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Effects of Posture Orientation and Vibration on Trunk Muscles for Bike Riders Using Electromyography

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Abstract

Daily commute on bike has proven to be an economical way of transportation in many countries. Muscle fatigue significantly contributes to lower back pain and injuries, particularly among motorbike riders. This study focuses on investigating the phenomenon of muscle fatigue utilizing electromyography (EMG) to analyze and understand the impact of muscle fatigue on two major muscles responsible for maintaining posture while riding a bike. The mean power frequency is used as a measuring index, which indicates muscle fatigue. To evaluate the influence of different factors, the study focuses on two distinct trunk orientations: 90° and 60°. These orientations are chosen to simulate common riding positions adopted by motorbike riders. Additionally, the study examines the impact of vibration on muscle fatigue by comparing conditions with and without vibration. It is observed that the vibration and the 60-degree trunk angle are significant factors in inducing fatigue, as evidenced by a greater slowdown of mean power frequency for both the erector spinae and multifidus muscles ($P<0.05$). These findings highlight the importance of considering trunk angle and vibration exposure when addressing muscle fatigue in motorbike riders. Understanding these specific

factors can inform the design of ergonomic interventions, such as optimizing riding postures and incorporating vibration-dampening mechanisms, to minimize the detrimental effects of muscle fatigue.

Keywords
Ergonomics, Human Factors, Electromyography, Muscle Fatigue and Bike riders.

1. Introduction
Fatigue is a common non-specific symptom experienced by many people and is associated with many health conditions. Often defined as an overwhelming sense of tiredness, lack of energy, and feeling of exhaustion, fatigue relates to a difficulty in performing voluntary tasks (Wan et al.,(2017). Muscle fatigue is defined as a decrease in maximal force or power production in response to contractile activity (Gruet et al., 2013). The response has been quantified by researchers using many methodologies. Among such methodologies, EMG has been widely used as a measure of the index for muscle activity analysis. Electromyography analysis can shed light on the onset and development of muscular fatigue as well as the timing and intensity of muscle activation(Gandevia, 2001). EMG has also been used in different aspects of Ergonomics (Aoi et al., 2015; URYU et al., 2014; YAMAGUCHI et al., 2014) . There are different methods used in measuring muscle fatigue through EMG such as FFT (fast Fourier transform) and MTM (method time measurement) technique (Graham et al., 2015; Rampichini et al., 2020; Roldán-Jiménez et al., 2018). FFT analysis involves fixed electrodes on muscle under observation along with other parameters, including time and frequency. The results are then compared with an index formally measured for individual values for graphical use of finding fatigue level in representation (Remes and Eskelinen, 1994; Roldán-Jiménez et al., 2018) .

1.1 Objectives
This research study focuses on the effect of posture and vibration on bike riders. The muscle fatigue induced under different conditions has been elaborated through the use of mean power frequency which has been used as an index of fatigue. In order to achieve these objectives an extensive literature review has been done which focuses on different aspects of muscle fatigue and musculoskeletal disorders.

2. Literature review
Measuring muscle fatigue is important and can be used to diagnose and treat conditions such as muscle disorders, chronic fatigue syndrome, and other neurological conditions (Rasool et al., 2012; Remes and Eskelinen, 1994). It can also help improve the performance of athletes and can be used to develop programs and routines to help enhance the stamina and performance of athletes (Roy et al., 1989; Urabe et al., 2005). A better understanding of muscle fatigue related to posture is important for enhancing workplace comfort and enhancing the performance and productivity of both blue color and white color workforce. Prolonged standing or sitting can cause muscle-related injuries (Glousman, 1993; YOON et al., 2015) Have studied the effect of muscle fatigue in motorcycle racers/users. Delivery workers spend long hours in sitting postures on motorbikes which causes lower back pain and injuries (Lancere et al., 2023). Motorbike is a major source of commuting in developing countries like Pakistan and India (Gefen, 2002; Waters and Dick, 2014). Long riding hours cause significant fatigue and low back pain (Gefen, 2002).

