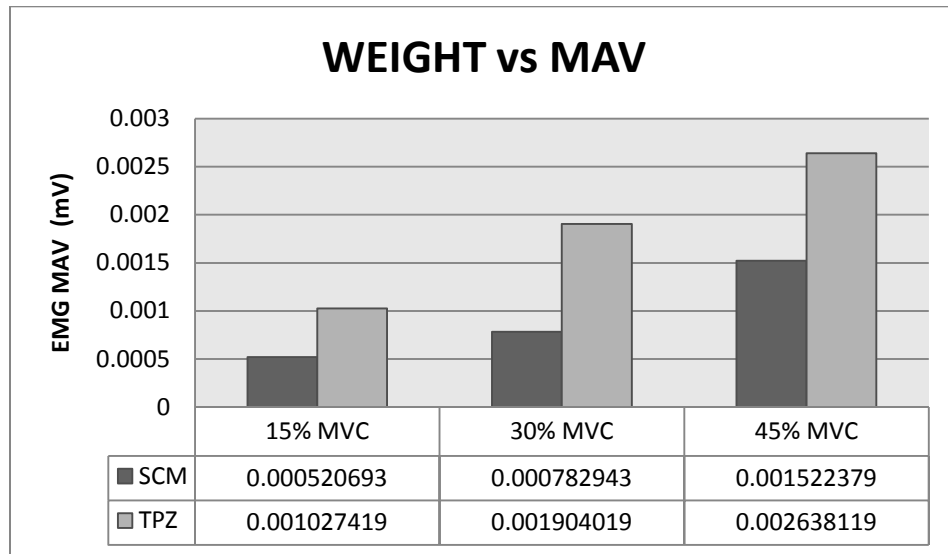
Comparisons of means for different levels of gender

Alpha 0.05 Standard Error for Comparison 8.8484

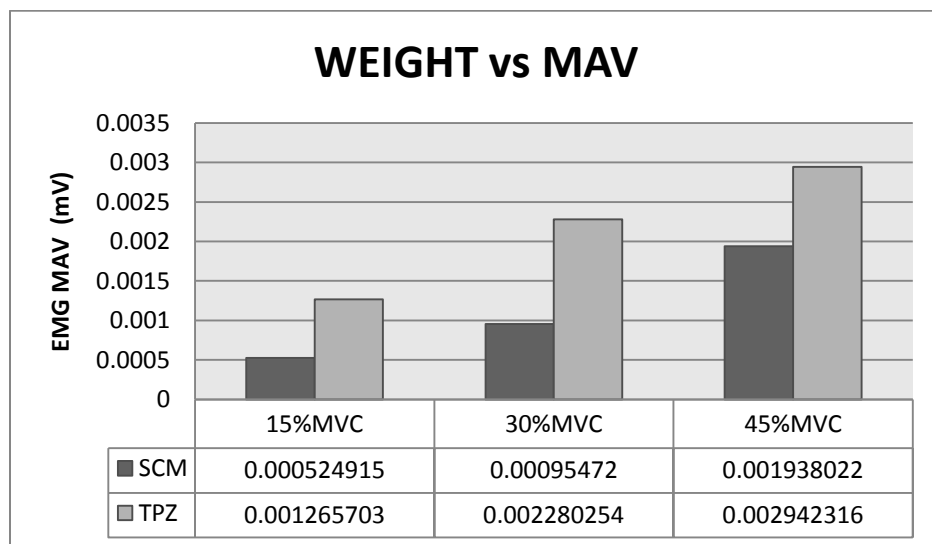
Critical Q Value 5.059 Critical Value for Comparison 31.656

Error terms used: gender\*trial and gender\*trial\*weight

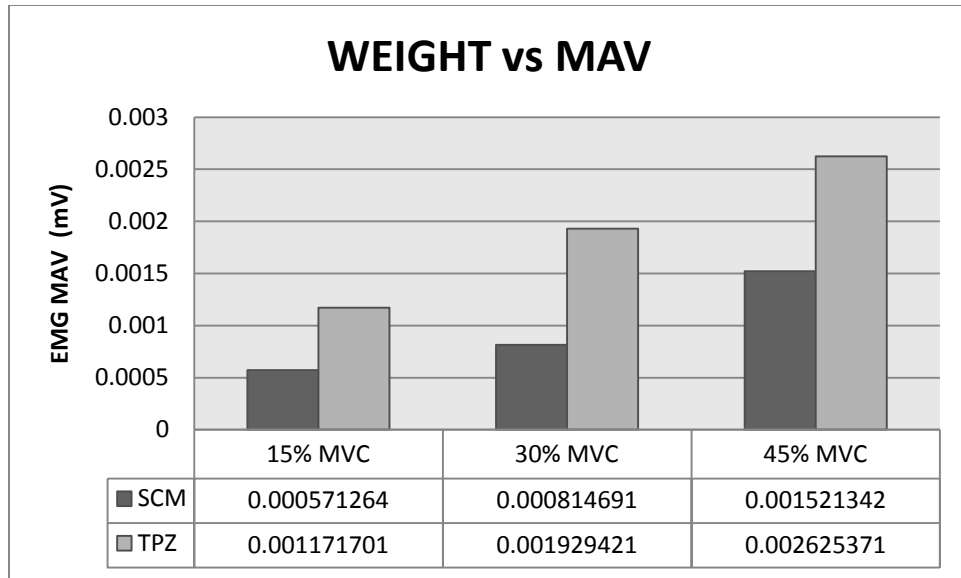
## APPENDIX –E Effect of weight increase on EMG activity



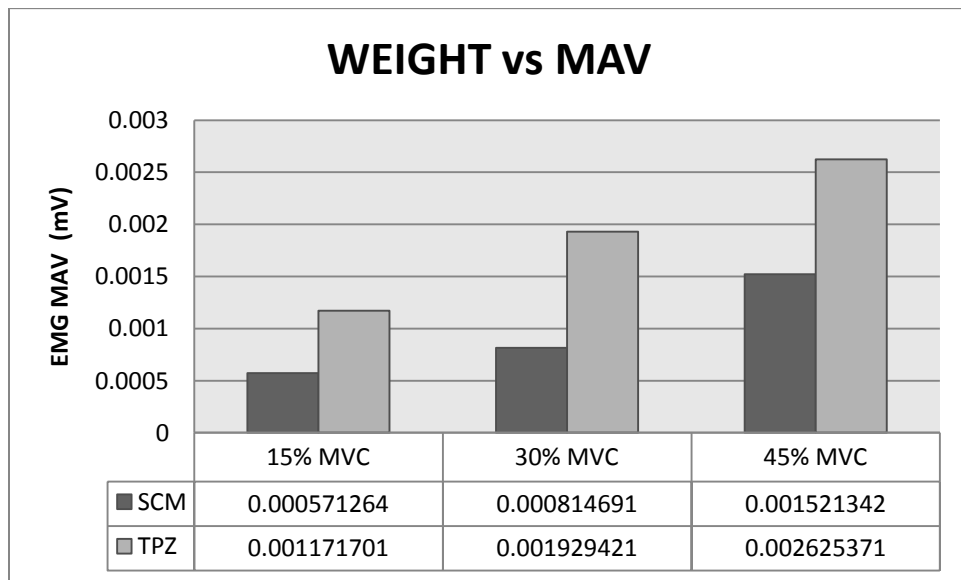
Effect of weight increase on EMG activity “Participant1”



