2004

Effects of automobile seating posture on trunk muscle activity

Milton Maada-Gormoh Saidu
Louisiana State University and Agricultural and Mechanical College, msaidu1@lsu.edu

Recommended Citation

Saidu, Milton Maada-Gormoh, "Effects of automobile seating posture on trunk muscle activity" (2004). *LSU Master's Theses*. 2755.
https://digitalcommons.lsu.edu/gradschool_theses/2755

EFFECTS OF AUTOMOBILE SEATING POSTURE ON TRUNK MUSCLE ACTIVITY

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

Industrial and Manufacturing Systems Engineering Department

by
Milton Maada-Gormoh Saidu
B.S. in Physics Ed., University of Sierra Leone, 2001
May 2004

Dedicated to my parents Patrick and Rosaline Saidu for their
love and endless support in my academic pursuit.

ACKNOWLEDGEMENTS

First, I would like to acknowledge God for his grace through my savior Jesus Christ that covered me through all situations. I would also like to acknowledge numerous people who supported me through my entire academic journey.

I would like to express my gratitude to Dr. Aghazadeh, my major advisor for his endless support as a teacher, administrator, and parent. He was always there to listen and to help in the calm and rough seas. I also want to thank him for inspiring and stimulating my interest in my area of study. I would like to express my sincere thanks to Dr. Sarker who was very supportive through my program. I express great thanks to Dr. Harvey, for the endless encouragement and inspiration all through my project. I want to thank him for making me understand and accept that with perseverance my goal can be achieved. Without his support I would not have come this far.

I would like to acknowledge and thank people of the Louisiana State University – BioMMed Laboratory, Dr. Gus Kousuolas, Mrs. Li Huang, Dr. Baghian, Dr. Chouljenko, Dr. Foster, Mrs. Burrell and Mrs. Olivier. They all gave their support in various ways when I needed it. Finally I would like to thank my parents who gave me the foundation I am building on. I would like to thank my siblings, Olive, Emma, Janette, Patrick and Patricia who supported me in various ways. Thanks to my special friends who encouraged me to press on when I needed their support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Reports for adult population indicate that almost 80% of the adult population has reported some form of lower back aches. Each year American workers suffer more than 300,000 lost-time injuries involving musculoskeletal disorders of the back, with the costs that run into billions of dollars.

Sedentary tasks are known to be major contributing factors of back pain. Prior studies have indicated that the myoelectric activity of the lumbar region decreases when the back rest inclination of a seat increased. An increase in seat pan inclination so that it increases pressure on the leg muscles is also a cause for back pain. Seating posture is also known to be a leading cause of back pain. This study focuses on the response of the latissimus dorsi muscle in the trunk, to the backrest and seat angle inclinations for different seating postures.

Twenty one participants took part in the backrest experiment. The automobile seat backrest angle was varied for two angles of 90 and 100 degrees in a one hour driving session. Ten participants took part in the seat angle experiment; the seat was set at 0 and 10 degrees for a 30 minutes session at each angle. The muscle activity of the latissimus dorsi was recorded for seating postures at each angle.

Based on the electromyography data, the results of analyses of variance for mean of root mean square values for the backrest experiment ($P < 0.05$) showed significant change. In seat angle experiment the analysis of variation of the mean values for root mean square values at ($P < 0.05$) was significant. It is concluded that increased backrest and inclined seat angle decreases muscle activity in the latissimus dorsi muscle.

CHAPTER 1

INTRODUCTION

Reports for adult population indicate that almost 80% of the adult population has reported some form of lower back aches associated with spinal disorders, muscle strains and/or medical problems. These problems are generally derived from causes such as compressed disks, sprained lumbar muscles, prolapsed disks, sitting, lying or standing wrongly (Ray, J. and Tooms, R., 1993). Each year American workers suffer more than 300,000 lost-time injuries involving musculoskeletal disorders of the back, with the costs that run into billions of dollars. Praemer et al. (1992) published a summarized report of the musculoskeletal cases occurring in the United States. In a population of 1000 persons 124 were found to have muskuloskeletal impairments in 1988. Low back pain is a one of the common muskuloskeletal impairments, which is often caused when a muscle or ligament holding the vertebra in its proper position is subjected to strain. When the muscles and ligaments become weak, the spine loses its stability, which results in pain. People who are overweight may have also low back pain because of the added stress on their back. Back pain may occur when there is inflammation of the muscles, joints, bones, and connective tissues of the back, as a result of an infection or immune system disorder. Congenital and degenerative arthritic disorders may also cause back pain.

One element that may contribute to back pain is the design of automotive seats. The automobile industry has strongly encouraged research in the area of objective comfort and other related postures (Gyi et al., 1998). The posture of a driver is one of the most important issues to consider in a design process of a vehicle (Porter and Gyi, 1998). The posture does not only involve the car seat, it also involves the conditions of the task, such as static or dynamic seating posture. Few studies have yet attempted to correlate seat angle and back rest inclination with muscle activity of the Latissimus Dorsi, in the lower back.

Despite the efforts of several car manufacturers to develop new seats which increase usability in terms of seat comfort, there is still a wide range of back disorders associated with occupational driving. Comfort integrates a sense of well-being with health and safety, but conversely discomfort is mainly related to biomechanical factors, which involves muscular and skeletal systems (Zhang et al., 1996). The extent to which the backrest inclination affects the back muscles of the driver in a seating posture has not been extensively studied for automobile drivers. The focus of this study is to asses the effect a seat back rest and the seat angle have on the trunk muscle of the lower back latissimus dorsi.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 Incidents of Back Pain

In the last decade a significant amount of research has been done in connection with back-related injuries and disorders. According to Dayo (1998), up to 80% of all adults will eventually experience back pain at some particular time in their life. It is a leading reason for physician office visits, and for hospitalization and surgery including work disability. About 35-40% of people report low back pain that lasts 24 hours or more each month and approximately 6% have had longstanding or seriously disabling low back pain within the previous 12 months. The costs of low back pain disability to the individual sufferer, their families, employers and society are massive. Grandjean (1980) found that the risk of herniated lumbar intervertebral disc is known to be high in drivers. The herniation in the lumbar discs may be due to high intradiscal pressure caused by lack of lumbar support.

2.2 Measures of Back Pain

2.2.1 Physiology, Anatomy and Electromyography

To understanding the function of the muscles around the spine and the lumbar region, it is vital to study relative positions of the muscles to the spine and ribcage and to describe the muscle activity possible sources of pain for the muscles. This will include (a) Ligaments and Tendons, (b) Erector Spinae (c) Multifidus Spinae (d) Latissimus Dorsi (e) Electromyography (f) Muscle activity and (g) Sources of back Pain.

(a) Ligaments and tendons: Ligaments and tendons are dense connective tissues which are similar in morphology and function (Chaffin et al., 1991). Ligaments and tendons protect and support the body and its organs (Hatipkarasulu, 2002). Tendons attach muscle to bone, transmitting forces from the muscle to bone (Chaffin et al., 1991). Tendons therefore have high tensile strength and high modulus of elasticity (Kumar, 1999; Kumar, 2001). These structures help to distribute load to other structures in the joint (Youdas et al., 2000).

Ligaments and tendons generally include three elements: cells, ground substance, and fibers. Ligament and tendon cells are formed from mesodermal embryonic cells. The ground substance support cells, binding them together, and providing a means of substance exchange between the blood and cells. The fibers are the source of strength and support for tissues within the ligaments and tendons (Hatipkarasulu, 2002). There are generally three different types of fibers: collagen fibers, elastic fibers, and reticular fibers. The collagen fibers are typically organized in parallel bundles in tendons, but some non-parallel ligaments do exist (Chaffin et al., 1991). These fibers elongate slightly when under tension, and become increasingly stiffer until they yield. This is due to the wavy configuration which the fibers have before fiber deformation occurs (Chaffin et al., 1991). Under a load, these fibers will rearrange their position parallel to the axis of stress. When load is increased to the point of failure, the fibers begin to glide over one another as they rapture (Tkaezuk, 1968 as in Hatipkarasulu, 2002).

(b) Erector Spinae muscle: The erector spinae muscles are of two types. The superficial fibers run most laterally to the spine and have long muscle bundles. These muscle bundles in general extend from the pelvis to the skull (Roskopf, 2002). The superficial aspects of these muscles considered are the iliocostalis thoracis and longissimus thoracis (Figure 1). The muscles pull on the dorsal aspect of the sacrum, flexing it on the ilium to create a sacroiliac joint stability. The deep erector spinae muscles of the thoracic spine are the spinal thoracis, semispinalis thoracis and rotators thoracis (Roskopf, 2002).

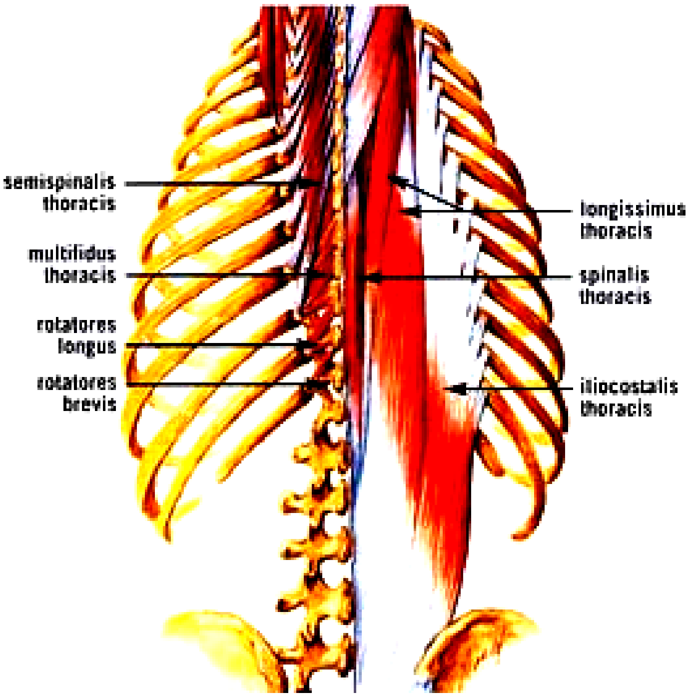


Figure 1: Superficial muscles of the back (Roskopf, 2002)

(c) The Multifidus Spinae: These muscles originate from the transverse processes of all thoracic vertebrae, and runs supermedially and attaches to each spinous process (Roskopf, 2002).

(d) Latissimus Dorsi: This is a broad flat muscle on either side of the back (Fig 2). The muscle may be divided into separate fascicles, frequently with one arising from the scapula. It rises no higher, in point of origin, than the first lumbar spine. The latissimus dorsi is designed to move the upper limb or to raise the entire trunk.

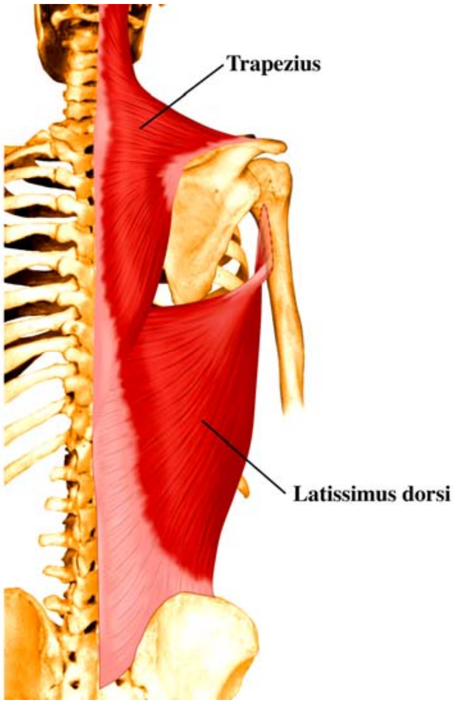


Figure 2 Posterior view of the latisimuss dorsi (Roskpf, 2002)

(e) Electromyography (EMG): Electromyography (EMG) focuses on electrical signal analysis during muscle contraction. The signals from the muscles are associated with contracting muscles (Solomonow et al., 1995). When conditions are normal, an action potential activates the muscle fibers of the motor unit (Paton and Wand, 1967 as in Solomonow et al., 1995). The activated muscles then generate ions across the cell membranes of muscle cell and produces electromagnetic field, which can be detected by an electrode that is placed near the muscle fibers in activation. Surface electrodes serve as the site of connection between the body and the collection system; they are often used on large muscle groups as a form of measuring physiological activity (Solomonow et al., 1995).

The EMG methods used, in assessing the resulting workload in workstation design, are very practical. Procedures of this type require several recordings in sequence, at intervals (Aaras et al., 1996). Some of the factors influencing EMG recordings are: (1) electrode type (2) electrode placement, (3) electrode contact area, (4) source and amplifier input impedance, (5) direction of movement of extremity type, (5) velocity of muscle contraction, (6) muscle length, (7) tissue distance between electrodes and muscle and (8) muscle temperature (Chaffin et al., 1999). The EMG interference effect tends to be multiplicative, suggesting that the variability they cause may be removed by normalizing the data, so that comparison of recordings between subjects, and between different occasions can be accomplished (Aaras et al., 1996).