Vibration is another source of muscle fatigue (Torrado et al., 2021). Motorbike riding causes whole-body vibrations which are another significant source of muscle fatigue, particularly the lower trunk muscle of the erector spinae and multifidus (Kalc et al., 2020; Memon et al., 2013; Starkey, 2016; Starkey et al., 2021). This fatigue also depends on the age of the automobile, engine size, body size, type of seat, and type of suspension (Otadi et al., 2019) . Professional motorcycle riders like traffic police who ride for extended hours, approximately 5.64 h per day, are more at risk of discomfort and poor performance due to over-exposure to vibration (Shivakumara and Sridhar, 2010). The exposure of the human hand-arm in an active state to vibration can cause changes in muscular tendons and elevated fatigue levels. Studies conducted in this respect contribute to a better understanding and optimal results (Halsberghe et al., 2016; Jelačić and Pikula, 2019). The transmission of vibration from the machine to the whole body is through the subject itself affecting comfort level and normal body function (Koyano et al., 2003). For fatigue investigation due to engine vibration, the connectors between the frame and engine are examined systematically as these connections are an integral part of a component model (Balasubramanian and Jagannath, 2014). This study is explicitly arranged to establish an optimal relation between vibration and muscle fatigue.

Previous studies conducted in industries have explored the link between trunk positions and trunk fatigue; however, causes and suggestions for the rehabilitation and optimization of low back pain associated with driving motorbike due to vibration, different postures, and seat materials needs to be discussed because of its greater usage in developing countries. The purpose of this study is to offer better knowledge concerning muscle fatigue while sitting, riding a motorbike, or sitting that involves vibration. Activities like bike riding and sitting in different postures occupy a fair amount of time in our routine life.

3. Materials and Methods

Subjects: Thirteen male subjects participated in this research (mean age between 15 to 40, weight, 50-70 kg, stature = 179 SD±3cm, and BMI=22.5 SD±2.5). The exclusion criteria for this study include subjects with no back pain history and no other musculoskeletal skeletal disorders. The subjects included all were volunteered.

3.1 Muscle selection and locations of electrodes

Tri-polar EMG (Ag-Ag/cl) electrode configuration was used with an inter-electrode distance of 20mm. Before starting the skin was cleaned and shaved with alcohol. The skin was left to dry for one minute to reduce the impedance and then pasted with the conducting gel on the electrodes. EMG was recorded from two muscles erector spinae and multifidus. To minimize the signals between the muscle and the electrode, electrodes were placed carefully on the muscles. The sensor location terms and conditions recommended made by SENIAM (Bhattacharya, 2014). For erector spinae, the electrodes were placed on one finger with medial from the line from the posterior spinae superior to the lowest point in the ribs (rib 6 or 7). For multifidus, electrodes need to be placed on and aligned with a line from the caudal tip posterior spina iliaca superior to the interspace between l1 and l2 interspace at the level l5 spinous process (i.e. about 2-3cm from the midline.

3.2 Apparatus

A two-channel EMG system (Thought Technology Ltd.8205) was used to acquire EMG signals with a sampling rate of 2048Hz. The (Ag-Ag/cl) tri-polar configuration for each was used with an electrode size of 10mm and an inter-electrode distance of 20mm. A biograph software was used to record the signals.

3.3 Pre-processing EMG signals

The EMG signals were sampled at 2048Hz, and bandpass filtered with cutoff frequency 10-500Hz. The muscles were activated intermittently while driving a motorbike.

3.4 Experimental Design

The experiment consists of riding tasks in the ignition and non-ignition states with sitting positions at 90-degree and 60-degree angles. Trunk orientation and vibration time are independent variables. A total of 13 participants took part in the experiment. Subjects remained in the test position for 10 minutes in both vibration and non-vibration modes. Sitting positions tried during driving were 90 degrees and 60 degrees. The time for performing experiments was 9 AM to 10 AM. To minimize the difference in pre-experimental fatigue every performing individual was assumed to have taken rest/sleep for at least 6 hours before taking part in the experiment (Figure 1 and Figure 2).