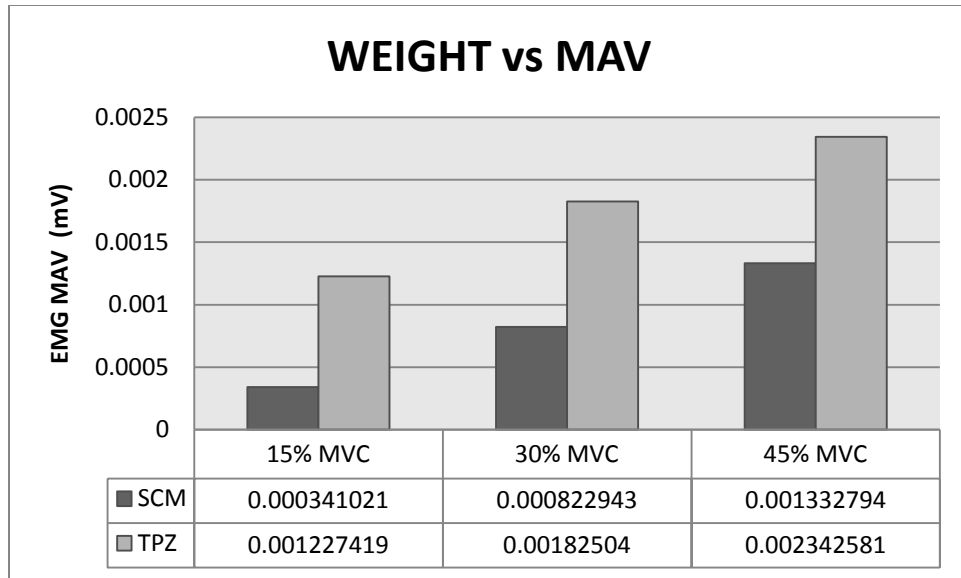
Effect of weight increase on EMG activity “Participant2”



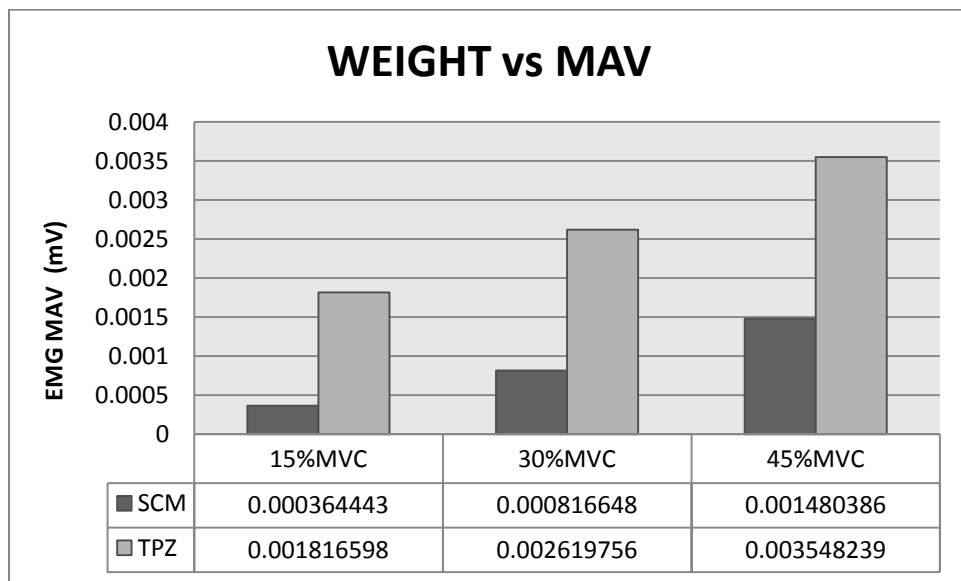
Effect of weight increase on EMG activity "Participant3"



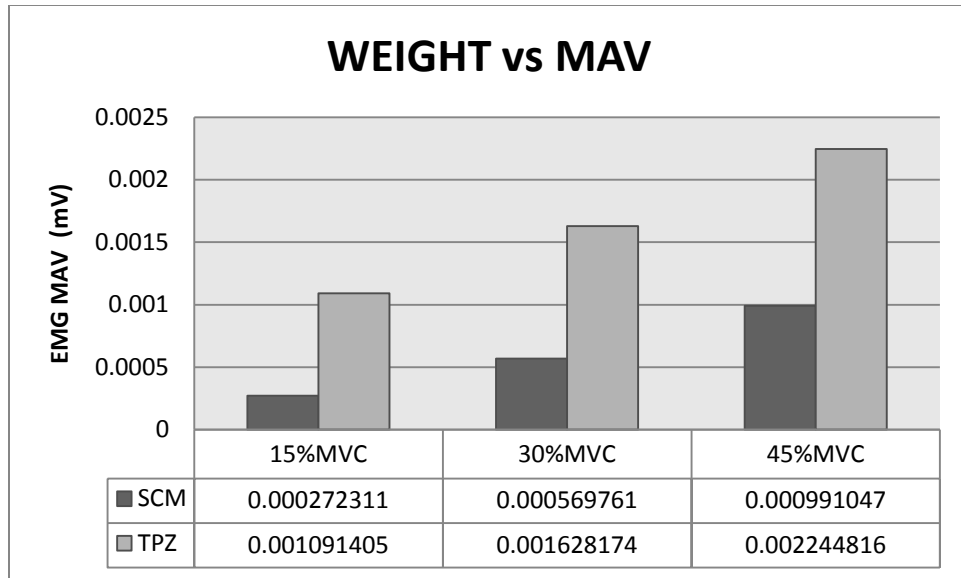
Effect of weight increase on EMG activity "Participant4"



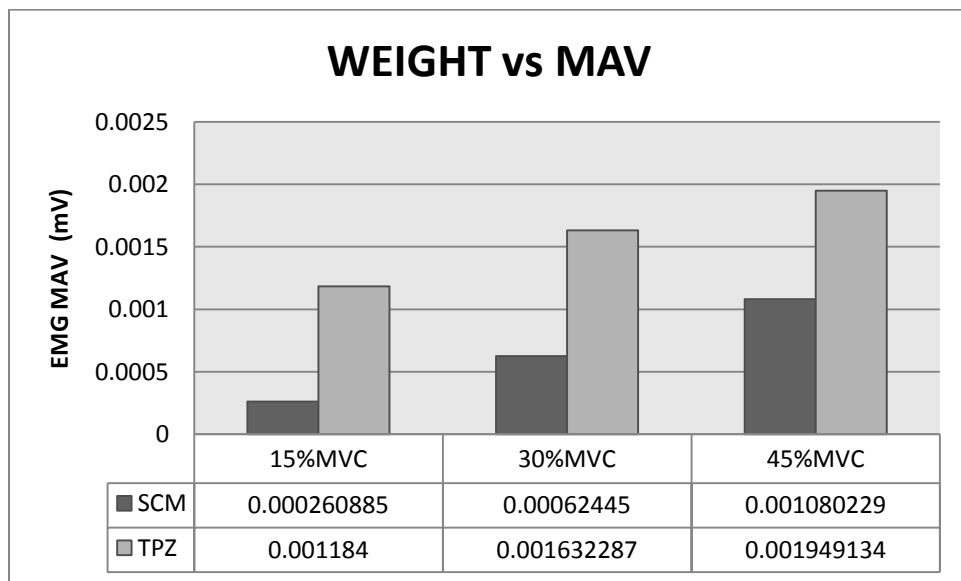
Effect of weight increase on EMG activity "Participant5"



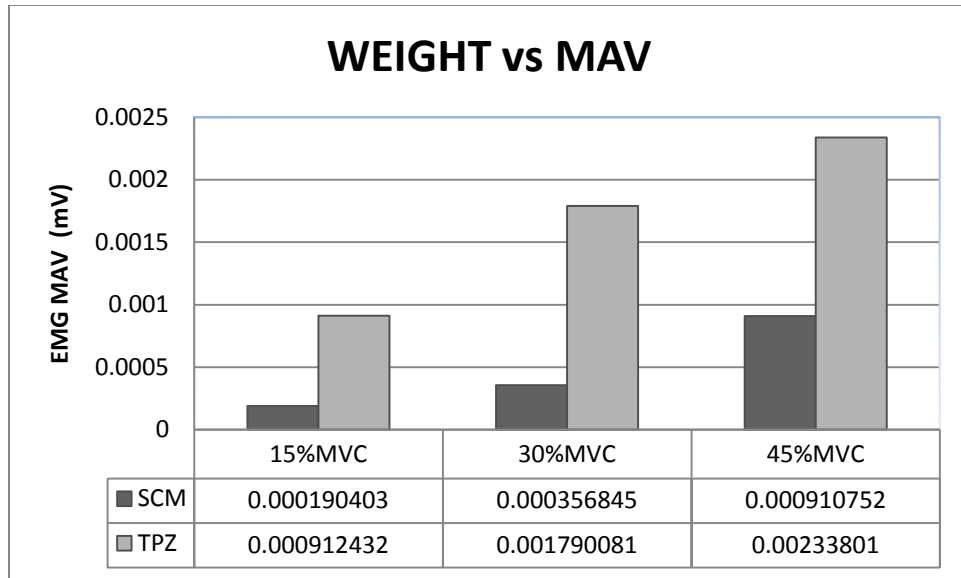
Effect of weight increase on EMG activity "Participant6"