(f) Muscle Activity: The failure to maintain the required or expected force, defined as muscle “fatigue,” is accompanied by changes in muscle electrical activity (Dimitrova and Dimitrov, 2003). The muscle fiber propagation velocity (MFPV) in relation to the motor unit potential (MUP) is used to interpret muscle activity in electromyography. Motor units (MU) may become metabolically overloaded, with a subject developing muscle pain and strain when performing a given task (Zennaro et al., 2003). The presence of a continuous activity overload, in low threshold muscle units (MU) leads to a potential for fiber injuries.

(G) Source of Back Pain: There have been many epidemiological studies of risk factors for low back pain, but there are few risk factors established in the prospective studies and the understanding of these risk factors remains relatively crude. Individuals who perform jobs requiring manual materials handling, particularly repeated heavy lifting and lifting while twisting, are at increased risk of back pain, leading to work absence. Exposure to whole-body vibration and job requirements for static postures as in the case of driving are also associated with back pain (Skovron, 1992).

In a study conducted by Anderson et al. (1974), it was found that myoelectric activity not only decreased in the lumbar region, but also in the thoracic and cervical areas of the spine when there is an increase in the back rest inclination. Knutsson et al., (1996) studied the effect on additional lumbar support and found that the muscle activity was reduced when support was both in front of and behind the plane of the backrest. Anderson et al. (1974) found the influence of the lumbar support to be small. This study was further extended by Hosea et al. (1986, as in Anderson et al., 1999) by recording the myoelectric activities of several back muscles while subjects were driving over a period of three and a half hours. It was found that the myoelectric activity decreased when the backrest inclination increased in all areas of the spine, but increased when the lumbar support exceeded 7cm, and the lowest recordings were at lumbar support of 5cm.

Lundervold (1958) studied the different vertical locations of the backrest on back muscle activity. In his study lower muscle activity levels were found when the back support was located in the lumbar region than when it was in the thoracic region.

Kelsey and Hardy (1975), in a study of the epidemiology of acute herniated lumbar intervertebral disc, found that driving of motor vehicles was associated with an increased risk for developing the disease. Men who spend more than half of their workday in a car were found to have three times an increased risk of herniation of the disc. Boden (1990) conducted a study of 67 individuals who had no history of back pain or sciatica (leg pain from low-back conditions). Half of the group had a bulging disk, a less severe condition, which is often blamed for pain. It was also found that 80% of adults older than 60 have a bulging disk, and more than a third of them have herniated disks visible by magnetic resonance imaging (MRI).

In the 1970's a series of research studies were conducted in which the pressure of the discs were measured in a standing and sitting postures in different chairs and with different back supports (Andersson et al., 1974). Research into lower back pain and associated disability by Waddell (1982) show that assessment of nerve function for back pain was found to be reliable, but assessment of the back itself had to be considerably modified and examination improved by incorporating actual measurements.

2.3 Vehicle Seat Design

Technological and economical developments have led to an increase in people performing driving tasks. The design and assessment of the driver's posture has introduced complexity with respect to traditional seating designs. The feet of the driver do not generally give full assistance for body support because they are devoted primarily to the use of the pedals. The balance and control of the body have to be assured by seat equipment with long inclined backrest and lateral supports (Grieco, 1986).

2.3.1 Sitting Task

The sitting position is typically divided into anterior, middle and posterior sitting postures (Figure 3), depending on the task and the chair or seat. The center of mass of the body determines the effects and proportion of the weight of the body, which is passed down to the different surfaces of support (Chaffin et al., 1991)

A leaning forward posture known as the “anterior seating” posture can be reached either by a forward rotation of the pelvis with the spine in a straight position or with no rotation of the pelvis, while maintaining a thoracic kyphosis (Figure 4) shape of the spine.

When seated in a middle posture, the center of mass is directly above the ischial tuberosities, and the floor supports about 25% of the body weight. When relaxed in a middle posture, the lumbar spine could be straight or slightly in a shape of kyphosis. In leaning backward, which is in the posterior seating postures, less than 25% of the body weight is supported by the floor. The center of mass is behind the ischial tuberosities.

2.3.2 Chair/ Seat

Seats are classified into two groups of (1) dynamic and (2) stationary. Dynamic chairs allow movement of the chair back lumbar support. Dynamic movement allows a reclined posture to be achieved allowing relaxation of back muscles and movement of the spinal column. This type of chair also makes a change of posture possible by stimulating alternation of activity of different parts of the extensor musculature and the spine. The outcome of using a dynamic chair is reduction of spinal shrinkage, which usually occurs in a static posture (Dieen et al., 2001). A seating task that allows frequent postural changes and periods of relaxation of the extensor musculature prevents discomfort for prolonged periods.

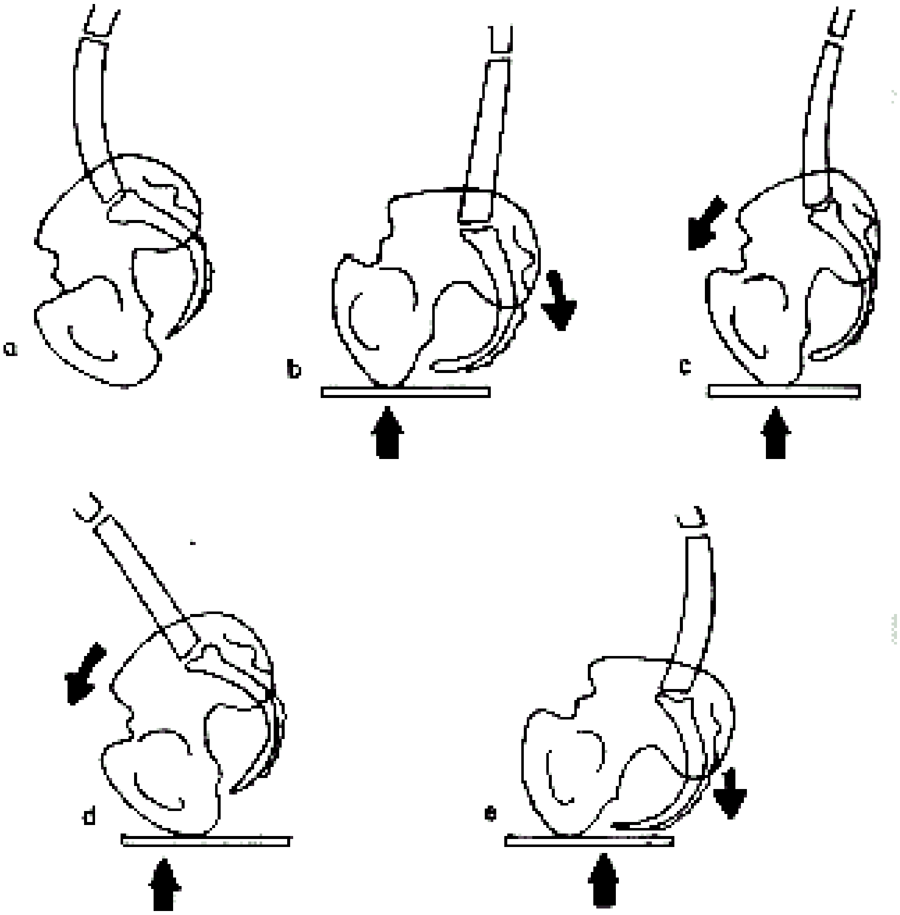


Figure 3 The pelvis and the lumbar part of the spine. (a) Standing; (b) Sitting relaxed, unsupported in the middle position; (c) sitting erect, unsupported in the middle position; (d) Sitting in anterior posterior; (e) Sitting in the posterior posture (Chaffin et al., 1999)

Stationary chairs have a feature such as a fixed back support. Automobile seats generally have some characteristics of stationary chairs. Other characteristics which could be changed include seat inclination. In most trucks and cars, the backrest inclination can be varied for various angles. The seat back rest remains at a fixed angle when the vehicle is in use.

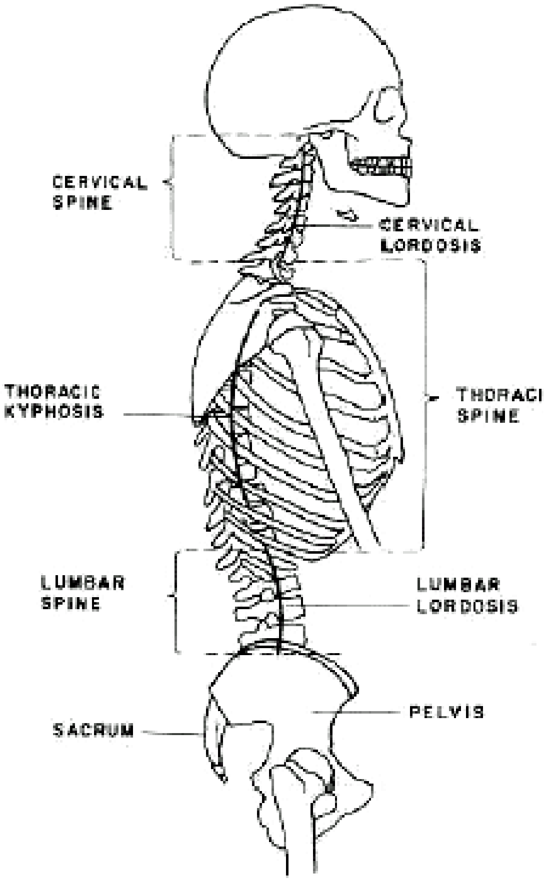


Figure 4 The segments of the spine. four segments- the cervical, thoracic and lumbar segment, and the sacrum. The lateral view above shows lumbar lordosis, a thoracic kyphosis, and a cervical lordosis (Chaffin et al., 1999)

The effect of a forward slopped seat pan in a seating posture is to some extent neutralized if there is no backrest. But the tilting seat may actually be useful in allowing variation in seating posture and load exerted on the spine when making changes from forward – leaning posture to a posterior relaxed position.

In a study by Kamijo et al. (1982), 43 car seats were evaluated as being comfortable or uncomfortable, although the time duration of the evaluation was not indicated. Their results stated that static pressure distribution “approximately correlated” with the difference between comfortable and uncomfortable seats. Lee and Ferraiuolo (1993) performed an experiment in which they used 100 participants to evaluate 16 visually similar car seats. The seats were fabricated with varying parameters of foam thickness and hardness, back contour and angle, cushion angle, spring suspension rates and side support. Participants sat for two minutes to assess their perceived comfort in ten body areas. The study concluded that there were not enough correlation between pressure and subjective comfort to form the bases of design.

Shen and Galer (1993) attempted to build a multifactor model of sitting discomfort using interface pressure measurements. They were able to identify the “force applied to the body,” “the sitting posture,” the “moveability of the body on the seat” and the “time seating in a posture” as factors in the model. The experiment required 11 participants to each sit in a chair for a 40 minutes session. Two seat angles (10 and 20 degrees) and three seat cushion to back rest angles (95, 100 and 105 degrees) were used in a random order to give six postures. The ratings of discomfort were not due to postural differences, although pressure measurements did reflect changes. The short duration of the participants in each posture was an issue of concern, as discomfort may considerably vary with time. Kroemer (1971) found that if a chair is too high such that there is pressure on the back of thighs, the participant tend to slide forward resulting in back pain if the pressure is prolonged. Such postures may be evident in modern cars with adjustable seat features. In a study by Bendix et al. (1985) on the acceptability of seats, a tiltable seat was used to compare a forward sloping postures and backward sloping postures. It was found this seat was favored to other seats with less body movements. In a study by Wu et al. (1998) the pelvic support consisting of a forward sloping wedge of foam was tested as an addition to conventional office seating for VDT work. In the first experiment a questionnaire investigation was carried out on the impressions of 10 male and 10 female subjects who sat using pelvic supports. The general result from the questionnaire was that the waist and pelvis were felt to be stable and the evaluation was more positive with the support than without

The main reasons why driving and car seats result in back pain is the distortion of the shape of the spine resulting in the triggering of the sharp warning pain at one of the lowest two joints. It is therefore this effect that needs to be understood as part of car seat design (Gorman, 1998). The backrest is an important aspect of a car seat design that has been a major area of focus. Magnusson et al. (1994) conducted a study to determine the effects of backrest inclination on the spine shrinkage. The study focused on static sitting and seated whole- body vibrations. The backrest inclinations tested were 110 degrees and 120 degrees. The study found that less shrinkage occurred at 110 degree than it did at 120 degrees during the static seating. The incorporation of vibration gave results that were opposite to static seating. It was thus concluded that an inclined backrest reduces the effects of vibration which as a result deemed it necessary to emphasis seat materials that attenuate vibration.