Figure 1. Sitting position at 90 degrees

Figure 2. Sitting position at 60 degrees

4. Procedure

EMG device with sensor electrodes, bike, and biograph was used to gather the required data. A total number of 13 motorbike riders took part in the experiment to identify the concerned muscles in the vital part of the process. SENIAM muscle indicator guideline was used to identify the erector spinae and multifidus muscle. For effective transmission of signals, every individual skin spot where the patch was to be pasted was shaved and rinsed with water and gelled. Single route same bike was used for recording uniformly. All trails were taken between 9 AM to 10 AM hence minimizing the effect of the time of the day on EMG and other related parameters. All subjects were trained and guided to drive at 90-degree and 60-degree angles focusing on erector spinae and multifidus muscles.

5. Results

A two-sample t-test was performed to check if there is a significant difference between fatigue states at different states of ignition and bike riding positions. It was observed that there was a significant difference between the erecter spinae between the conditions of all the values as shown in the table. However, it was observed that there is no significant difference between the mean power frequencies of 60-degree-on and 60-degree-off positions both conditions for ignition-off conditions (Table 1).

Table 1. Significance of Posture on Erector Spinae Muscle

Erector spinae	Erector spinae	Þ-value
60 degrees on	60 degrees off	0.3071592
60 degrees on	90 degrees on	*0.0249053
60 degrees on	90 degrees off	*0.0000705
60 degrees 0ff	90 degree on	*0.0006768
60 degrees off	90 degrees off	*0.00000000005
90 degree on	90 degrees off	*0.0000003

The same test for performed for the multifidus muscle for the same conditions. It was observed that there was a significant difference between the multifidus between the conditions for all the values as shown in the table. However, it was observed that there is no significant difference between the mean power frequencies of both 60-degrees-on, 60-degrees-off, and 60-degrees-on and 90-degrees-on position conditions for ignition-off conditions (Table 2).

Table 2. Significance of Posture on multifidus muscles

Multifidus	Multifidus	Þ-value
60 degrees on	60 degrees off	0.174139
60 degrees on	90 degrees on	0.5570461
60 degrees on	90 degrees off	*0.0000092
60 degrees 0ff	90 degree on	*0.0178376
60 degrees off	90 degrees off	*0.000000001
90 degree on	90 degrees off	*0.0000002

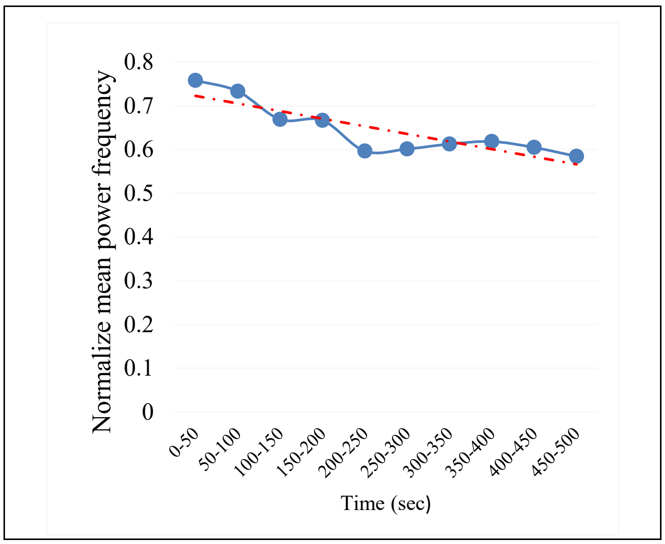

Figure 3(a). Normalized Mean Power Frequency without vibration 90 degrees for erector spinae

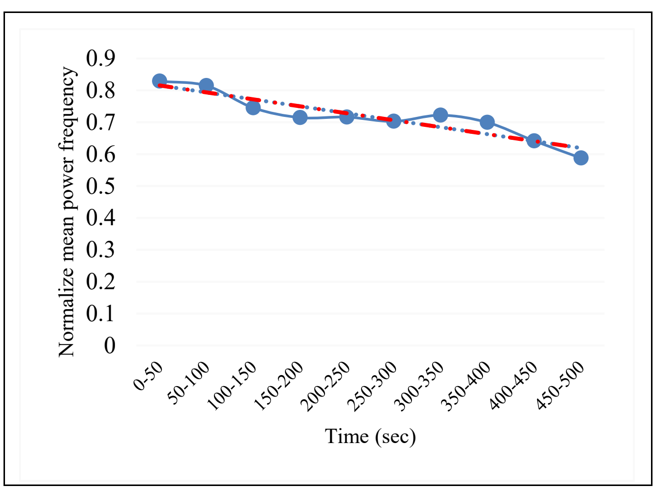

Figure 3(b). Normalized Mean Power Frequency without vibration 60 degrees for erector spinae