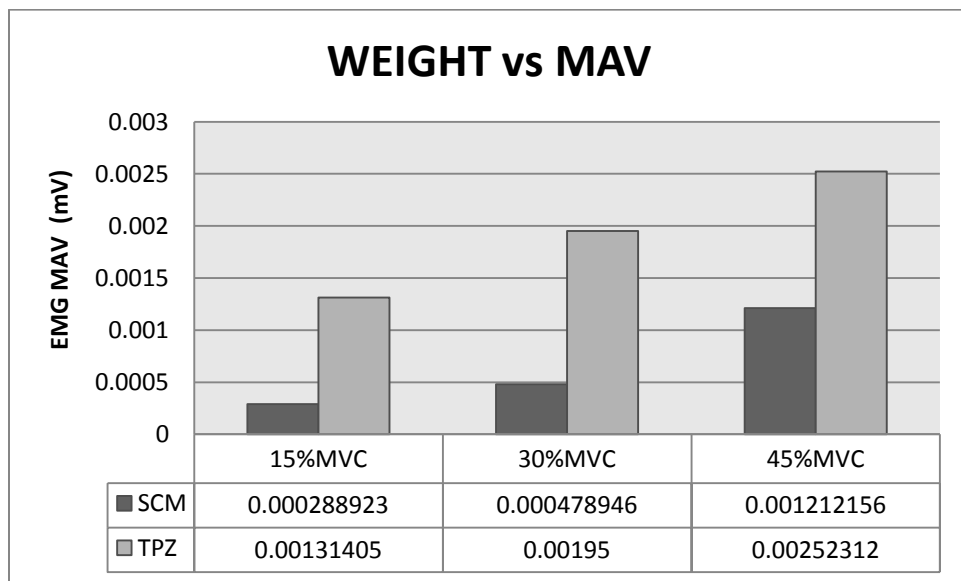
Effect of weight increase on EMG activity "Participant7"



Effect of weight increase on EMG activity "Participant8"

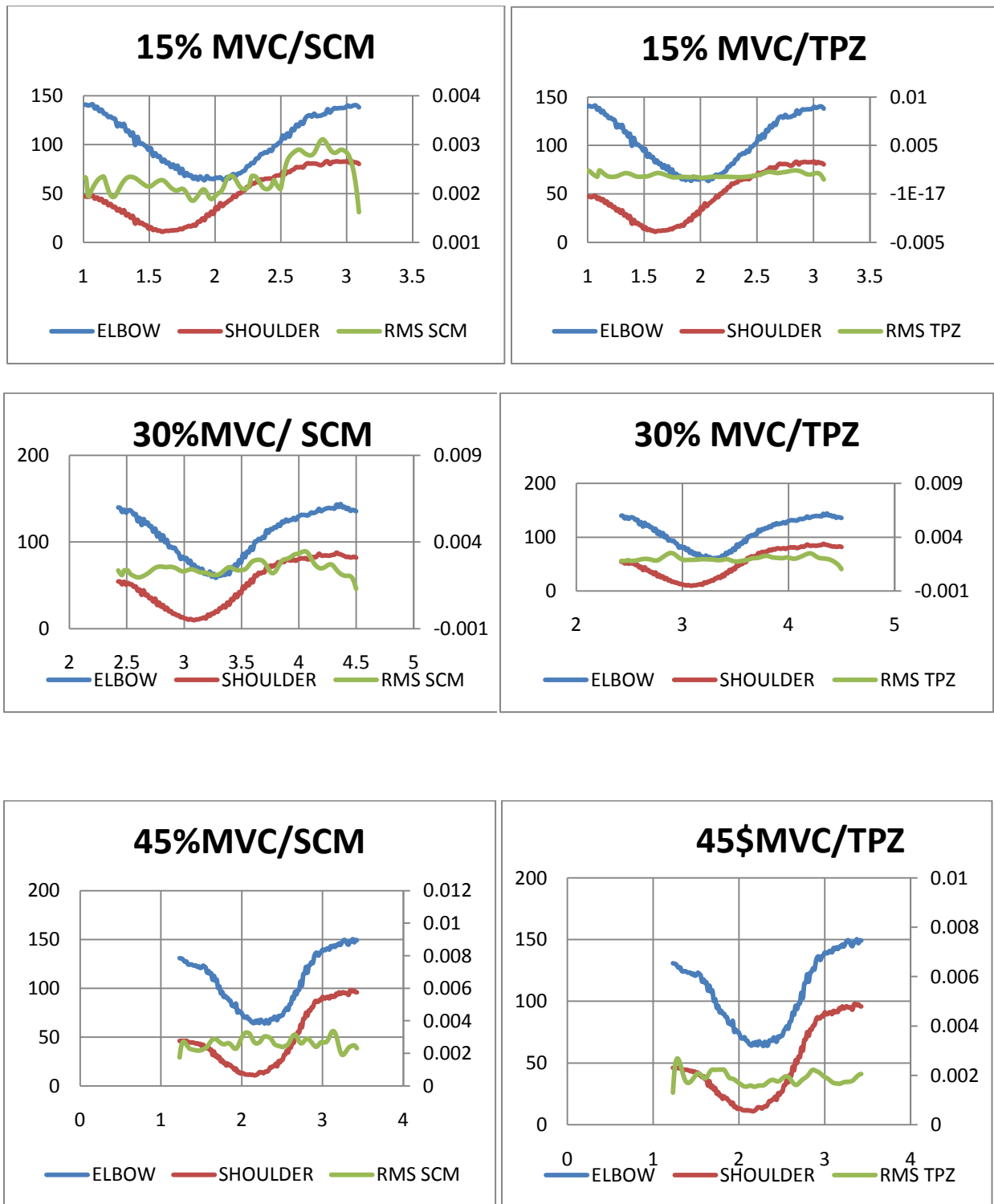


Effect of weight increase on EMG activity "Participant9"