A study carried out by Anderson (1974) and Anderson et al. (1975) showed that the disc pressure and the electromyography activity of the erector spinae muscle decreased markedly when the back rest inclination was increased from 90 to 120 degrees, with further decrease occurring through the use of a lumbar support (Anderson et al., 1979). Reed (1998) made recordings of muscle activities in driving postures and found results that were supportive of studies by Andersson et al. (1975).

There has been high hope in the automotive industry that measurement of the interface pressure while sitting can be used to predict areas of subjective seat discomfort. The Vehicle Ergonomics Groups have established methods for evaluating the driver’s workstation in terms of the seat comfort, vision and reach, using subjective discomfort data. Although this data is of high quality, road trials typically take several months to complete and are often carried out when the car is ready for production (Porter, 1995).

Some approaches have been adopted by researchers for the assessment of comfort relevant to design of seats in terms of physiological/anatomical, subjective, postural, and performance - based measures, all of which have been described in great detail by Lueder (1983). Wong and Baker (1988) developed another form of subjective assessment using a pain rating scale. The emergence of pressure measurement techniques in designing passenger seats for comfort has generated considerable interest in the automotive industry. Subjective methods have usually assessed either general or localized comfort states. Several subjective approaches have been used in conjunction to achieve an overall assessment of a seat (Grandjean et al., 1980).

The use of subjective responses regarding comfort often entails four assumptions, as described by Branton (1996). Two of these four assumptions are relevant to this discussion. The first assumption is that respondents are aware of their feelings of comfort, and the second is that those feelings of comfort can be verbalized. Comfort scales with phrases such as ‘quite comfortable’ or ‘somewhat comfortable’ can be defined as a fuzzy set, with each category as a fuzzy subset (Ma and Cao, 1982). In order to analyze subjective evaluations, Zadeh (1965) first formulated the theory of fuzzy sets, and based on that theory Ma and Cao (1982) developed a fuzzy set model of category judgment and multistage evaluation method (MEM). This method eliminates the difficulty in determining whether or not a particular object belongs to a category (a set), such as “comfortable,” “somewhat comfortable” or “not comfortable,” since membership on a fuzzy set is on a yes/no basis.

There is little consensus on whether comfort and discomfort should be regarded as being a bipolar continuum or as two experiential dimensions. Hertzberg (1958) first operationally defined “comfort,” as “the absence of discomfort,” Jurgen (1980) has suggested that restless movements are presumably associated with attempts to compensate for uncomfortable conditions. Branton and Grayson (1967) achieved compatible results by filming a few participants for long- term and observing them for a short- term test.

In a study conducted by Jianghong and Long (1994) the comfort of a passenger seat for a new bus was evaluated using a fuzzy set model of a multistage comfort scale (MCS). This was adopted for measurement of comfort with techniques of human back shape and EMG measurements, including posture analysis. Thirty university students participated in the study. It was concluded that MCS is a rapid and comprehensive evaluation method for single chair. There was a significant difference in the EMG of back muscles between the two sitting postures (sitting upright and slumped sitting posture) at all the seat heights. Jones et al. (1961) has shown that participant have a clear concept of their best and most comfortable postures, and that these do not always coincide. A “2-dimension JOHN” kinetic computer model of the human body was used in a study by Ekern et al. (1997) to compare two seat designs, one of which was a prototype articulating seat and the other was a current production automotive seat. Simulations showed that the prototype seat supported a wider range of posture than the automotive seat.

On the whole muscle activity can be evaluated primarily by using EMG readings, which can be supported by subjective analysis of comfort or pain level responses from the participants. It is acceptable to vary the seat backrest angle and measure the muscle activity of the erector spinae muscle (Andersson et al., 1974; Reed, 1998; Hosea et al., 1986) and the procedure can be applied to the latissimus dorsi muscle. In the study by Bendix et al. (1985) supported by Wu et al. (1998) it was conclusive that in a tiltable seat, a forward sloping position was preferred to other postures.

Table 1: Summary of Literature Review

Researcher	Year	Focus of study	Conclusions
Lundervold	1958	Muscle activity at different vertical locations of the backrest	Muscle activity was lower with the backrest located in the lumbar region.
Anderson et al.	1974	Determined muscle activity in the lumber, thoracic and cervical region with increase in back rest inclination	Muscle activity decreased
Bendix	1985	Acceptability of seats, comparing forward sloping postures and backward sloping postures.	Tiltable seat was preferred to other seats
Hosea et al.	1986	Muscle activity of several back muscles in a driving Setup	Muscle activity decreased with increase in back rest inclination
Knutsson et al.	1996	Effect of additional lumbar support on muscle activity	Muscle activity decreased with support both in front and behind backrest plane
Reed	1998	Recorded muscle activities in driving postures	Muscle activity decreased

CHAPTER 3

RATIONALE AND OBJECTIVES

Researchers have taken extensive approaches to assess comfort in car seat design in terms of posture. As summarized in previous sections studies have indicated that the myoelectric activity of the erector spinae muscle in the lower back decreases when the backrest inclination increased in all areas of the spine Andersson et al., 1974; Reed, 1998, Hosea et al., 1986). However Hosae et al. (1986) found the muscle activity to increase with back rest inclination when the lumbar support height exceeded 7cm. Specific tests have yet to be performed on the latissimus dorsi, to determine how it responds. The seat angle effect is also a vital parameter that is yet to be studied, to determine its effect on the latissimus dorsi. Another study also indicates that a tilting seat was more preferable by the users to a fixed seat (Bendix et al., 1985; Wu et al., 1998).

In view of prior research, this study was conducted by varying the backrest inclination and the seat angle while recording the muscle activity of the latissimus dorsi, which is a major muscle in the lower back. The backrest was set at two angles (90 & 100-degrees) and the seat angle was set at 0 & 10-degrees to the horizontal axis. These postures were tested to determine how the latissimus dorsi responds to the variables. The main goal of the study was therefore:

1. To investigate how backrest inclinations affect the muscle activity of the latissimus dorsi.
2. To also determine how the seat angle affects the latissimus dorsi in the lower back.

The information obtained from the study may provide clearer understanding of how backrest angle in a sitting posture is most likely to cause back pain in terms of muscle fatigue and injury to the lower back. This will be done by hypothesizing that:

(a) The muscle activity of the latissimus dorsi does not change for backrest experiment.

(b) The muscle activity of the latissimus dorsi does not change for the seat angle experiment.

The study may also arouse interest into finding out how other areas of the musculoskeletal system respond to other variables of an automobile seat for further research.

CHAPTER 4

METHODOLOGY AND PROCEDURE

4.1 Materials

A seat manufactured for 1991 “Subaru Legacy” car with adjustable backrest features was used to vary backrest and seat angles. The seat was then cushioned with a layer of soft foam to increase “comfortability” and reduce pressure on electrodes. Also a driving simulator (CH racing system, CH products) was operated via a computer interface and connected to a computer to simulate the entire driving process.

Surface electromyography (EMG) electrodes were used to acquire signals from the muscle fibers. An EMG amplifier and an analog-digital converter were used to record filter, and send signals to the computer storage system for processing. A redux gel electrolyte was used for filling the electrode cups to facilitate contact with the skin and improve conductivity for the signals. Two electrode pairs were used with each attached to left and right side of the latissimus dorsi muscle. The distance between each pair of electrode was 20 millimeters.

4.2 Subjects

Participants were selected in two groups for separate experimental set-ups. First group participated in the seat back rest set-up, while the second group, were in the seat angle set-up. Twenty-one participants without any history of back pain were, randomly selected to participate in the first set-up. This consisted of 15 males with a mean age of 23.9 years, (standard deviation of 5.06) and 6 females with a mean age of 22.1yearrs (standard deviation of 2.04). The average height of men was 165 cm, while that of women was 157cm. All participants were selected from the Louisiana State University student population. Another sample population of 10 students consisting of four female and three male students was selected to participate in seat angle experiment. The mean age of the population was 20.9 years (standard deviation 1.37), with an average height of 154.75cm and average weight of 149.4 lbs.

4.3 Study Procedure

The driving task simulating workstation was setup in the laboratory (Figure 5 & Figure 6). Experiments for backrest and seat angle were performed on separate days and with two sample populations. At the start of each driving session the participants completed a consent form for approval to partake in experiment. Each participant’s anthropometric and demographic data was recorded after the first session. Participants wore very light clothing and their driving postures were measured using a goniometer. Each randomly selected participant was briefly trained on how to operate the driving simulator, which lasted, anywhere from five to fifteen minutes. Training of participants was implemented with the focus of helping to familiarize with navigation, and use of the controls and accessories on the simulator, such as blinkers, shifting gear, checking mirrors and pedals. The pedals for gas and brake are the same for a regular power transmission car. The first level of the simulation program allowed each participant to practice using all the controls, which are very user friendly, giving commentaries on the progress of performance while driving. When a participant felt comfortable enough, the experiment was then started.

But the entire driving task was simulated for two one hour sessions, for the backrest set-up. The seat angle set-up was simulated for two sessions of thirty minutes each. The back rest was kept constant at 90-degrees to the seat while the seat angle was varied. All data was collected at intervals of five minutes for ten seconds, and were then integrated to account for the duration of the session under test. At the end of each session participants completed a questionnaire. Prior to starting the driving task, the skin of the participants back was prepared for attaching the electrodes by slightly wiping the skin with alcohol. The electrodes were filled of redux gel electrolyte.

Each pair of electrodes was placed on either side of the lower back on the latissimus dorsi, corresponding to the L2 lumbar vertebral column (Figure 7). The electrodes were attached along the muscle fibers of the latissimus dorsi, with each pair at a distance of 2cm. This allowed deeper penetration of the muscle fibers and sensitivity to signals. A ground electrode from each pair was attached at a neutral bony area in the cervical region of the spine. The EMG signals were amplified 10 times and converted from analog to digital (A/D), at a rate of 1000 sample signals per second and stored in the computer. The signals were band pass filtered at {1- 300 Hz}. Considering that the primary focus was to determine the effect of the backrest and seat angle on muscle activity of the latissimus dorsi in the trunk, the testing of the muscles were specifically on the muscle fibers of that muscle.

Figure 5: The Driving workstation.