Figure 3 (a, b) shows that mean power frequency is declining with time. This is consistent with the hypothesis that muscle fatigue in erector spinae is increasing at a back angle of a 60-degree angle. This is also indicative that posture plays a significant role in muscle fatigue. The mean power frequency for erector spinae at 90-degree posture is 0.85 which decreases to 0.69 at 60-degree. Moreover, vibration also remained a key variant causing fluctuation in fatigue.

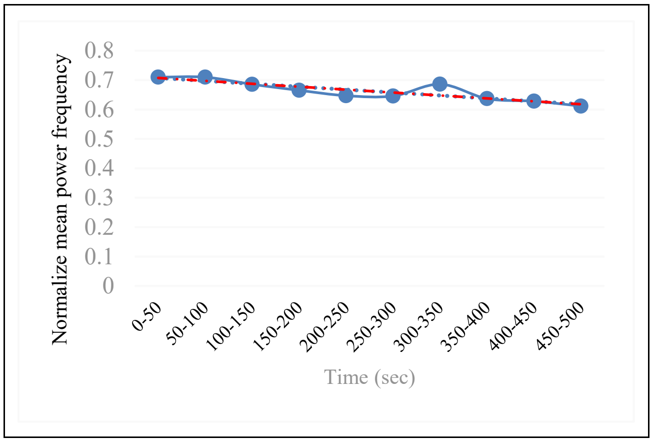

Figure 4(a). Normalized Mean Power Frequency vibration 90 degrees for erector spinae

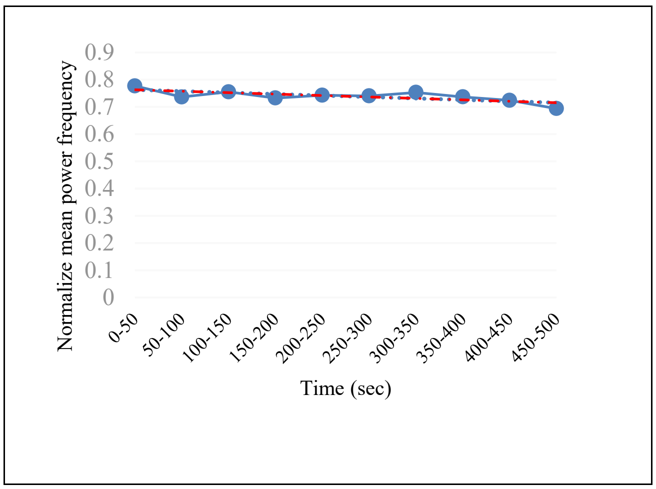

Figure 4 (b). Normalized Mean Power Frequency vibration 60 degrees for erector spinae

Figure 4 (a, b) shows the slope of the normalized mean power frequency. The fatigue in this case is caused by a posture of 90-degree and 60-degree and with motorbike with vibrations is much steeper than without vibration for the same posture suggesting that vibration has an adverse effect on muscle strength. The fatigue increases with time at a faster pace with vibration than without vibration. The fatigue value shown by the decreasing Normalized mean power frequency decreases from 0.73 to 0.58. This value is less than 0.85 to 0.69.

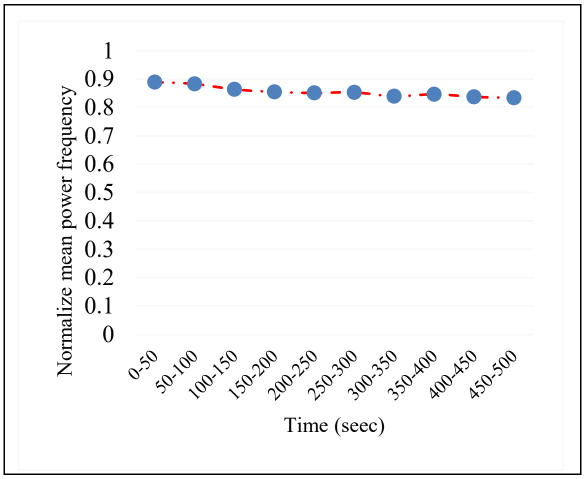

Figure 5(a). Normalized Mean Power Frequency without vibration 90 degrees for multifidus