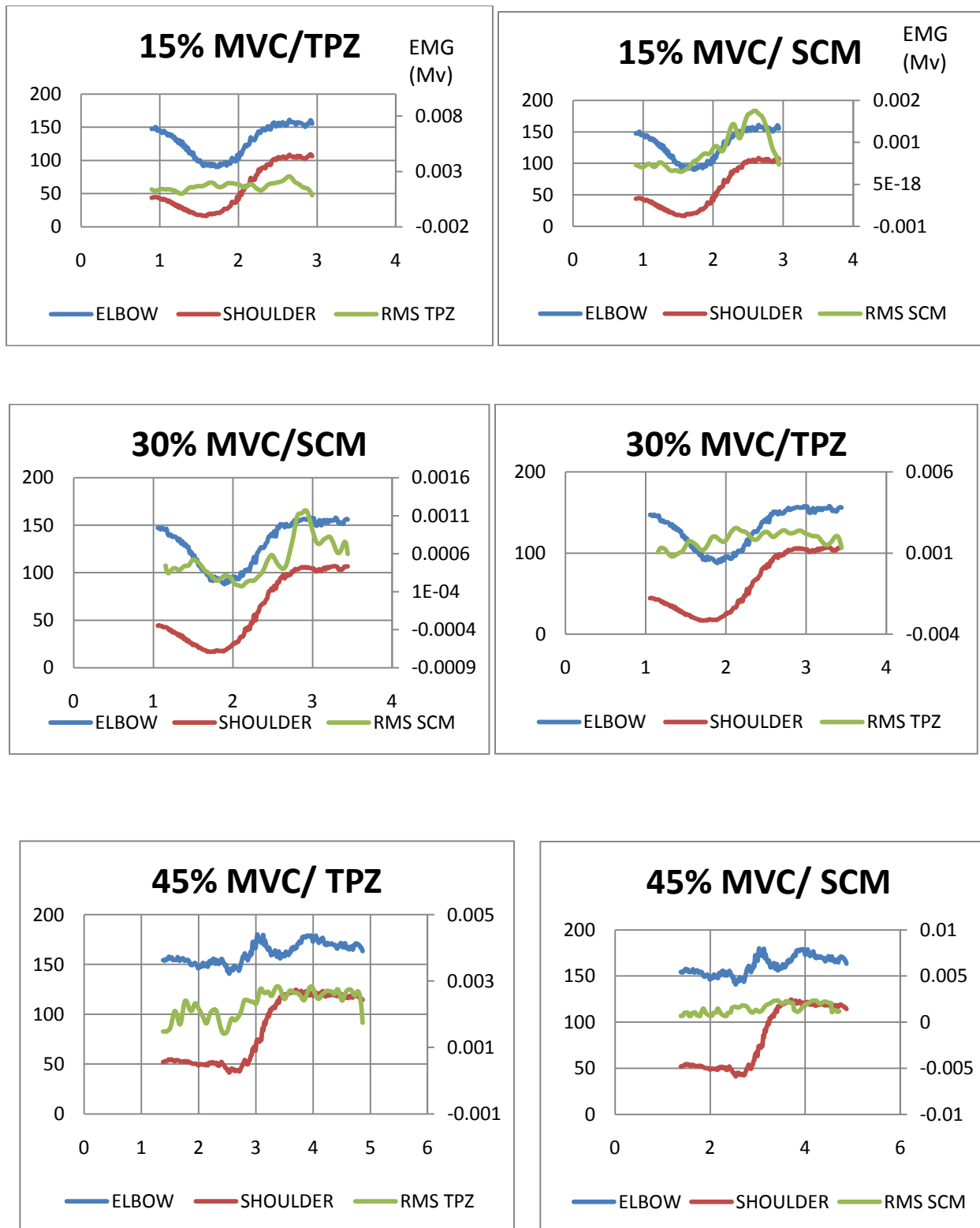


Effect of weight increase on EMG activity "Participant10"

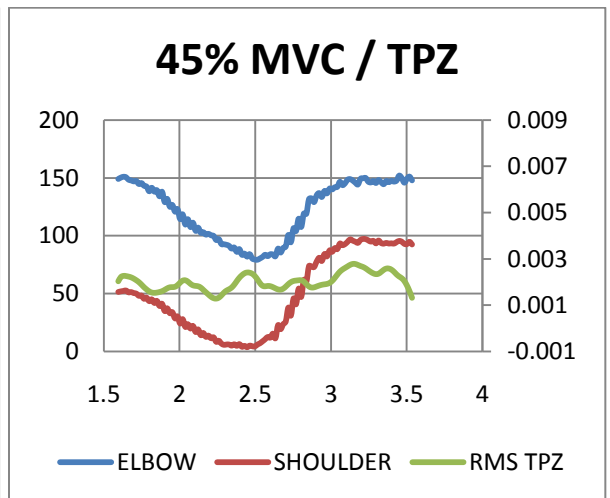
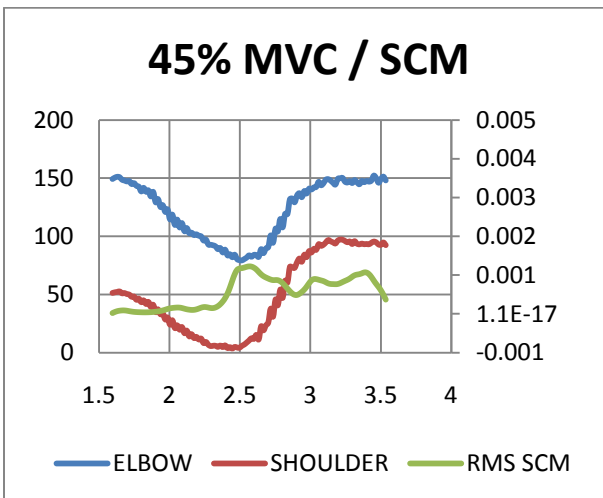
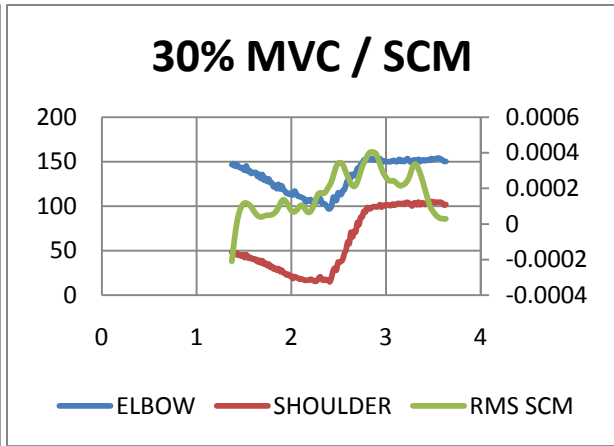
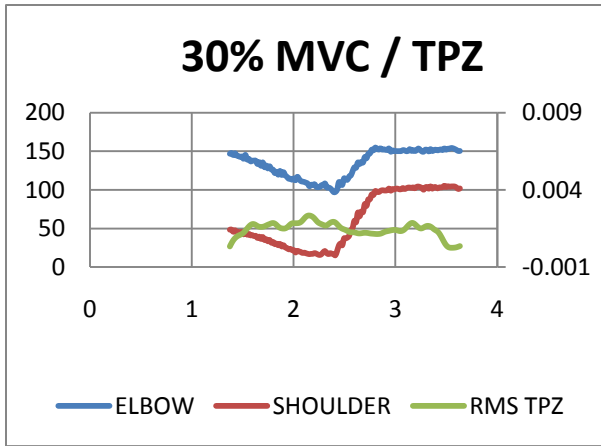
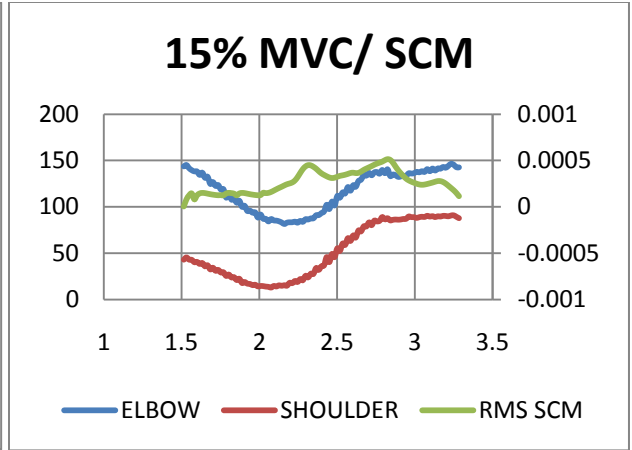
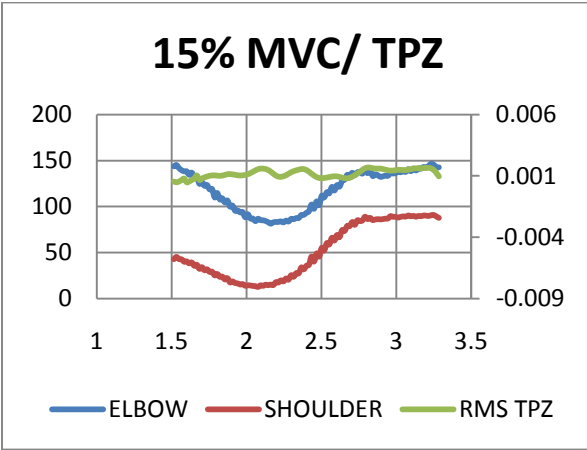