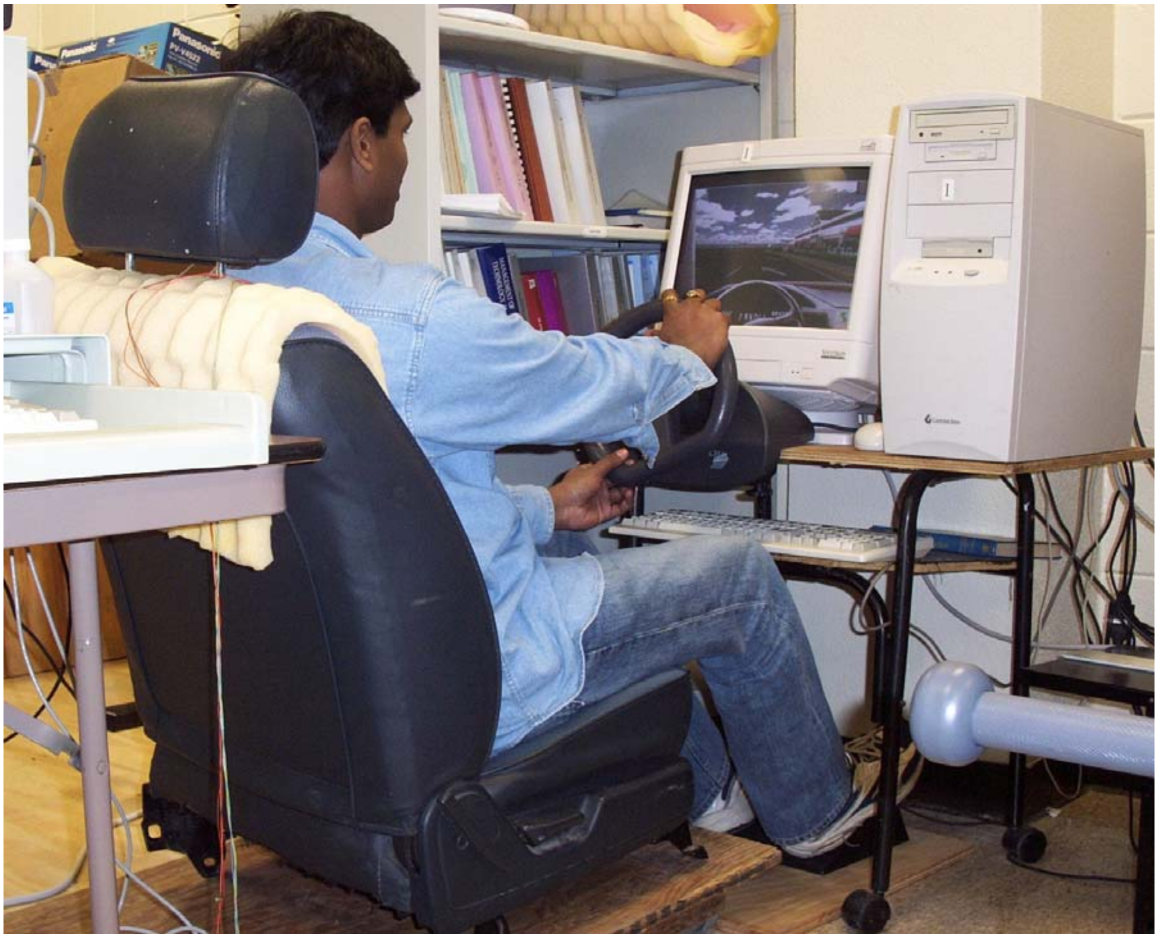


Figure 6: Participant in experimental session

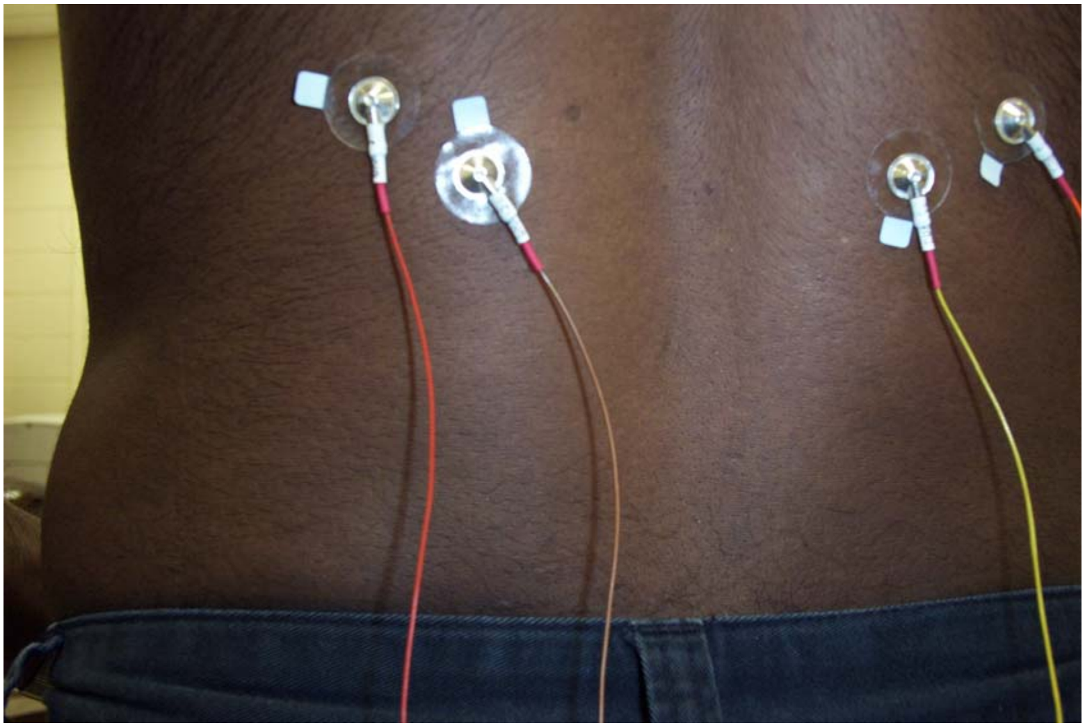


Figure 7: Electrode placement

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Empirical Analysis

All data were analyzed by using computerized EMG signal processing techniques. Waly et al. (1985) found that techniques of computerized EMG signal processing, provides sensitive indices in measuring the degree of muscular fatigue due to static work. The results obtained from the EMG signals were analyzed using an analysis of variance ANOVA method for the root mean square (RMS) of myoelectric values as a good source to determine muscle activity with respect to the backrest and seat angle postures. The root mean square is the square root of the integration of the squared EMG signal divided by the time period of the integration.

The following variables were deduced as shown below.

1. Peak –to –Peak amplitude is the range R.

2. Standard deviation (S.D.) = Square Root [sum Y(i) – Ym $]^2$/ N-1

$$= \sqrt{\left(\sum Yi - Ym\right)^2 / N - 1}$$

Ym = Mean value of y

Yi = Sample number I of the EMG

N = Number of EMG Samples.

T = Total time

m = Muscle activity

RMS [m (t)] = $\sqrt{\frac{1}{T}\int_{t}^{t+T} m^2(t)dt}$

Backrest Experiment

This experiment examined muscle activity of the latissimus dorsi at two backrest angles 90 and 100-degrees. Table 2 and Table 3 give the RMS (average root mean square) and percentage integrated electromyography IEMG (This is expressed as the percentage maximum voluntary contraction of the muscles) values for men and women respectively who participated in the backrest experiment. Table 4 gives the RMS and the IEMG at various time intervals for all participants (men & women) at both backrest angles. The analysis for this study was done using the RMS values. The values were calculated for the initial position of the seating posture, and progressive readings were taken with time in minutes through the whole driving simulation for each session, at a specific backrest angle. The results were analyzed using the Ariel performance analysis system (APAS) software on the EMG computer and statistically analyzed using SPSS, and Excel analysis statistical software. This allowed a comprehensive analysis of the EMG signals. An analysis of variation (ANOVA) of the RMS means for both angles, was performed for the data of all participants using a t- test with alpha (α) = 0.05, p = 0.01 (Table 4). The ANOVA test was done to determine any differences between the RMS mean values at 90 and 100-degrees backrest angles.

The results were significant and indicate a difference of 0.22 between the means at both 90 and 100-degrees backrest angles for all participants, which indicates that the mean value at 90-degrees was 58 % greater than the value at 100-degrees backrest angle. The RMS values for the initial readings of men had a difference of 0.91, which implies that the 90-degree RMS value was 77.9% greater than the 100-degrees RMS values. The final readings for the men also indicate a difference of 0.76, with 90-degrees RMS greater than 100-degree value by 76.8%**.**

The initial results for the women show that RMS values at 90 & 100-degrees had a difference of 0.27 and this indicates that the 90-degrees RMS was 60% greater than that of 100-degrees. The final values have a difference of 0.4 and the 90-degree RMS value was greater than the 100-degree RMS value by 65%.

Table 2: Average root mean square and IEMG for men (backrest angles)

	INITIAL READING			**FINAL READING**	
PARAMETER	RMS	IEMG		RMS	IEMG
90 degrees	1.27	75.40%		1.09	80.3%
100 degrees	0.36	85.10%		0.33	91.4%

Table 3: Average root mean square and IEMG for women (backrest angles)

	INITIAL READING			**FINAL READING**	
PARAMETER	RMS	IEMG		RMS	IEMG
90 degrees	0.78	72.8%		0.86	66.7%
100 degrees	0.51	80.2%		0.46	73.3%

Table 4: Root mean square and IEMG values for men & women (backrest angles)

Time (minutes)	RMS-90 Degrees	IEMG- 90	RMS-100 Degrees	IEMG- 100
0	1.24	86.3	0.92	85.5
5	1.09	80.8	0.90	92.1
10	1.01	86.3	0.87	87.2
15	0.99	84.4	0.80	89.3
20	0.91	86.8	0.59	90.2
25	0.89	87.3	0.54	92.9
30	0.73	88.5	0.50	92.9
35	0.71	89.9	0.49	91.7
40	0.69	91.2	0.48	90.6
45	0.64	91.4	0.40	90.5
50	0.6	92.3	0.40	83.7
55	0.44	93.2	0.34	90.7
60	0.30	94.1	0.23	91.3
Average	0.79	88.6	0.57	89.9

Table 5: ANOVA table for paired T-test Back Rest (men & women)

Paired Differences Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
.3023	.35591	.09871	3.063	12	.01

Paired Samples Test

The graph in Figure 8 shows the plot of the RMS values with time for 90 & 100-degrees back rest angles. The trend in the 90-degrees graph has a negative slope of -1.34 E^-2 this indicates the RMS decreased with time. The slope of the graph for the 100-degrees angle also showed a negative value of -1.13 E^-02. The slope in the graph of the 100-degrees angle emerges to be smaller than that for 90-degrees. The decrease in RMS with time generally shows an increase in fatigue and decrease in muscle activity with time, which leads to pain or fatigue.

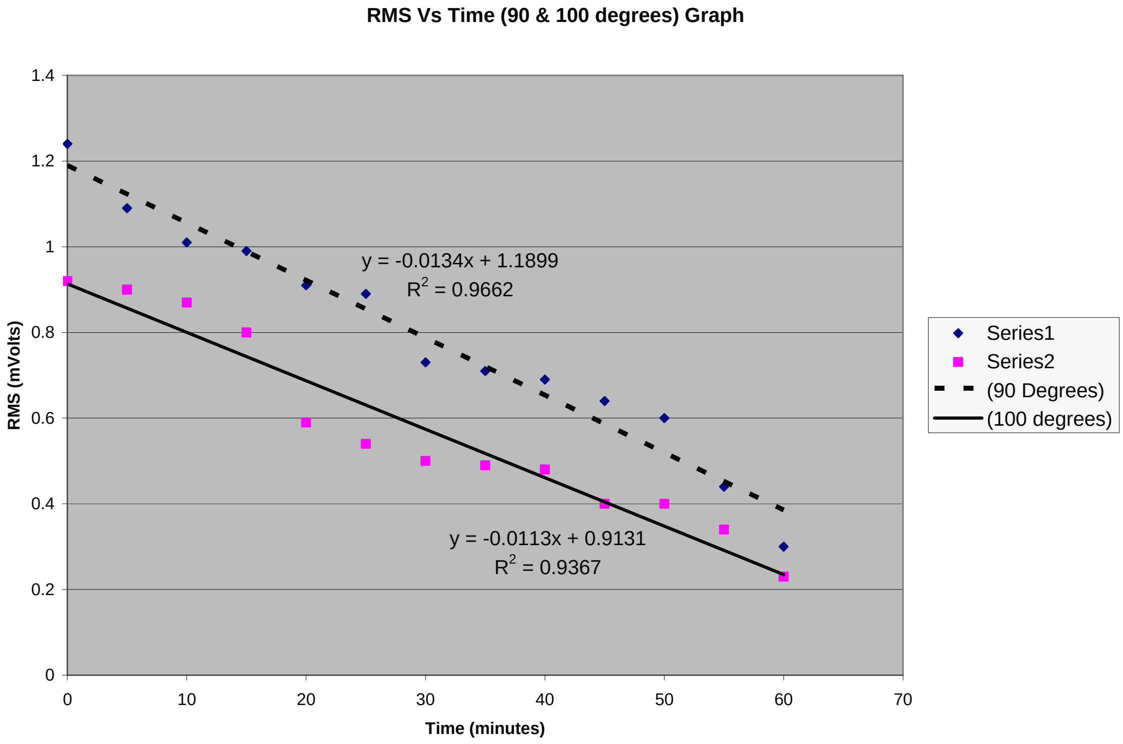


Figure 8: Graph of Rms-Time for backrest angle 90 & 100 degrees

Seat Angle Experiment

In the seat angle experiment the muscle activity of the latissimus dorsi was examined at two seat angles of 0 and 10-degrees. Table 8 gives the values of the RMS and the IEMG at various time intervals for both seat angles. An analysis of variance (ANOVA) of the means was performed from the values of the root mean square (RMS) using a t-test at alpha (α) = 0.05 which gave p= 0.034 (Table 9). The ANOVA test was done to determine the difference between the mean RMS values for both seat angles. There was a significant difference between the mean values of all participants (men and women) at both seat angles.

The results for all participants indicate a difference of 0.68 in RMS values for both 0 & 10-degrees. The RMS value at 0-degrees was 72.7% greater than the value at 10-degrees. The RMS values for the initial readings of men (Table 6) shows a difference of 0.6 for seat angles of 0 & 10 degrees, with RMS value for angle 0-degree 68% greater than the RMS value of 10-degrees seat angle. The final values for men indicate that the RMS 0-degree is 86% greater than RMS 10-degrees, and both have a difference of 1.06. In the case of the women (Table 7) the initial RMS 10-degrees was 95% greater than RMS 0-degrees. The two angles had a difference of 0.62. However the final readings had a difference of 0.65 with RMS 0-degrees 79% greater than RMS 10-degrees.

A plot of the RMS values with time for seat angle 0-degrees and 10-degrees (Figure 9) were done, which gave a linear trend for the graph plots. The graph of the data for 0-degrees seat angle showed a positive trend in the RMS values with time where as the trend of the data with time was negative for the 10-degrees data. The 0-degrees positive slope explains the relationship of the muscle activity increasing with time, which can be associated with decrease in the chances of developing pain or fatigue. Also the negative slope at 10-degrees explains the relationship of the muscle activity decreasing with time which could also be associated with increase in the chances of developing pain or fatigue in the lower back muscle (Latissimus dorsi).

