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Impact of vehicle seat back inclination on occupational driving safety

Milton Saidu[1*], Fereydoun Aghazadeh[2]

[1]Department of Petroleum Engineering Technology and Safety Management
Nicholls State University, Thibodaux, LA 70310

[2]Department of Mechanical and Industrial Engineering
Louisiana State University, Baton Rouge, LA70803-6405

milton.saidu@nicholls.edu, aghazadeh@lsu.edu

Abstract

This study determined effect of automobile seat backrest inclination on *lattisimus dorsi* muscle electromyographic (EMG) activity. Myoelectric activity was determined at two seat backrest angles (90 degrees and 100 degrees inclinations). Twenty-one (21) participants were engaged in the study. Electromygraphic activity at 90 degrees inclination had slope value of -0.065 mV/minute while 100 degrees had slope value -0.044 mV/minute. Myoelectric data indicated activity at 100 degrees was lesser than at 90 degrees for *latissimus dorsi* muscles. Results of the experiment were significant ($P=0.01$). Myoelectric results indicated that activity of the *latissimus dorsi* muscles decreased with increase in backrest angle.

Key words: Electromyography, back-pain, muscle activity, automobile seat, seating posture, fatigue.

1-Background of back pain challenges

Long-term exposure to sedentary task and postural stress in an occupational driving environment is associated with an increased risk of musculoskeletal disorders (Bovenzi, 1996; Mozafari et al., 2015, Lurati, 2018). Over 80% of adult population in the United States (U.S.) has reported some form of lower backache associated with spinal disorders, muscle strains and medical problems (Pai and Sundaram, 2004; Ronchese and Bovenzi, 2012; Sowah et al., 2018). These musculoskeletal disorders are generally attributed to occupational exposures such as stress, awkward postures, noise and whole body vibrations leading to compressed disks, sprained lumbar muscles and prolapsed disks (Ronchese and Bovenzi, 2012; Dong et al., 2019). The effect of such back disorders has often affected worker performance and sometimes resulting in lost time on the job and disability (Lardon et al., 2018).

Low back pain is one of the common musculoskeletal impairments, which is often caused when a muscle or ligament holding the vertebra in its position is subjected to strain such as in sedentary task (Mastalerz and Palczewska, 2010; Lardon et al., 2018). There is a high level of prevalence of low back pain reported among professional drivers, including professional truck drivers and police officers (Gruevski et al., 2016; Kim et al., 2016).

*Corresponding author
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A study of 8,447,167 person-years of data between 1998 and 2006 for military members in a vehicle operator occupation indicated that the back pain incidence rate was 54.2 per 1,000 person-years (Knox et al., 2014). Occupational factors may also predispose workers to risks of lower back pain (Sowah et al., 2018).

2-Automobile seat backrest inclination and impact on back pain

The need to prevent causes of occupational safety hazards continues to be a focus of research in most occupations including sedentary tasks of driving (Gyi et al., 1998; Kim et al., 2016). Lumbar support has been associated with decreased reports of low back pain during driving exposures and sedentary tasks (De Carvalho and Callaghan, 2012; Bouwens et al., 2018; Wang et al., 2018). The posture of a driver is one of the most important issues to consider in a design process of a vehicle (Gyi and Porter, 1998; Blood, et al., 2015; Kim et al., 2016; Varela et al., 2019). An automobile seat design includes shape and backrest inclination, which affect seating posture (Chen et al., 2005; Filtness et al., 2014; Guo et al., 2016). Efforts of several car seat manufacturers is focused on developing new seats with the need to increase options such as lumbar support, seat height, backrest inclination, temperature and more for comfort of the driver while minimizing musculoskeletal disorders associated with driving. Comfort is a measure in seat design that integrates positive tactile experiences and a sense of well-being with health and safety (Kamp, 2012). Discomfort is mainly associated with biomechanical factors, which affect muscular and skeletal systems impacted by design parameters including duration of task, seat and backrest angles (Zhang et al., 1996; Sammonds et al., 2017). Previous studies by Anderson et al. (1974) and Hosea et al. (1986) indicated a decrease in myoelectric muscle activity with increase in backrest inclination of 90 to 120 degrees in all areas of the spine. However, Hosea et al. indicated that activity levels increased in the lumbar erector spinea muscles with a lumbar back support taller than 7cm. Studies by Joxsson and Jonsson, (1975), indicated that activity in the *latissimus dorsi* was small and only occurred in ipsilateral rotation of the steering wheel in functions of upper limb muscles in car driving. The study however did not consider myoelectric activity at different backrest inclinations. Studies by De Carvalho and Callaghan, (2012) only focused on lumbar support height and the impact on the vertebral discs. Impact of seat backrest angle on *latissimus dorsi* muscle activity, was also not investigated in their studies. Recent studies have focused on discomfort ratings due to lumbar postures and thoracic support, however muscle activity was not determined (Gruevski et al., 2016). Evidence of epidemiological studies to support optimal seat design, particularly for use of lumbar support, seat inclination and prevalence of clinically significant low-back pain among drivers is still inconsistent (Chen et al., 2005; Guo et al., 2016). The novelty of this study is that the analysis of the myoelectric readings is new fundamental information to gaining an insight on impact of seat back rest inclination on risk of pain and injury of the *Lattissimus Dorsi* in performance of a sedentary driving task. Prior studies have not done myoelectric analysis of fatigue in this muscle as it relates to driving posture.