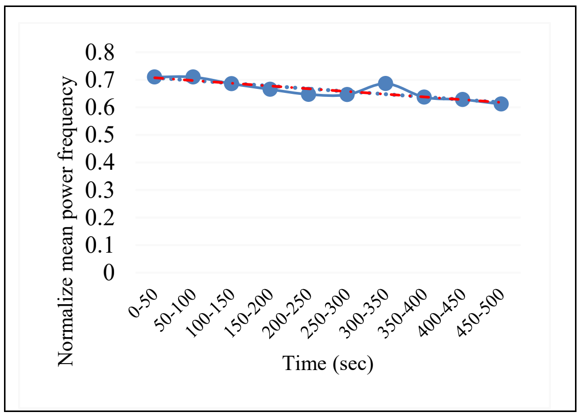

Figure 5(b). Normalized Mean Power Frequency without vibration 60 degrees for *multifidus*

Figure 5 (a, b) shows that the multifidus muscle exhibits similar patterns to the spinae erector muscle. Over time muscle fatigue increases whereas the normalized mean power frequency decreases from 0.88 to 0.83. This effect is even more prominent when posture is at 60 degrees as the combined effect of posture and vibration is straining the muscle more. The value for normalized mean power frequency changes from 0.71 to 0.61.

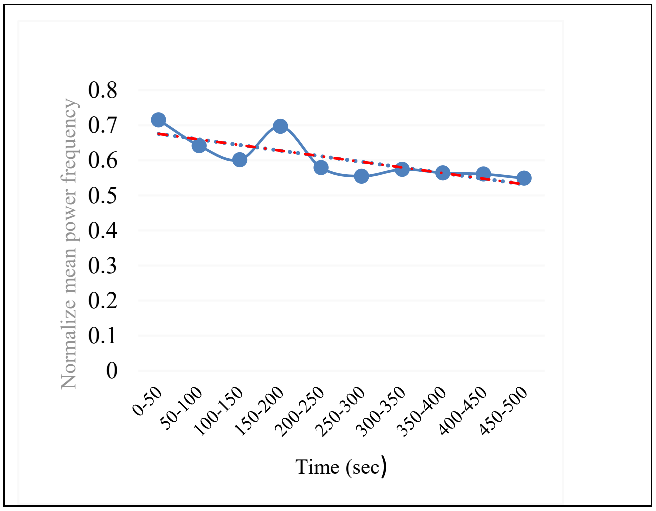

Figure 6(a). Normalized Mean Power Frequency vibration 90 degrees for multifidu*s*

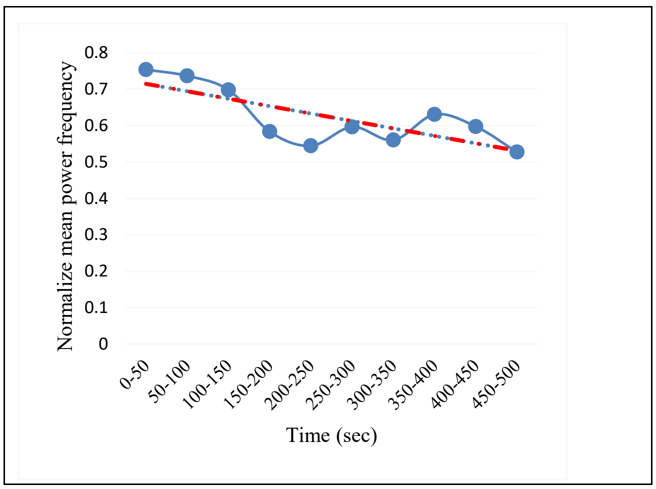

Figure 6 (b). Normalized Mean Power Frequency vibration 60 degrees for multifidus

Figure 6 (a, b) shows that muscle fatigue in the multifidus muscle is more in the state where the posture is also affecting the muscle that it reduces from 0.7 to 0.6. Whereas in the state of 60-degree posture, the slope is even steeper from 0.78 to 0.5.