Table 6: Average root mean square and IEMG for men (seat angles)

	INITIAL READING			**FINAL READING**	
PARAMETER	RMS	IEMG		RMS	IEMG
0-degrees	1.15	77.3%		1.25	82.8%
10-degrees	0.55	86.1%		0.19	80.2%

Table 7: Average root mean square and IEMG for women (seat angles)

	INITIAL READING			**FINAL READING**	
PARAMETER	RMS	IEMG		RMS	IEMG
0-degrees	0.03	77.7%		0.88	51.7%
10-degrees	0.65	49.9%		0.23	50.6%

Table 8: Root mean square and IEMG values for men & women (seat angles)

TIME (Minutes)	**RMS 0- Degrees**	**IEMG**	**RMS 10- Degrees**	**IEMG**
0	0.92	81.5	0.94	84.6
5	1.03	83.4	0.48	85.0
10	1.04	85.7	0.46	81.5
15	1.08	88.1	0.38	80.8
20	1.14	73.3	0.26	86.8
25	1.18	86.2	0.21	87.3
30	1.23	79.3	0.12	76.7
Average	1.09	70.73	0.41	83.24

Table 9: ANOVA table for paired T-test for seat angle (men & women)

Paired Differences Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
.5171	.50195	.18972	2.726	6	.034

Paired Samples Test

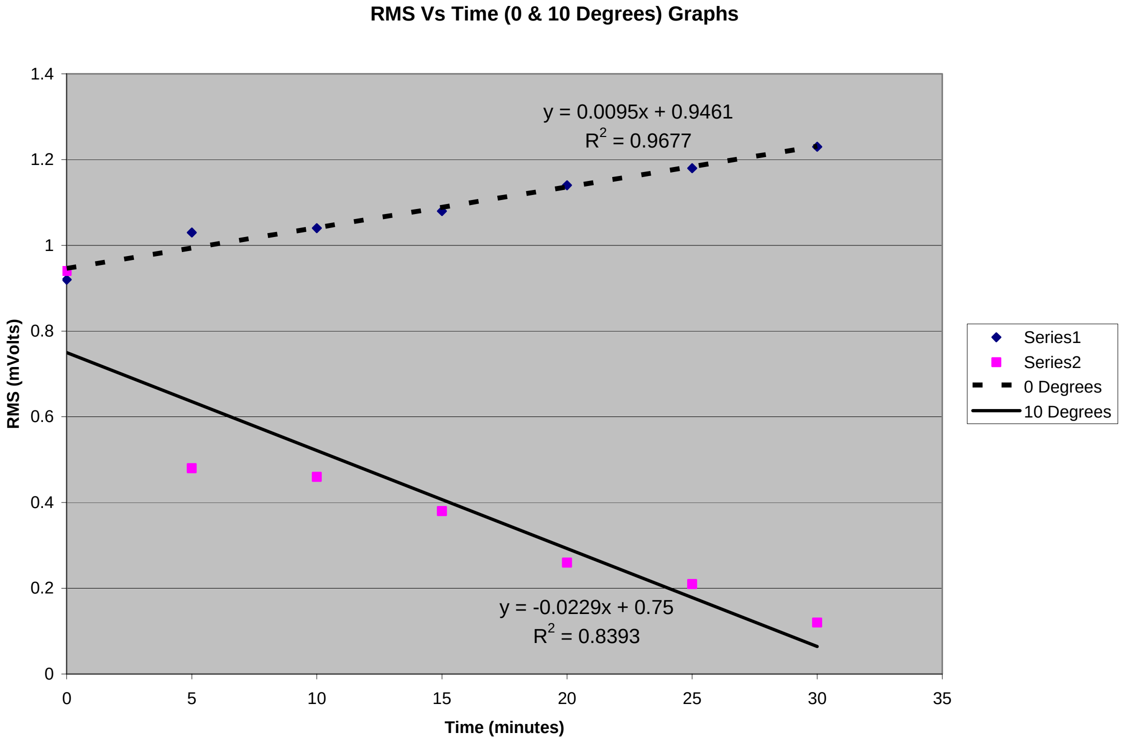


Figure 9: Graph of Rms-Time for seat angle 0 &10 degrees

RMS-0: Root mean square at 0-degrees

RMS-0: Y = -9.5 E^-3 (X) + 0.9461

RMS10: Root mean square at 10-degrees

RMS10: Y = - 1.23E ^-02 (X) + 0.75

5.1.1 Linear Model

Y= MX + C for a straight line indicating the equation of the line.
RMS = Y (Dependent variable)

M = Slope of the line (Rms/Time)

X = Time (Independent variable)

C = Intercept/constant/error variance

A linear model from the graphs showed that the RMS values increased with time for the seat angle at 0-degrees with a slope of 9.5 E^-3. At 10-degrees seat angle the slope decreased with time giving a value of - 1.2E^-02. The model could not determine what factor was significant in the decrease or increase of RMS values. All statistical analysis was performed using SPSS statistical software and Excel.

5.2 Subjective Analysis

A subjective evaluation of the seating postures was done for both backrest and seat angle postures. This evaluation was done using two sets of questionnaires, the first was based on a "Wong-Baker" pain scale and second a "Body part discomfort chart" (Appendix A & B). The "Wong-Baker" pain rating scale, ranged from 0 – 5, the "Body part discomfort chart" ranked comfort from 1-7, for various parts of the body (Appendix B). Analysis was done using the mean pain ratings from the participants at two backrest angles, and mean discomfort levels at the two seat angles.

Back Rest Experiment

In subjective evaluation of the backrest inclination at 90-degrees backrest inclination, 80% percent of men experienced pain. The women had 50% percent who experienced back pain at 90-degrees backrest inclination (Table 10). At the 100-degrees angle 40% of men and 34 % of women experienced back pain. The number of male and female participants that experienced pain was graphically represented also Table 11 shows the number of participants that responded to the back pain levels shown (Appendix A). Table 11 indicates same average which suggests same pain level was experienced from their responses. Graphs below (Figure 10 & Figure 11) show the number of subjects that experienced back pain, based on the Wong- baker faces pain rating scale, which was used in the subjective evaluation of pain for all participants. The X-axis represent the pain levels from 1-7 and the Y-axis represent the number of participants that experienced pain at a certain level. The levels of pain are as indicated in the questionnaire, starting from the least, zero (0) for no hurt, and ends with five (5) for hurts most. Figure10 shows eight people who reported no pain for level 0 (bar #1) and another nine experienced pain level 1 (bar #2), while one experienced a pain level of 2 (bar #3) and two at level 3 (bar #4), one at level 4 (bar #5) and zero at level 5.

Table 10: Back pain subjective values expressed in percentages

GENDER	**PAIN AT 90 DEGREES**	**PAIN AT 100 DEGREES**
Men	80%	40%
Women	50%	34%

Table 11: Back pain subjective values

Pain Expressions	**Number at 90 – Degrees**	**Number at 100 – Degrees**
No Hurt (0)	8	3
Hurts a little bit (1)	9	8
Hurts a little more (2)	1	8
Hurts even more (3)	2	0
Hurts a whole lot (4)	1	2
Hurts worse (5)	0	0
Average	3.5	3.5

GRAPH OF PAIN LEVEL FOR PARTICIPANTS

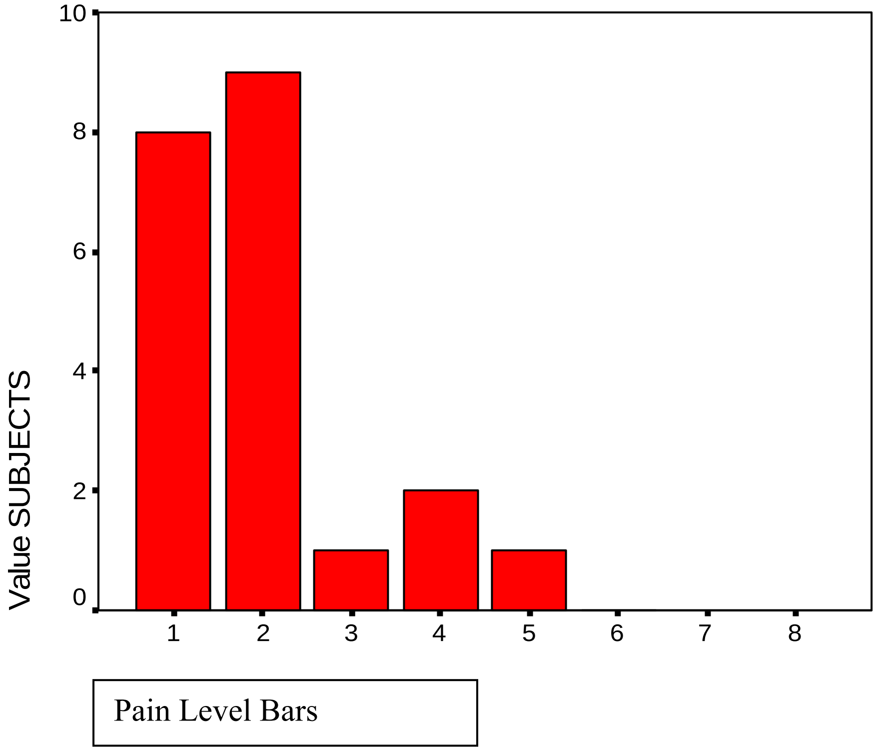


Figure 10: Graph of pain level for participants at 90 -degrees

In Figure 11 below three men reported no pain at level 0 (bar #1), eight experienced pain level 1 (bar #2), another eight at level 2 (bar #3), zero was at level 3 (bar #4), two at level 4 (bar #5) and zero at level 5.

GRAPH OF PAIN LEVEL FOR PARTICIPANTS

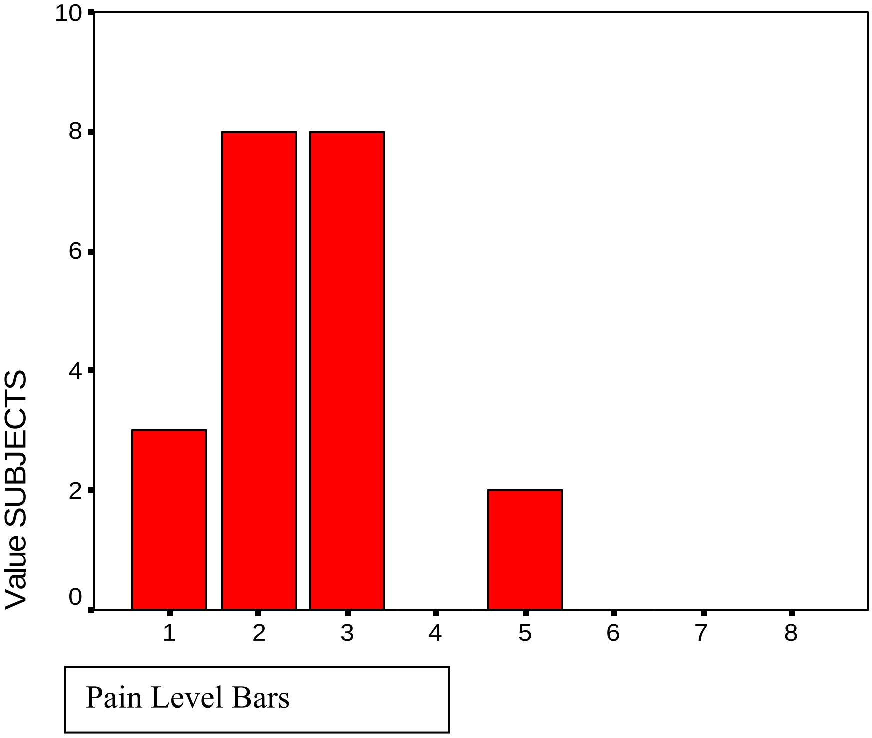


Figure 11: Graph of pain level for participants at 100-degrees

Seat Angle Experiment

Data for seven variables were collected from the seat discomfort questionnaire for both seat angles (Appendixes D & E). For statistical analysis one variable (lower back scale) was calculated from the 7- point comfort/discomfort scale. The mean rating over the session of each angle was calculated. The mean rating at 0-degrees was 4.3, while the rating at 10-degrees was 4.6. An ANOVA (Table 14) analysis was done at $\alpha = 0.05$, gave $p = 0.541$.The mean values show a difference in the means, with the mean value for 10-degrees higher than that of 0-degrees although not statistically supported. Consequently the differences between the means may only suggest whether the participants at 10-degrees experienced more discomfort compared to participants at 0-degrees. Although the value 4.0 on the comfort scale indicates neutral, the 0-degree value is 4.3 which may suggest that there was no discomfort at that seat angle. The value of 4.6 for the 10-degree angle may suggest that the participants were slightly uncomfortable at that seat angle. Differences were found in the averages of more body areas, the buttock, thighs, knees and the calf as shown in the summary table (Appendix F). In the subjective evaluation of the seat angles (Table 12), 66% of the men experienced discomfort in the lower back at 0-degrees seat angle. At 10-degrees seat angle, 83% of the men experienced discomfort in the lower back. Among the women 25% experienced discomfort at 0-degrees and 50% of them experienced discomfort at 10-degrees seat angle. The subjective responses of discomfort for seat angles of 0 & 10-degrees are indicated in the Table 13. These give the number of participants that responded to each discomfort scale (Appendix B) and a graphical representation of the two is also shown in Figure 12 & Figure 13.