The focus of this study was to determine the effect of backrest inclination on the myoelectric activity of the trunk muscle *latissimus dorsi* in a sedentary driving posture at two backrest inclinations (90 and 100 degree) to the seat.

3-Driving simulation experiment

A seat manufactured for 2009 “Subaru Legacy” car with adjustable backrest features was used to perform the driving task with two backrest angles. The seat was cushioned with a layer of soft foam to increase comfort as it also reduced pressure on electrodes attached to participant. A driving simulator (CH driving simulation system, (www.chproducts.com)) was used in the driving task. The task was operated via a computer interface for 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 for processing and storing data. 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 approximately 20 millimeters. Muscle activity is theoretically computed as a "root mean square" (RMS) electrical signal from the muscle activity (Waly et al., 1985; McCary et al., 2018). The RMS represents the square root of the average power of the EMG signals recorded from muscle contractions for the driving simulation period. The expression for determining the electrical activity from EMG software is as follows:

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

Note: Where RMS is root mean square, m is muscle activity and T is total time.

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, when the muscle of a subject develops muscle pain and strain while performing a given task (Zennaro et al., 2003; Dimitrov, and Dimitriva, 2003, Barszap, et al., 2016; McCary, et al., 2018).

3-1-Study population

Twenty-one participants without any history of back pain were, randomly selected to participate in the study. There were 15 males in the group with a mean age of 23.9 years, (standard deviation of 5.06) and 6 females with a mean age of 22.1 years (standard deviation of 2.04). The average height of men was 165 cm; while that of women was 157 cm. Participants were selected from a university student population.

3-2-Study procedure

The driving simulating workstation (Figure 1) was setup in the laboratory for the backrest study. At the start of each driving session the participants completed a consent form for approval to partake in study. Each participant's anthropometric and demographic data was recorded. Participants wore very light clothing and their driving postures were measured using a Goniometer. Each participant was trained on how to operate the driving simulator prior to the experiment. Training focused on guiding participants to be familiarized with navigation of virtual driving, and use of the controls and accessories on the simulator, such as blinkers, shifting gear, checking mirrors and pedals.

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 with 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. The electrodes were attached along the muscle fibers of the *latissimus dorsi*, with each pair at a distance of 2 centimeters. 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. Seat backrest was kept constant at 90-degrees to the seat base in the study for duration of 1-hour driving simulation. The participants were scheduled for the second part of the study on another day after resting back muscles. The seat backrest inclination was set at 100-degrees in the second session and simulation lasted for 1-hour. All data was collected at regular iterations and were then integrated for the duration of the experiment. Computerized EMG signal processing technique was used to analyze the data. The analysis was done with "Ariel Performance Analysis System (APAS)" software. 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}.

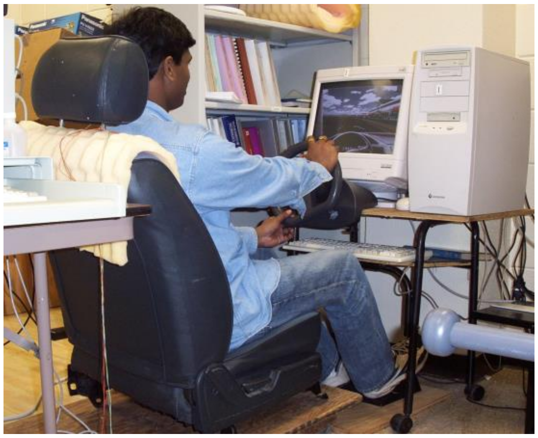

Fig 1. Participant in experimental session

4-Results

Integrated EMG (IEMG) signal processing technique was used in the data collection. 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 in relation to the backrest inclinations. Measurements at 90-degree and 100 degree backrest angles were as indicated in Table-1. An analysis of variation (ANOVA) of the RMS means for both angles, was performed for all data set using an alpha (α) = 0.05. Graph of data is indicated in figure-2.