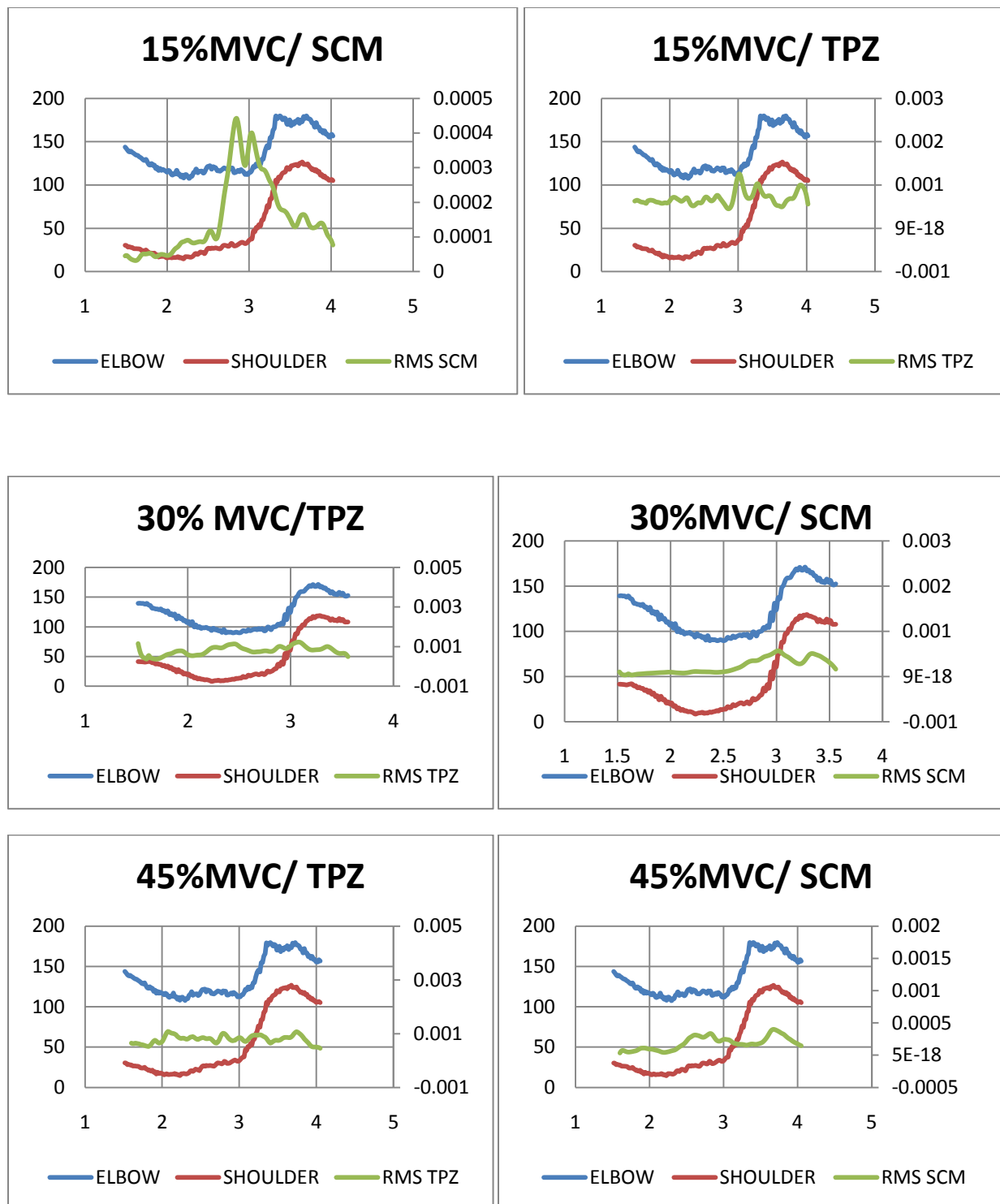
Participant 1 (15%, 30%, 45%) Angles vs. EMG



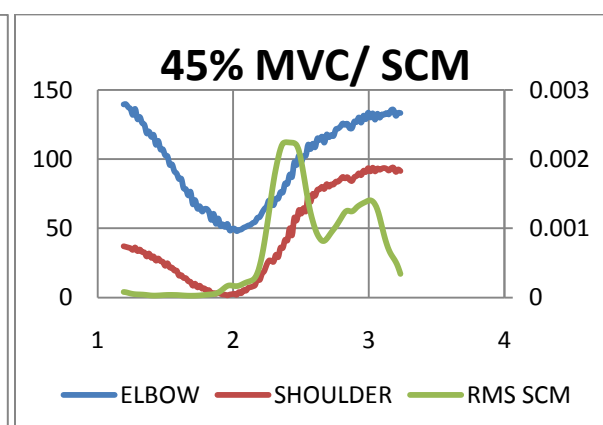
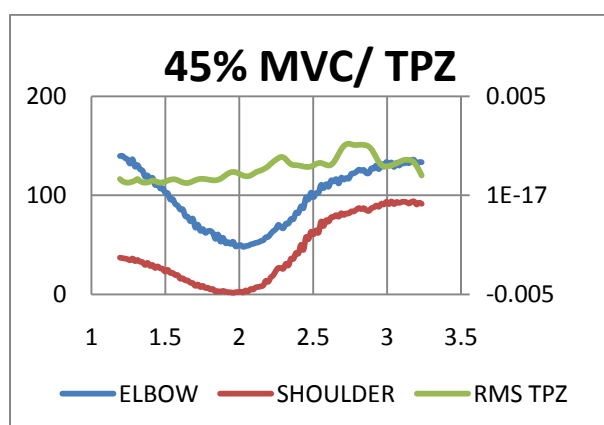
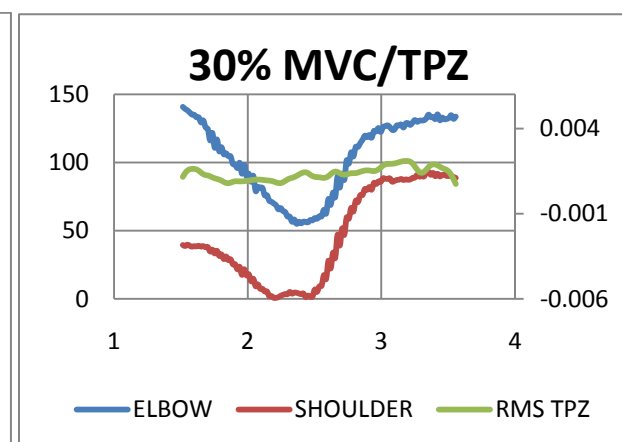
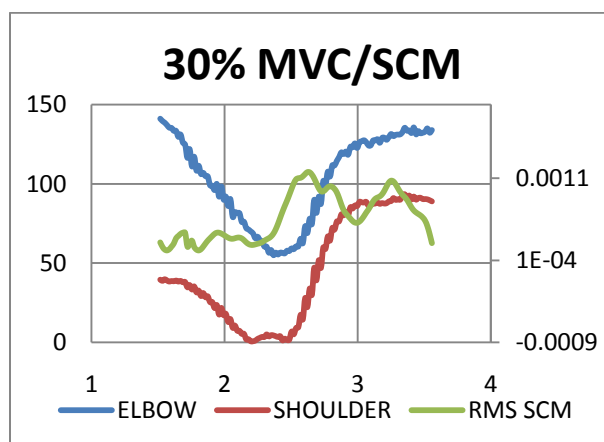
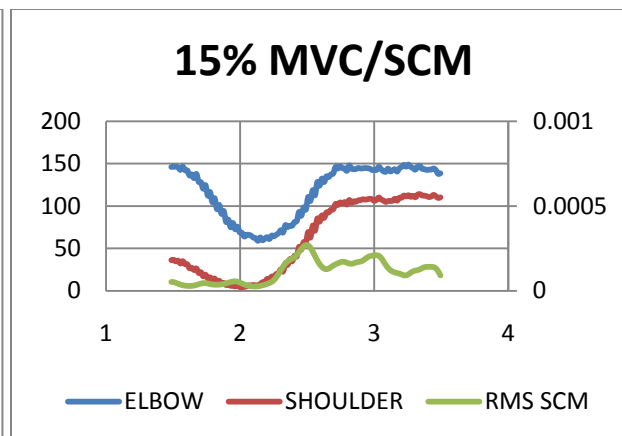
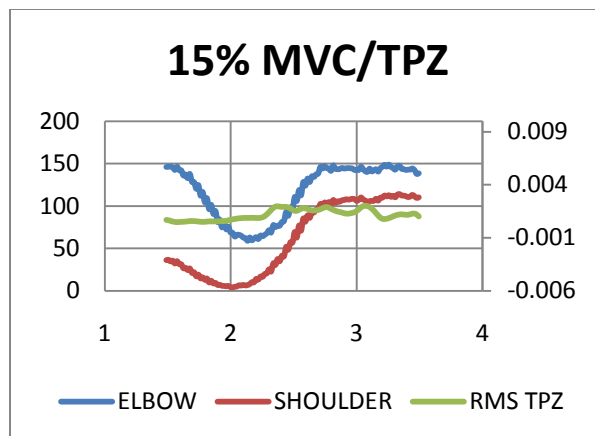
Participant 2 (15%, 30%, 45%) Angles vs. EMG