Table 12: Lower back discomfort subjective values expressed in percentages

GENDER	DISCOMFORT AT 0 – DEGREES	DISCOMFORT AT 10 – DEGREES
Men	66%	83%
Women	25%	50%

Table 13: Subjective values for lower back pain (men and women)

Discomfort	Number at 0 -degree	Number at 10 –degree
1	0	0
2	1	1
3	2	0
4	2	2
5	4	5
6	1	1
7	0	1
Average	1.4	1.4

TABLE 14: ANOVA table for seat comfort analysis

Paired Differences Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
-.3000	1.49443	.47258	-.635	9	.541

GRAPH OF SUBJECTIVE DATA FOR SEAT ANGLE 0 -DEGREES

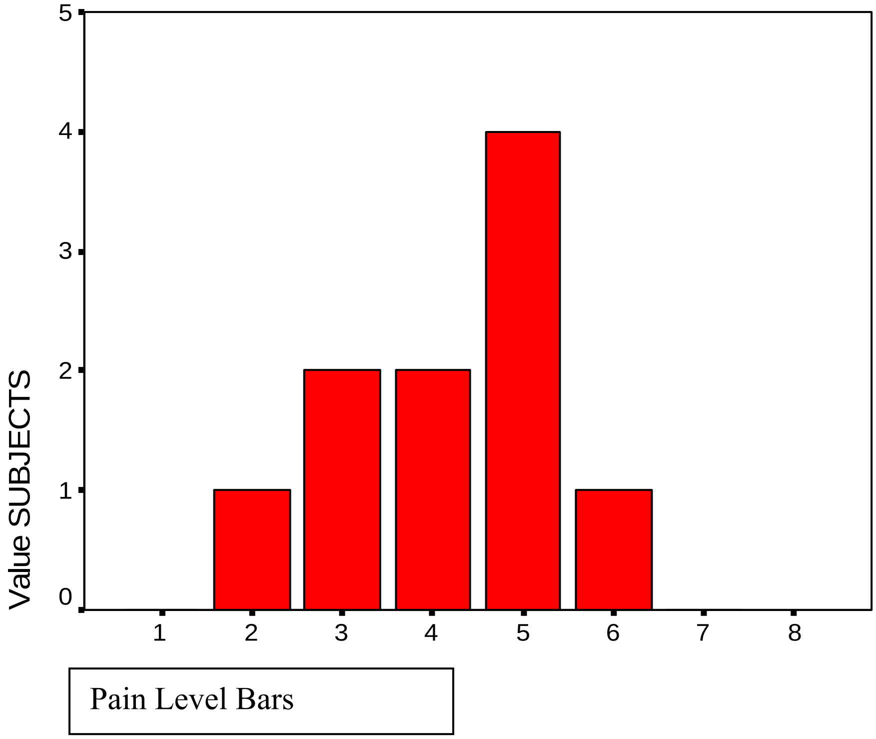


Figure 12: Graph of subjective data for seat angle 0- degrees

GRAPH OF SUBJECTIVE DATA FOR SEAT ANGLE AT 10 -DEGREES

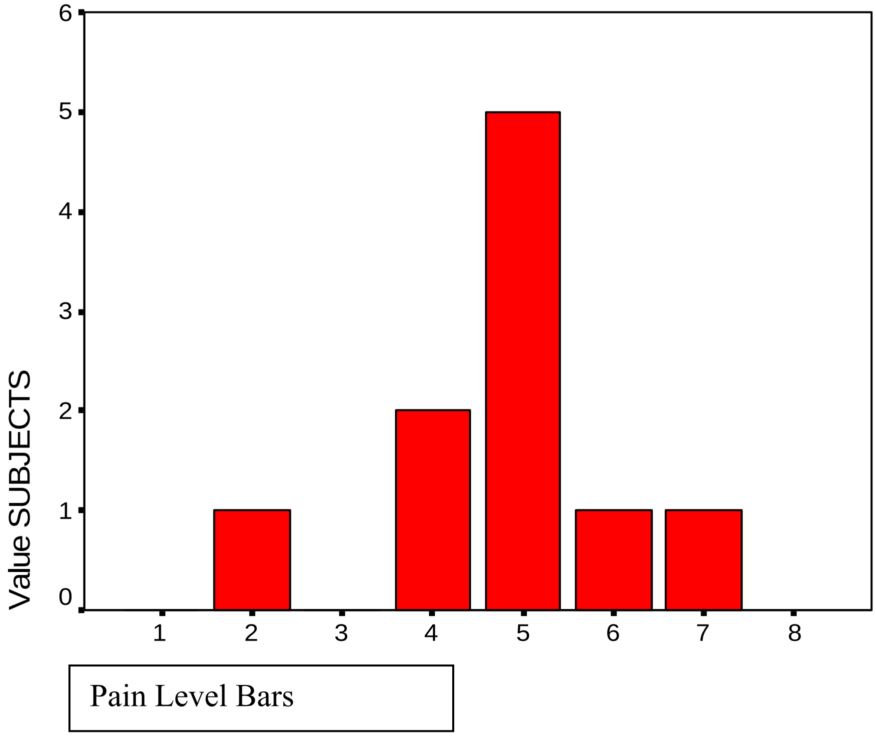


Figure 13: Graph of subjective data for seat angle 10 -degrees

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 Backrest Experiment

The results from the average RMS values for all participants indicate a difference of 0.22 for the values of 90-degrees and 100-degrees backrest angle. The 90-degree RMS value was 58% greater than the value for 100-degrees for all participants. Comparing the RMS values for Table1 (men) for angles of 90 and 100 degrees, showed that in both stages the muscle activity was less at 100 than at 90 degrees. The value for RMS 90-degrees was 57.4% greater than the value for 100-degrees for men at the initial values at the start of the experiment. At the final stage RMS at 90-degrees was also 56.6% greater than RMS 100-degrees value. Decreasing RMS value with time can be attributed to muscle fatigue setting into the muscle due to less contraction occurring. The initial stage for men shows RMS-90 degrees as 1.27 and that for RMS-100 as 0.36. In the final stage, the RMS (90) was 1.09 as compared to 0.33 for RMS-100 degrees. This may suggest that participants were exposed to back pain at 100 degrees backrest angle, than at 90 degrees this was due to the muscle fatigue setting in faster at 100 degrees as compared to 90 degrees as the values decreased. In Table 2 (for women) the initial RMS-90 degrees value show 0.78 as compared to 0.51 for 100 degrees. The RMS for 90-degrees was 60% greater than RMS 100-degrees value. This also follows the trend, which suggests a lower muscle activity leading to fatigue at 100 degrees than at 90 degrees for women. The final RMS (90) value (Table 2) is 0.86 and RMS (100) is 0.46 also depicting the same trend. In the final values the RMS 90 was also 65% greater than RMS 100-degrees value. Further analysis of the data for all participants gave $p<0.05$. Interpretations of RMS values were such that the lower the RMS value the lesser the muscle contraction, and tendency to experience pain over time. This was used to determine what seat and backrest angles could be recommended for driving from these experiments.

Consequently there was a significant change in the means of the RMS values, the muscle activity was therefore accepted to have changed and the participants may have experienced significant differences in pain level at the two backrest angles. Considering the fact that numbers for the average RMS values in Table 3 have slight deviations this may suggest that the increase in back rest angle to 90-degrees has a negative effect on the muscles, increasing the exposure to back pain and fatigue as muscle activity decreases at a faster rate. Therefore the increase in the back rest angle increases the chances of experiencing back pain over time in that posture. The outcome of this study may suggest driving in a seating posture of 90-degrees backrest angle.

The decrease in muscle activity with increased angle may be due to the fact that the lumbar support is more than 7cm high extending from the base of the seat all the way to the thoracic region, and is likely to affect the muscle activity. In a study by Hosae et al. (1986), his findings supported previous studies by Andersson et al. (1974), Andersson et al. (1975) and Reed (1998) which stated a positive decrease in muscle activity of the erector spinae muscle, with increase in back rest inclination. But the study by Hosae et al. (1986) also found that an increased lumbar support height greater than 7cm had an effect on the myoelectric acitivty of the back muscles although he found the myoelectric activity of several back muscles to decrease in all areas of the spine. This study therefore supports previous study of Andersson et al. (1974), Andersson et al. (1975), Reed (1998) and Hosae et al. The graphs of the RMS with time indicate that values for both angles decreased as the driving task prolonged. This suggests that driving over a long period leads to fatigue in the lower back muscles.

In this experiment the muscle activity changed significantly to be conclusive. Another cause for this could be due to the fact that experiment was simulated for an hour which was long enough to detect any differences in activity of the muscle. It is also important to recognize that posture is directly affected by the position of the pelvis because it is rigidly attached to the spine segment. Consequently, chairs with lower back/pelvic support help maintain proper pelvis/spinal column balance and more effectively promote lumbar lordosis. The car seat used had a back support fused with the lumbar support as one unit that extends from the lower back to the thoracic region, as a result the back rest support made proper contact with the lumbar area of the trunk and every area of the back against the seat backrest. Another issue is the experimental setup procedure was static, previous studies show that vibration helps to reduce the spinal height shrinkage unlike the case of static experimental setups.

6.2 Seat Angle Experiment

The results for all participants at both 0 & 10-degrees showed a difference of 0.68. The RMS values at 0-degrees were 72% greater than 10-degrees RMS value. The initial RMS values for men showed a difference of 0.6 and the RMS 0-degree value was 68% greater than 10-degree value. The final values for men for both angles had a difference of 1.06 with RMS 0-degrees 86% greater than RMS 10-degrees. The initial RMS values for women also showed a difference of 0.62 with RMS value 10-degrees on the other hand 95% greater than RMS 0-degrees. Although the RMS for 10-degrees was higher in the initial value for women, however in the final reading it turned out to be smaller with RMS 0-degrees 79% greater than the value of the RMS 10-degrees with a difference of 0.62. This therefore followed the trend of the other readings. Therefore there was a significant change in the mean RMS values, which shows that both men and women had the tendency to experience fatigue due to muscle activity at 10-degrees than at 0-degrees.

In this experiment only the seat angle was varied, the back rest was kept constant at 90-degrees to the seat. The statistical analysis of the data showed a significant difference between the means for seat angles at 0-degrees and 10-degrees at $p< 0.05$. The mean of the RMS values at 0-degrees was 0.92, and the mean for 10-degrees was 0.41, with a paired mean difference of 0.52. This shows that the muscle activity at 10-degrees seat angle decreased rapidly leading to fatigue faster than the muscle activity at 0-degrees seat angle. This indicates that a seat at 0-degrees is less likely to cause back pain compared to an inclination of 10-degrees. A possible reason for this could be the muscles balancing the trunk against the intra-abdominal pressure; it could also be the seat pressing against the poplitial area of the thighs. The slope of the graphs for 0-degrees showed a gradual increase in RMS with time which indicates lower risk of fatigue setting in at that posture. At the 10-degrees angle the slope decreased with time showing a high risk of fatigue setting in with time. This study does not support previous research by Bendix et al. (1985) because it based on a car seat but in his study of tiltable seats he found that participants preferred the tiltable seat although he found no difference between tiltability and seat angle. In this study the seat pan was not sloped downward; it was kept at 0-degrees (horizontal) and inclined upwards at 10-degrees for the next setting. It is therefore recommended from this study that seat angle of 0-degrees is suitable for driving an automobile.

6.3 Future Considerations

Three directions of research can be suggested for further investigation of both experiments. The number of trial angles should be increased to observe a continuous trend in the muscle activity with time, for the angles of the seat and back rest.

The second suggestion of further research is to increase the sample size of all the participants for both genders. This may enhance the capability to observe the responses of both genders in terms of their responses to the muscle activity at various angles.

The third suggestion is to use different automobile seats and compare the posture effects they will have on the muscle activity of the latissimus dorsi and other muscles. Significant focus in previous studies has been mainly on the erectus spinae in the back. How ever, the back consists of different subgroups of muscles which may respond separately to different seats and angles.

REFERENCES

Aaras, A., Veierod, M. B., Ortengren, R., Larsen, S., Ro O., 1996 "Reproducibility and stability of normalized EMG measurements on musculus trapezius", *Ergonomics*, **39** (2) 171 - 185.