Table 1. Root mean square and IEMG values

Time (minutes)	**RMS-90 (mV/sec) Degrees**	**RMS-100(mV/sec) Degrees**
0	1.24	0.92
5	1.09	0.90
10	1.01	0.87
15	0.99	0.80
20	0.91	0.59
25	0.89	0.54
30	0.73	0.50
35	0.71	0.49
40	0.69	0.48
45	0.64	0.40
50	0.60	0.40
55	0.44	0.34
60	0.30	0.23
Average	**0.79**	**0.57**

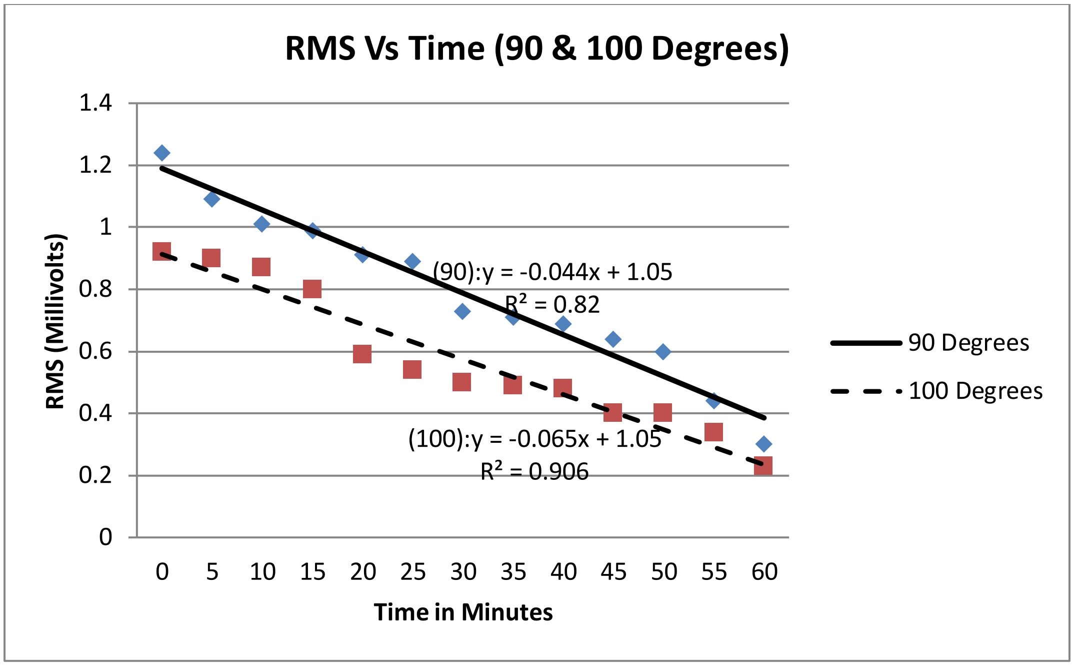

Fig 2. Graph of RMS-Time for backrest angle 90 & 100 degrees

5-Discussion

The ANOVA test indicated a significant difference between the RMS values (Table-1) at 90-degrees and 100-degrees backrest angles at *p=0.01*. Graph of RMS values at 90-degrees had a negative slope of -0.044 millivolts per second (mV/sec) indicating the decrease in muscle activity in myoelectric signals from the muscle for simulation duration. Graph for the 100-degrees angle also had a negative value of -0.065 millivolts per second (mV/sec) indicating a slightly lesser muscle activity when the backrest was at this angle. The two data sets indicate that muscle activity did start at a higher value, but decreased over time. However, the slopes indicate that there was an overall decreased muscle activity at 100-degrees inclination compared to the 90-degree inclination. The results differ from studies by Anderson et al., (1974) that only analyzed myoelectric muscle activity with lumbar support angle for *erector spinea* muscles. Results in this study differed from Joxsson and Jonsson, (1975) which also indicated that the *latissimus dorsi* was active only to a small extent in steering during driving, but did not include seat back inclination in relation to risk of fatigue or back pain. This study also differed from Hosae et al., (1986) in their study that indicated that a lumbar support greater than 7 centimeters in height increased the muscle activity of the *erector spinea* muscle. There is also a similarity with the previous study by De Carvalho and Callaghan, (2012) in identifying the impact of lumbar support on the posture. However, it differed from this study which focused on *latissimus dorsi* muscle activity at different backrest inclinations. In recent studies of Gruevski et al., (2016) only discomfort ratings were used for lumbar posture in simulated driving for police officers who spend extended periods in driving task. However, this study differs by using myoelectric activity of the *latissimus dorsi* muscle and a full (lumbar and thoracic) back support. The negative slopes indicate that muscles start at a high myoelectric activity and gradually decrease over time. It also indicates that 100-degree inclination may have less fatigue and risk of back pain impact on *latissimus dorsi* muscles over extended periods of driving compared to 90-degree backrest inclination. This study focused on impact of seat backrest lumbar and thoracic support on the *latissimus dorsi* muscle. The myoelectric muscle activity decreased with increase in seat backrest angle.

6-Conclusion

This study focused on the myoelectric activity of the *latissimus dorsi* muscle to determine backrest inclination impact on musculoskeletal seat posture and potential for back pain. Results therefore indicate that:

1. Prolonged driving periods will affect the *latissimus dorsi* muscles increasing risk of the muscle fatigue and back pain as indicated by the decline in myoelectric activity.
2. Seat backrest inclination of 100-degrees may have a lesser negative impact on the *latissimus dorsi* muscle and an automotive driver's risk of back pain over extended driving periods.

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