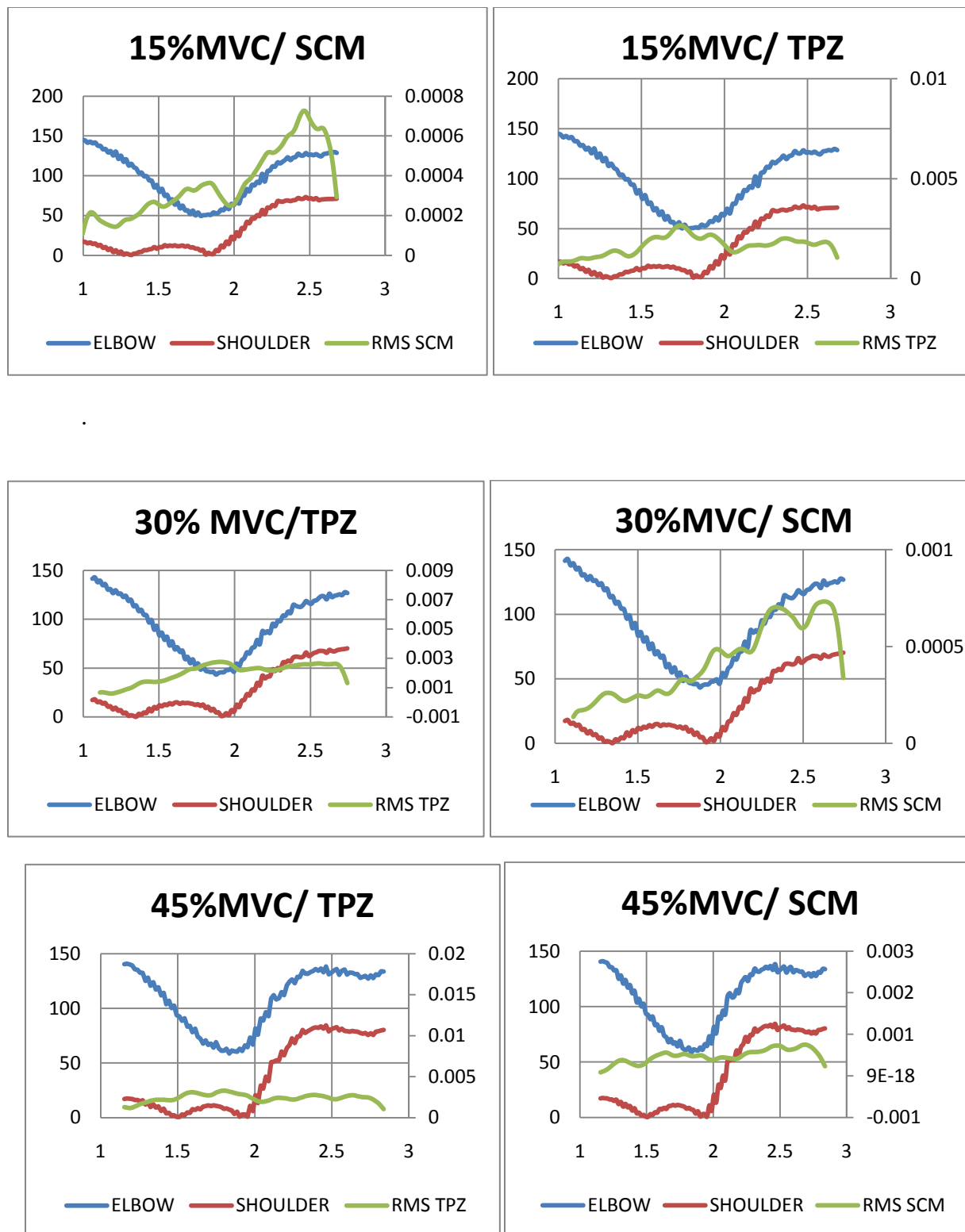
Participant 3 (15%, 30%, 45%) Angles vs. EMG