Andersson, G. B, Ortengren, R., 1974 “Lumbar disc pressure and myoelectric back Muscle activity during sitting. IV. Studies on a Driver’s Seat” *Scand J Rehab Med Suppl*., **3**, 73 – 90

Andersson, G. B, Ortengren, R., Nachemson, A. L., Elfstrom, G Broman, H., 1975 “The seating posture: an electromyographic and discometric study” *Orthop Clin N Am*, **6**, 105 - 120

Andreoni, G., Santambrogio, C. G., Rabuffetti, M., and Pedotti, A., 2002. “Methods for the analysis of posture and interface pressure of car drivers” *Applied Ergonomics*, **33**, 511-522.

Bendix, T., J., Winkel, Jersen, F., 1985 “ Comparism of office chairs with fixed forwards and backwards inclining, or tiltable seats.” *Eur. J. Appl. Physiol*., **54**, 378 – 385.

Bergman, R.A., 1991 “Doubled pectoralis quartus, axillary arch, chondroepitrochlearis, and the twist of the tendon of pectoralis major.” *Anat. Anz*., **173**: 23-26.

Bergman, R.A., Thompson, S.A., and F.A. Saadeh, 1988. “Anomalous fascicle and high origin of latissimus dorsi compensating for absence of serratus anterior.” *Anat. Anz*., **167**: 161-164.

Boden S.D., Davis D.O., Dina T.S., Patronas N.J., Wiesel S.W., 1990 “Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation.” *J Bone Joint Surg Am*., **72**, (3): 403-8.

Chaffin, D. B., Andersson, G. B., Martin, B. J., 1991 “ Text book of occupational biomechanics” Third edition, John Wiley & Sons Inc, ISB 0-471-60134-9

Chaffin, D. B., Andersson, G. B., Martin, B. J., 1999 “Text book of occupational biomechanics” Third edition, John Wiley & Sons Inc, ISB 0-471-24697-2

CH racing system, CH products, 970 Park Center Drive, Vista, CA, 92081, (www.chproducts.com)

Deyo, R., 1998 “Low-Back Pain.” *Scientific American*, **279**, (2): 48-53

Dieen, J. H., Looze, M. P., Hermans, V., 2001 “Effects of dynamic office chairs on trunk kinematics extensor EMG and spinal shrinkage.” *Ergonomics*, **44**, (7) 739 - 750.

Dimitrov, G.V., Dimitriva, N.A., 2003. “Interpretation of EMG changes with fatigue: facts Pitfalls and fallacies” *Journal of Electromyography and Kinesiology,* v**13**, i1 p13-36.

Ekern, D. F., Gedraitis, C. J., Hubbard, R. P., Bush, N. J., 1997 “Progress with Human Factors in Automotive Design: Seating Comfort, Visibility, and Safety” **Source:** *SAE Special Publications* v **1242**, 970592 125-133.

Essendrop, M., Andersen, T. B., and Schibye, B., 2002. “Increase in spinal stability Obtained at levels of intra- abdominal pressure and back muscle activity realistic to work situation” *Applied Ergonomics,* **33**, 471 - 476.

Gorman, J., 1998. “Car seats and the pelvic posture principle” *Journal of the McKenzie Institute (USA).*

Grieco, A., 1986 ”Sitting posture: An old problem and a new one.” *Ergonomics,* **29**, 345-362.

Grandjean, E., 1980 “Sitting posture of car drivers from the point of view of ergonomics” in Oborne, D. J. and Levis, J.A. (eds) Human Factors in Transport Research v**2** Acdemic Press, London, pp 205-213.

Granata, K., Marras, W., 1999. “Relation between spinal load factors and the high risk probability of occupational low-back disorder.” *Ergonomics,* **42**, 1187-1199.

Gyi, D.E., Porter, J.M., Robertson, N.K., 1998. “Seat pressure measurement technologies: considerations for their evaluation.” *Applied Ergonomic,* **29**, (2) pp. 85-91.

Gyi, E. D., Porter M. J., 1999. “Interface pressure and prediction of car seat discomfort” *Applied Ergonomics,* **30**, 99-107.

Gyi, E. D., Porter M. J., 1998. “Musculoskeletal problems and driving in police officers *Occup Med,* **48**: 153-160.

Hatipkarasulu, S. G., 2002 “Visco-Elastic Creep in the Lumbar Spine Associated with Static Flexion: A Feline Model” Thesis, Baton Rouge, Louisiana State University.

Hosea, T. M., Simon, S. R. Delatizky, J., Wong, M. A., Hsieh, C.C., 1986 “Myoelectric analysis of the paraspinal musculature in relation to automobile driving” *spine,* **11**, 928 –936.

Jianghong, Z., Long, T., 1994 “An evaluation of comfort of a bus seat.” *Appl. Ergon*., **25**, (6), 386-392

Kamijo, K., Tsujimura, H., Obara, H., Katsumata, M., 1982 “Evaluation of seating comfort. SAE technical paper series 820761.

Kelsey, J., Hardy, R. J., 1975 “Driving of motor vehicles as a risk factor for acute herniated lumbar intervertebral discs.” *Am J Epidemiology,* **102**, 63-73.

Knutson, B., Lindh, K., Telhag, H., 1966 “Sitting- an Electromyographic and mechanical study,” *Acta orthop*. Scand., **37**, 415.

Kroemer, K. H. E., 1971 “Seating in plant and office.” American Indusr. Hygien Ass. J., **2**, 132

Kumar, S., 2001 "Theories of musculoskeletal injury causation." *Ergonomics,* **44**1: 17– 47.

Kumar, S., 1999 "Biomechanics in ergonomics." Taylor & Francis Ltd, ISBN 0 7484 0704 9

Lee, J., Ferraiuolo, P., 1993 “Seat comfort. SAE Technical paper series 930105.

Leuder, R. K., 1983 “ Seat comfort: A review of the constrict in the office environment” *Human factors,* **18**, 339-345.

Lundervold, A. J. S., 1958 “Electromyographic Investigation during Typing.” *Ergonomics,* **1**, 226

Magnusson, M., Hanson, T., and Pope, H. M., 1994. “ The effects of Seat back inclination on spine height changes “ *Applied Ergonomics,* **25**, (5) 294-298.

Mientjes, M., Norman, R., Wells, R., McGill, S., 1999. “Assessment of an EMG-based method for continuous estimates of low back compression during asymmetrical occupational tasks” *Ergonomics*, **42**, 868-879.

Porter M. J., 1999, " Driving and musculoskeletal health" *Ergonomics,* **17**, (2) 8-11.

Praemer A., Funer S., and Rice D. P., 1992, “ Musckuloskeletal Conditions in the United States” *Amer. Acad. Orth. Surg*., Rosemont, IL, 1992, pp. 1- 199

Ray, J. D. and Tooms, R., 1993 “Lower-back muscle strains associated with supine resting positions” *Proceedings of the Annual Conference on Engineering in Medicine and Biology*, **15**, n pt 3, p 1077-1078

Reed, M. P., 1998. “Statistical and biomechanical prediction of automobile driving posture” Masters Thesis, University of Michigan, Ann Arbor, MI..

Rennaro, D., 2003 “Continuous, intermitted and sporadic motor unit activity in the trapezius muscle during prolonged computer work.” *Journal of electromyography and kinesiology*, **14**, 113-124.

Roskopf, G.,2002 “The spinal extensors: The stabilizers of the mid back” *IDEA Personal Trainer,* v**13**, i9 pp52.

Shen, W., Galer., I. A. R., 1993 “Development of a pressure related assessment model of seating comfort.” Proceedings of the Human Factors and Ergonomics society 37th annual meeting, (2) pp 831-835.

Solomonow, M., Acierno, S. P., Baratta, R. V., 1995 “ A practical guide to electromyography for ergonomists and biomechanists.” Occupational medicine research center, Louisiana State University Health Science Department of Orthopedics.

Skovron, M. L., 1992 “Epidemiology of low backpain” *Baillieres Clin Rheumatol,* **6**, (3): 559-73.

Toren, A., 2001. “Muscle activity and range of motion during active trunk rotation in a sitting posture.” *Applied Ergonomics,* **32**, 583 - 591.

Waddell, G., Main, C.J., Morris, E.W., Venner R.M., Rae P.S., Sharmy S.H., Galloway H., 1982 “Normality and reliability in the clinical assessment of backache” *Br Med J* (Clin Res Ed)., **22**, 284 (6328):1519-23

Waly S. M., Khalil, T. M., Asfour, S. S., 1985 “ Physiological basis of muscular fatigue: An electromyographic study” *American Journal of Physical Medicine,* **47**, 125-135.

Wong, D. and Baker, C., 1988 “Pain in children: comparison of assessment scales” *Pediatric Nursing,* **14**, (1) 9-17.

Wu, C., Miyamoto, H., Noro, K., 1998 “Research on pelvic angle variation when using a pelvic support “*Ergonomics,* v **41**, n 3, p 317-327

Yamaguchi, Y., F. Umezawa, and Y. Ishinada, 1972 “Sitting posture: An Electromyographic study on healthy and Nostalgic people.” *J. Jap. Othop. Assoc*., **46**, 277.

Youdas, J., Garrett, T. R., Egan, K. S., Therneau, M. T., 2000 “ Lumbar Lordosis and pelvic Inclination in Adults with Chronic low back pain.” *Physical therapy,* **80** i3 p261.

Zhao, J., and Tang L., 1994 “An evaluation of comfort of a bus seat” *Applied Ergonomics,* **25**, (6) 386-392.

Zang, L., Helander, M.G., Drury, C. G., 1996. " Identifying factors of comfort and discomfort in sitting." *Human Factors,* **38**, (3) 377-389.

Zennaro, D., Laubli, T., Krebs, D., Klipstein, A., Krueger, H., 2003 " Continuous intermitted and sporadic motor unit activity in the trapezius muscle during prolonged computer work." *Journal of electromyography and kinesiology,* **13**, (2) 113-124.

APPENDIX A

QUESTIONNAIRE FOR BACK PAIN

Questionnaire Number

Checked in by ….

Data input by….

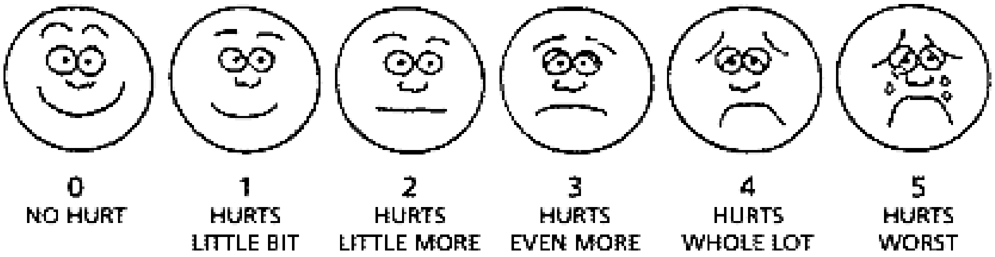
INTRODUCTION

This survey is to assess the level of pain experienced by each subject in each session of the driving task. This will be repeated for all angles of inclination.

INSTRUCTIONS

View the facial expressions and the scale of pain level to answer the questions below.

Translations of Wong-Baker FACES Pain Rating Scale



(Wong, D. and Baker, C., 1988)

Face 0 ***is very happy because he doesn't hurt at all.***

Face 1 ***hurts just a little bit.***

Face 2 ***hurts a little more.***

Face 3 ***hurts even more.***

Face 4 ***hurts a whole lot.***

Face 5 ***hurts as much as you can imagine, although you don't have to be crying to feel this bad.***

Choose the face that best describes how you feel.

1) Do you experience any back pain (Check one)

(a) Yes …….

(b) No ……..

2) What is your level of back pain from the Scale (circle one of the following)

0 No Hurt

1 Hurts little bit

2 Hurts little more

3 Hurts even more

4 Hurts a whole lot

5 Hurts worst

3) What is your age:……………….. years old

4) Gender: Male…………..

Female………

5) Height:……………………..

APPENDIX B

QUESTIONNAIRE FOR SEAT DISCOMFORT

Questionnaire Number

Checked in by ….

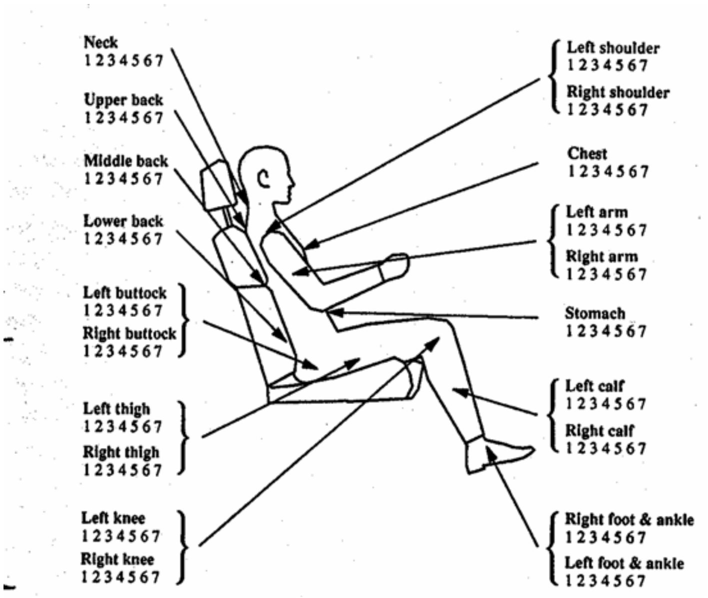
Data input by….

INTRODUCTION

This questionnaire is to assess the level of seat discomfort experienced by each subject in each session of the driving task. This will be repeated for both seat positions.

INSTRUCTIONS

1) View the body part discomfort chart and give your response for the all areas, according to the level of discomfort experienced.



Body part discomfort chart (Based on Corlett and Bishop, (1976) as in Gyi et al., 1998)

Interpretation of scales.

1. Very comfortable.
2. Moderately comfortable.
3. Fairly comfortable.
4. Neutral.
5. Slightly uncomfortable.
6. Moderately uncomfortable.
7. Very uncomfortable.

3) What is your age:………………..

4) Gender: Male…………..

Female………

5) Height:……………………..

6) Weight……………………..

7) Buttock -Knee length………………..

APPENDIX C

ANTHROPOMETRIC AND DEMOGRAPHIC DATA

Subjects	1	2	3	4	5	6	7	8	9	10	AVG	S.D.
Gender	F	F	F	M	F	M	M	M	M	M	N/A	N/A
Age	20	18	21	21	22	23	20	21	22	21	20.9	1.3
Height (cm)	162.5	160	162.5	187.5	160	180	192.5	170	167.5	167.5	171	11.07926
Weight (lbs)	125	116	130	165	130	170	165	163	150	180	149.4	21.20472
B-Knee length(Inches)	21	22.5	21	24	21	23	23	20.5	22	22.3	22.03	1.076151

F: female
M: Male
B – Knee length: Buttock – Knee length

APPENDIX D

SUBJECTIVE DATA FOR SEAT COMFORT AT 0-DEGREES

	neck	ubk	mbk	lbk	Lbut	Rbut	Lth	Rth	Lkn	Rkn	Lsh	Rsh	Chst	Lam	Ram	Stmc	Lcaf	Rcaf	RfA	LfA
1	3	3	3	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	7	7	5	4	2	2	2	2	2	2	6	6	3	4	4	2	5	5	3	3
3	2	5	1	2	5	4	1	1	1	1	5	5		3	3	3	1	1	1	1
4	3	5	6	6	2	2	1	1	5	5	4	4	2	2	2	1	2	2	2	2
5	5	5	4	5	1	1	1	1	1	1	5	5	1	1	1	2	1	1	2	2
6	5	5	4	4	5	5	4	4	4	4	4	4	4	4	4	4	3	3	3	3
7	1	5	1	5	1	1	1	1	1	1	2	2	1	2	2	1	2	2	3	3
8	5	6	6	6	4	4	3	3	4	5	3	5	3	3	5	3	3	3	3	3
9	2	3	3	3	2	4	2	3	2	3	2	4	2	2	3	2	2	4	2	4
10	5	3	2	5	5	3	6	4	4	4	4	5	4	4	4	4	5	4	5	4
Avg	3.8	4.7	3.5	4.3	2.9	2.8	22	2.1	2.5	2.7	3.6	4.1	2.3	2.6	2.9	2.3	2.5	2.6	2.5	2.6
S.D.	1.8	1.3	1.7	1.3	1.6	1.3	0.2	1.2	1.5	1.6	1.5	1.4	1.2	1.1	1.3	1.1	1.4	1.4	1.1	1.0

Body Parts

1. Neck
2. ubk- Upper back
3. mbk – Middle back
4. lbk – Lower back
5. Lbut – Left buttock
6. Rbut – Right Buttock
7. Lth – Left Thigh
8. Rth – Right Thigh
9. Lkn – Left Knee
10. Rkn – Right Knee
11. Chst - Chest
12. Lam – Left arm
13. Ram - Right arm
14. Stmc - Stomach
15. Lcaf – Left carf
16. Rcaf – Right carf
17. RfA – Right foot and Ankle
18. RfA – Left foot and Ankle
19. Lsh – Left Shoulder
20. Rsh – Right Shoulder

APPENDIX E

SUBJECTIVE DATA FOR SEAT COMFORT AT 10-DEGREES

	neck	ubk	mbk	lbk	Lbut	Rbut	Lth	Rth	Lkn	Rkn	Lsh	Rsh	Chst	Lam	Ram	Stmc	Lcaf	Rcaf	RfA	LfA
1	5	3	4	5	4	4	4	5	4	5	5	4	4	5	4	4	5	4		
2	5	5	3	5	2	2	1	1	1	1	2	2	1	1	1	1	1	1	1	1
3	2	4	4	2	2	5	2	5	2	5	2	3	2	3	3	3	2	5	2	5
4	2	2	3	4	5	6	6		5	5	3	3	5	4	4	5	3	3	3	3
5	2	3	4	3	2	2	2	2	1	1	1	1	2	1	1	2	1	1	1	1
6	2	2	4	5	2	2	1	1	3	3	3	3	1	1	2	1	1	1	2	1
7	5	5	6	6	2	2	1	1	3	3	5	5	2	3	3	1	1	1	1	1
8	3	4	5	5	4	4	4	4	4	4	4	4	3	3	3	4	3	3	3	3
9	4	5	1	5	2	2	7	6	2	2	2	2	1	1	1	1	5	5	3	3
10	5	6	6	6	4	4	3	3	4	5	3	5	3	3	5	3	3	5	3	3
Avg	3.5	3.9	4	4.6	2.9	3.3	3.1	3.1	2.9	3.4	3	3.2	2.4	2.5	2.7	2.5	2.5	2.9	2.1	2.3
S.D.	3.0	1.4	1.4	1.5	1.3	1.2	1.5	2.1	1.9	1.4	1.6	1.3	1.3	1.3	1.4	1.4	1.5	1.6	1.8	0.9

APPENDIX F

SUMMARY DATA FOR SEAT COMFORT AT 0 &10 DEGREES

0-deg	3.8	4.7	3.5	4.3	2.9	2.8	22	2.1	2.5	2.7	3.6	4.1	2.3	2.6	2.9	2.3	2.5	2.6	2.5	2.6
10-deg	3.5	3.9	4	4.6	2.9	3.3	3.1	3.1	2.9	3.4	3	3.2	2.4	2.5	2.7	2.5	2.5	2.9	2.1	2.3

APPENDIX G

CONSENT FOR PARTICIPATION IN RESEARCH

1. **Study Title**: Effects of Automobile Seating Posture on Trunk Muscle Activity.

2. **Performance Site**: Industrial Engineering Human Factors Laboratory

3. **Investigators**: The investigators listed below are available to answer questions about the research.

Dr Craig Harvey M, W 1:30 – 2:30 pm

225-578-5364

Dr. Fred Aghazadeh, M-F, 8:00 a.m. - 4:00 pm
504--388-5367

Milton Saidu (student) M – F, 6:00pm – 10 :00 pm

225-336-0986

4. **Purpose of the Study**: The purpose of this research project is to investigate the association of various seat inclinations of an automobile car seat, and the back muscle activity.

5. **Subject Inclusion**: Twenty-one participants will be selected from the Louisiana State University Baton Rouge campus population, for backrest experiment. Another ten participants will be selected for seat angle experiment. The ages of the participants would be between the ranges of (18- 30) years. All participants would be those capable of driving an automatic transmission car. Participants will be those with out any prior history of back problems.

6. **Number of Subjects**:

Backrest - 21

Seat angle- 10

7. **Study Procedures**: Each subject will have two pairs of laboratory surface electromyography (EMG) electrodes attached to the back muscles with an adhesive patch that sticks to the back. The participants will then operate a simulated driving workstation for three hours, at a particular seat angle. The procedure will be repeated for three other angles, for different days.

8. **Benefits**: There are no direct benefits to the subjects. However, information gained from the study may provide identification of driving seat inclinations that have a greater risk to cause back pain.

9. **Risks/Discomforts**: There is no risk in sticking the electrodes to the back; there is a slight discomfort, because the participants back will be exposed while fixing the electrodes. These discomforts will be minimized, by ensuring that each participant will have the same gender fixing the electrodes to his or her back. The 1hour simulation might cause back muscle discomfort for some participants.

10. **Right to Refuse**: Subjects may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which they might otherwise be entitled.

11. **Privacy**: Results of the study may be published, but no names or information identifying the participants will be included in the publication. The participant’s identity will remain confidential unless disclosure is required by law.

12. **Signatures**: The study has been discussed with me and all my questions have been

answered. I may direct any further questions regarding this study to the investigators. If I have questions about subjects' 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 this consent form.

....

Signature of Participant

Date: /   / 03

APPENDIX H

ANOVA TABLES FOR SEAT COMFORT ANALYSIS

Paired Samples Statistics

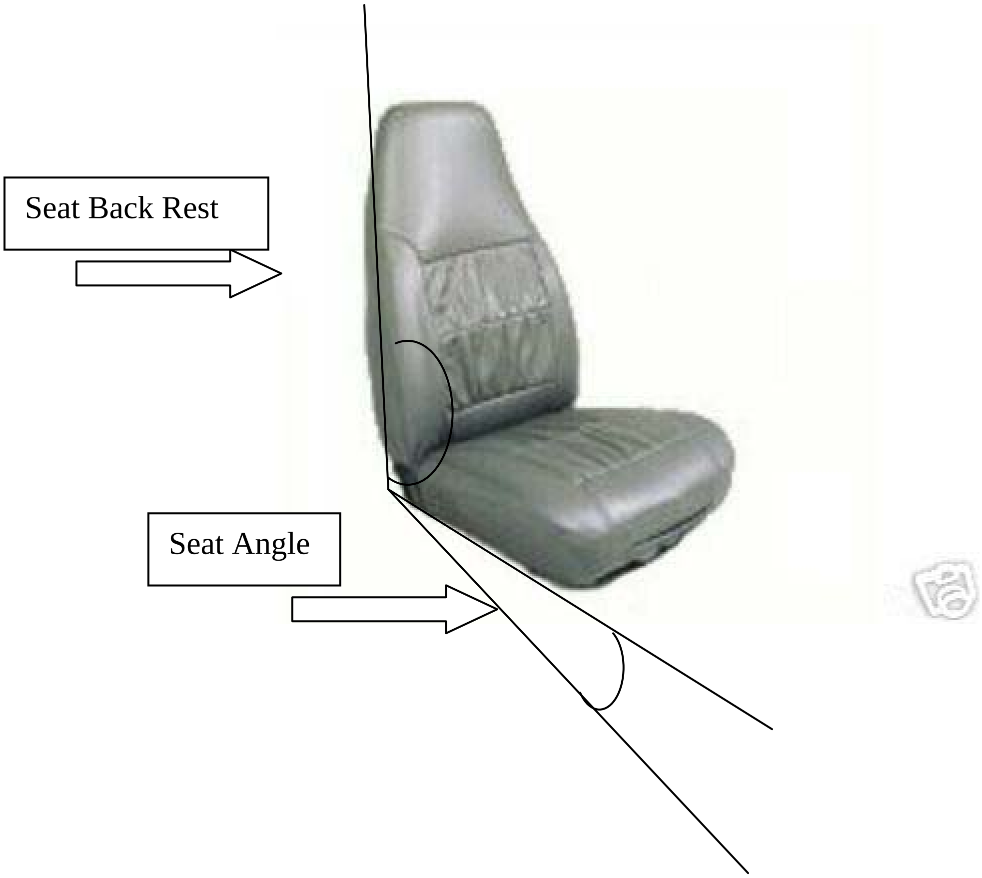
	N	Mean	Std. Deviation	Std. Error Mean
MEN	4	4.5000	3.51188	1.75594
WOMEN	6	1.0000	.89443	.36515

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	RMS0 – RMS10	-.3000	1.49443	.47258	-1.3691	.7691	-.635	9	.541

APPENDIX I

AUTOMOBILE SEAT ILLUSTRATION



VITA

Milton Maada-Gormoh Saidu was born in Njala, Sierra Leone, West Africa. He holds a Bachelor of Science degree in physics education, with a minor in mathematics, from the university of Sierra Leone (June, 2001). He is at this moment a candidate for the Master of Science in Industrial Engineering degree at Louisiana State University, Baton Rouge, Louisiana. He is expected to graduate in May 2004.

Prior to studies at the Louisiana State University, he taught physics at a community college for three months, and also volunteered as an assistant to the graphic artist and maintenance technician in the Educational Services Center, Njala University College, University of Sierra Leone.

His professional interest lie in the areas of ergonomic design of work stations, occupational biomechanics, Human factors engineering and Occupational Safety.