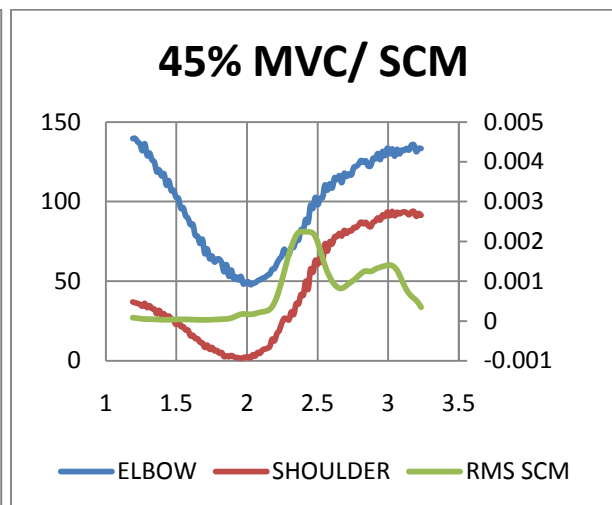
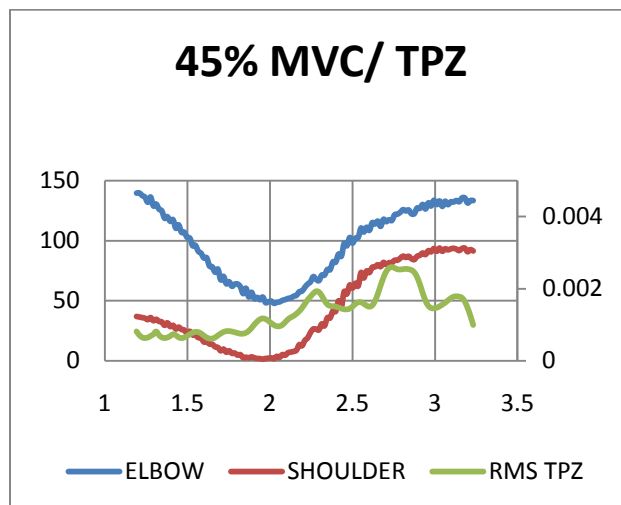
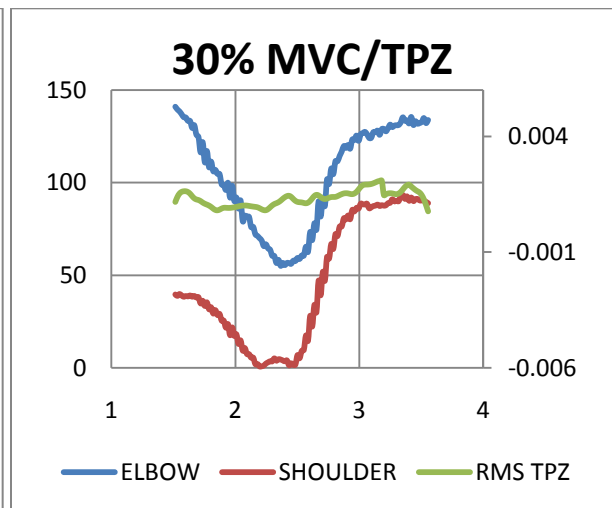
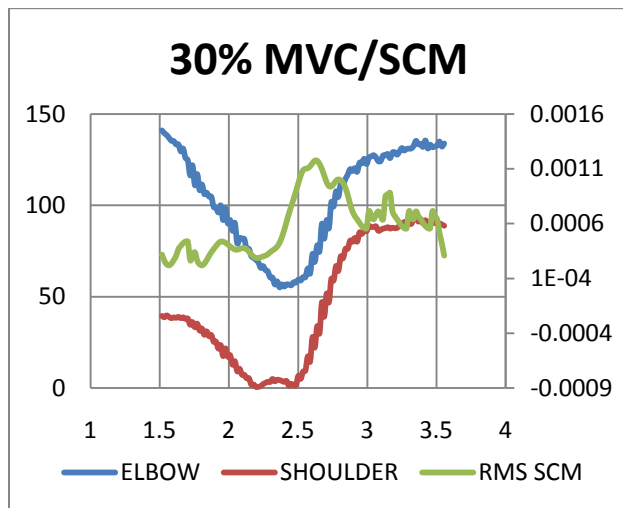
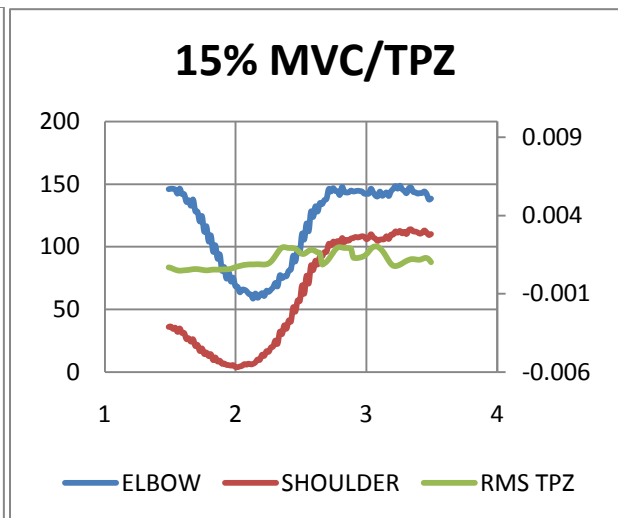
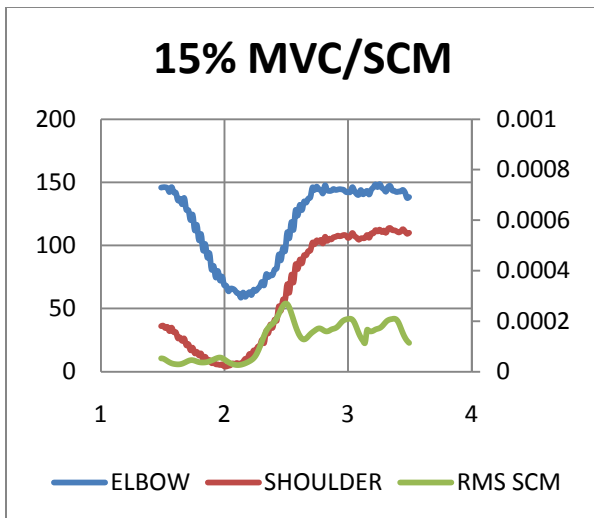
Participant 4 (15%, 30%, 45%) Angles vs. EMG



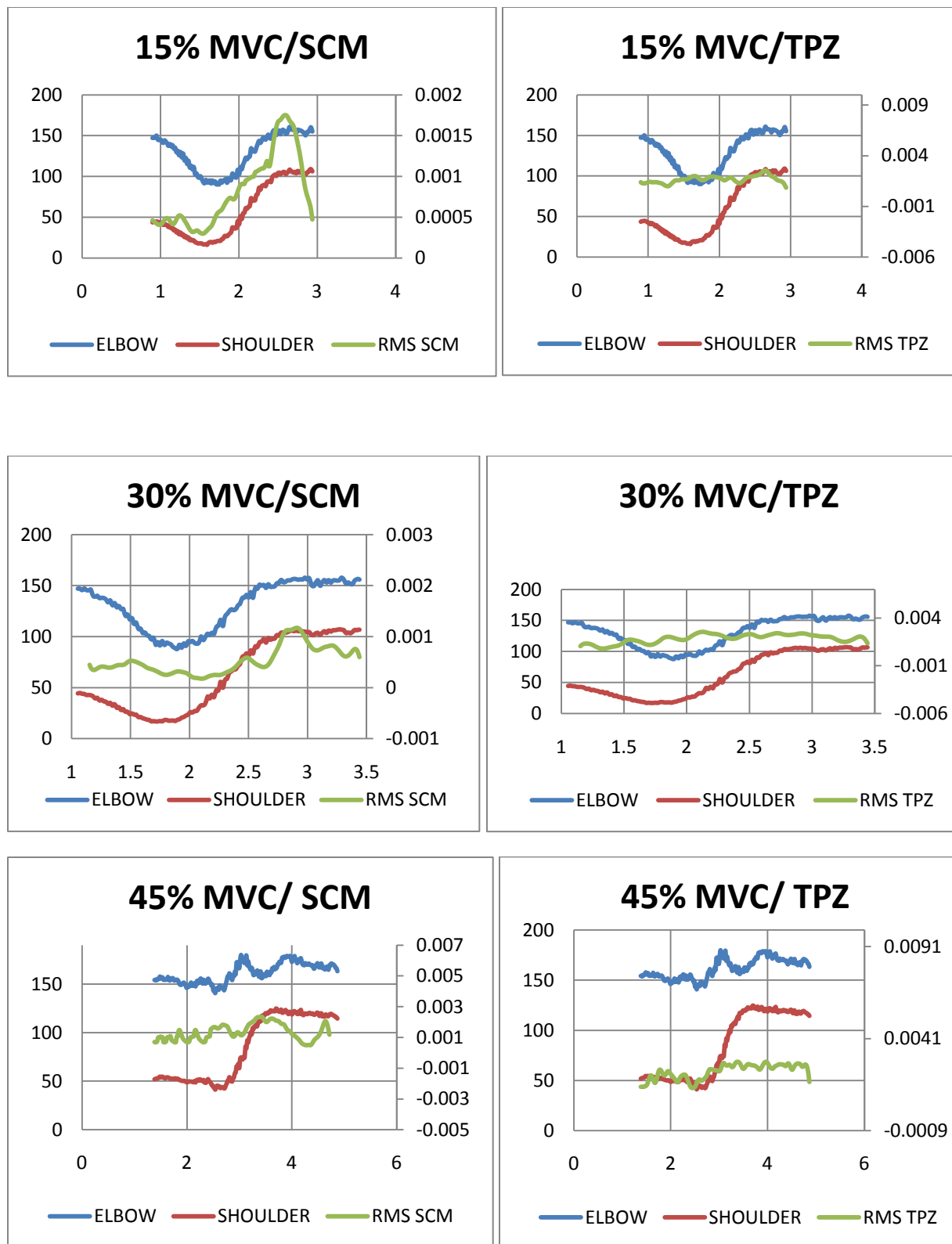
Participant 5 (15%, 30%, 45%) Angles vs. EMG



Participant 6 (15%, 30%, 45%) Angles vs. EMG

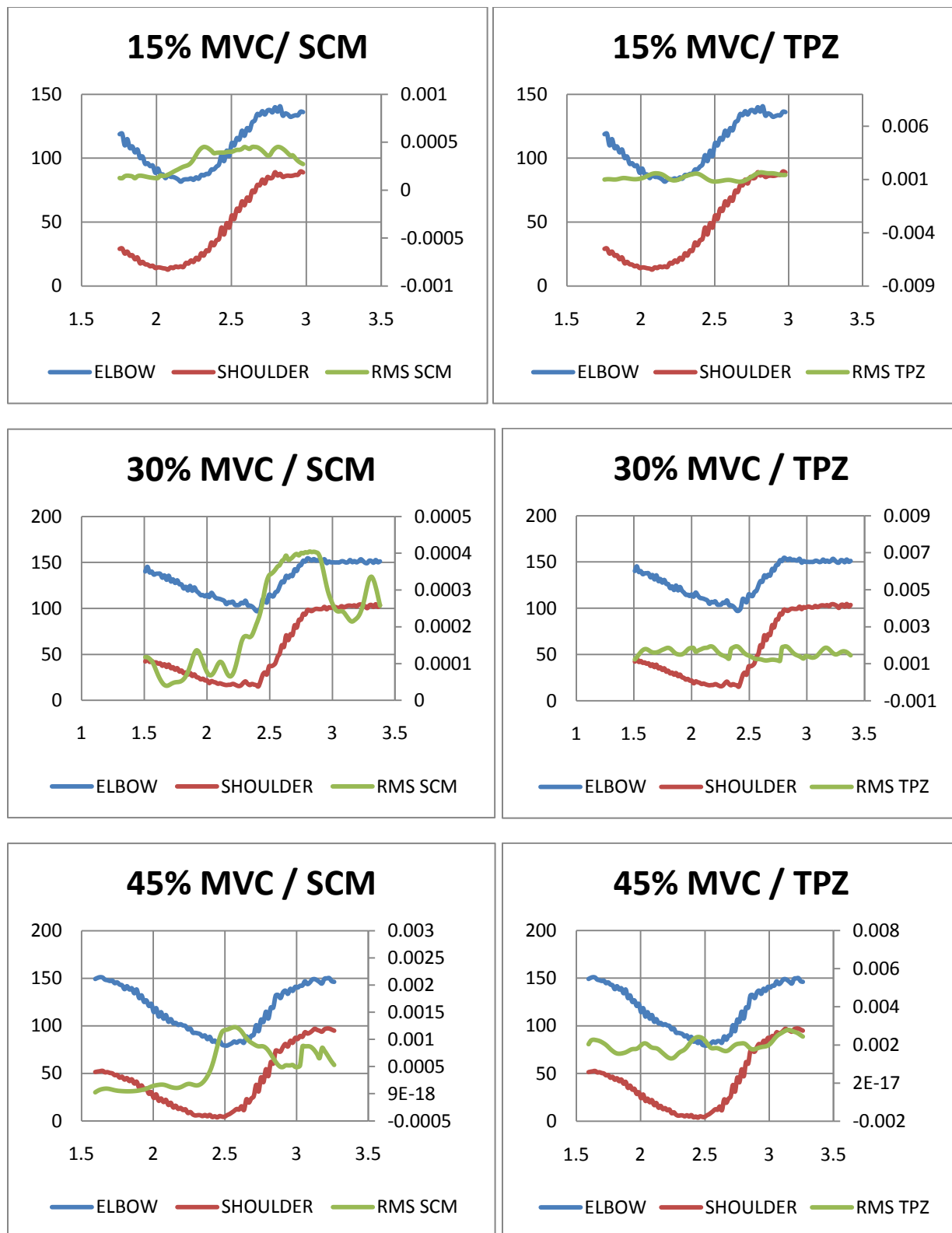


Participant 7 (15%, 30%, 45%) Angles vs. EMG

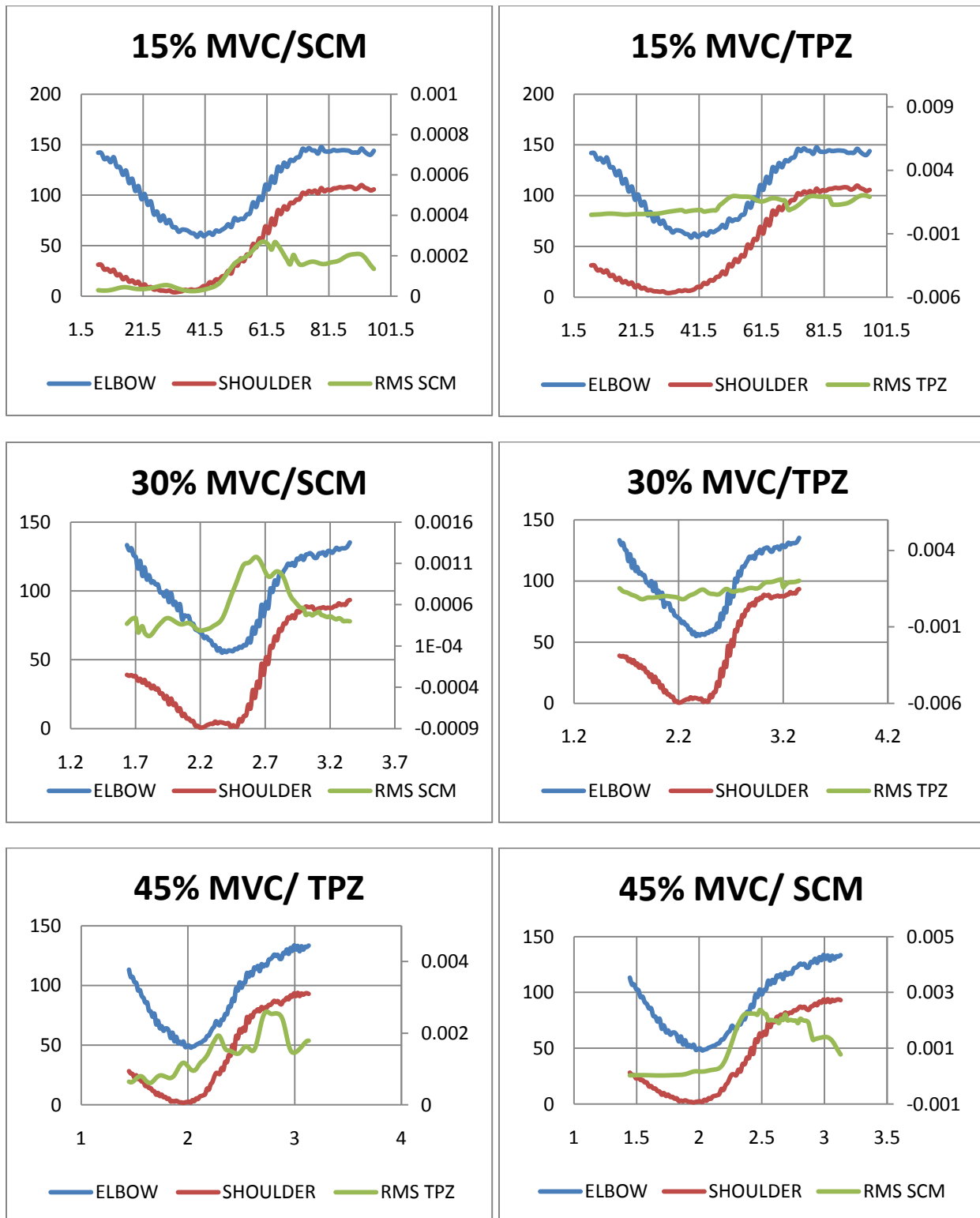


Participant 8 (15%, 30%, 45%) Angles vs. EMG





Participant 9 (15%, 30%, 45%) Angles vs. EMG



Participant 10 (15%, 30%, 45%) Angles vs. EMG

## **VITA**

Mohamed Wassim Mokrani was born in Jendouba, Tunisia, in February, 1980. Jendouba is known for its agriculture and tourism. He spent his childhood in Menzel Bouzelfa, where he attended middle school. He moved at age 15 to Tunis, where he attended high school and graduated in 1998. Mohamed attended the University of Science at Tunis where he majored in math and physics. Upon graduation, he transferred to Louisiana State University in Fall 2002, where he received a Bachelor of Science degree in Industrial Engineering in 2006 with a minor in safety engineering and quality control. After graduation, he worked at Baker Manufacturing Company where he served as a production engineer until August 2007. He re-joined the Department of Construction Management and Industrial Engineering (CMIE) at LSU in Fall 2007, where he worked at Ocshner Hospital as 6-sigma and lean engineer. He also worked as a project manager at MAN Turbo AG during his graduate studies at LSU. He expects to receive a Master of Science degree in Industrial Engineering in December of 2009.