The comparative decline in graph slope between vibration and non-vibration states shows a decrease in physical fatigue level in the non-vibration state in all postures (90 degrees, 60 degrees) and both muscles. The mean power frequency on the y-axis is the bound intercept showing the slope of the equation for 10 minutes (the equation of slope includes vibration and non-vibration for both muscles on both condition 60 and 90 degrees)

Table 3. Comparison of Normalized Mean Power Frequency slopes at posture angle 60° and 90° and vibration on and vibration off.

For erector spinae	90-degrees	60-degrees
Vibration	$y = -0.0174x + 0.7401\ R^2 = 0.7592$	$y = -0.0218x + 0.8371\ R^2 = 0.8586$
Non vibration	$y = -0.0035x + 0.8953\ R^2 = 0.5637$	$y = -0.0053x + 0.7683\ R^2 = 0.5404$
For multifidus	90-degrees	60-degrees
Vibration	$y = -0.016x + 0.6919\ R^2 = 0.6442$	$y = -0.0204x + 0.7352\ R^2 = 0.5938$
Non vibration	$y = -0.0057x + 0.8866\ R^2 = 0.8738$	$y = -0.0099x + 0.7173\ R^2 = 0.7733$

Table 3 shows the slopes of the different settings of the two muscles. The slope reading shows that sitting posture at 60 degrees induces higher muscle fatigue. It is also evident that when the ignition is on, the effect of vibration causes the muscle to fatigue more quickly over time. The normalized power frequency slope is at -0.0174 for 90-degree for erector spinae and -0.016 at 90-degree for multifidus, the slope decreases to -0.0218 and -0.024 for erector spinae and multifidus at 90-degree respectively. Similarly for erector spinae the worst conditions where the posture is at 60 degrees or similar the slope drastically descends from -0.0053 to -0.0218.

6. Discussion

Muscle fatigue is a significant cause of lower back pain. Long bike hours cause significant stress on lower back posture and also plays an important role in causing stress and injuries to trunk muscle and in particular lower muscles [31]. Posture affects the fatigue levels in bike riders. The statistical analysis of the mean power frequency indicates that the posture of 60 degrees inclination produces more fatigue than sitting the driver at 90 degrees on motorbikes. Further studies on the level of inclination or providing back support could further reduce the stress on the lower back muscles of the multifidus and erector spinae.

Vibration increases the stress on the erector spinae and multifidus thus increasing fatigue. In this study, we have found that the effect of vibration is significant and plays a major role in causing lower back injuries. The effect of vibrations can be reduced by design optimization of the seat and bike to reduce bike vibrations. However, more studies are needed to find the correlation between vibration and sitting posture.

The scope of this study is limited by the number of participants and the time in which this study was performed. Future research can be carried out by including other lower back muscles and shoulder and hands muscle to reduce stress on healthcare systems. The effect of bad infrastructure needs to be investigated in future studies to find the relationship between lower back injuries in bike riders and bad infrastructure.

7. Conclusions

Muscle fatigue is induced because of a lot of external and internal factors. This is also because of the load on different muscles for different durations. These factors contribute to lower back problems which put a lot of stress on the healthcare system. Bike riders are one group of society who are much more affected by lower back injuries. In this study, we have tried to find the effect of posture on the motorbike and the effects of vibration on the lower back muscle erector spinae and deep muscle multifidus of bike riders. We have used the SEMGs method for calculating the mean power frequency which indicates the fatigue in the muscles. The experimental setup was conducted on 13 subjects with different professions but who use a motorbike daily. It was evident that both vibration and posture affect muscle fatigue in both of the muscles.

This is followed by a statistical analysis which shows the correlation between the different variables of the experimental setup. In this study, we have used the Mean Power frequency as the indicator for fatigue in the two main lower back muscles, erector spinae, and multifidus. The SEMG is then recorded and using the fast Fourier transform it is converted from the time domain to the frequency domain. A t-test was performed to find out whether there is any correlation between the two experimental setups i-e vibration and posture that were designed to experiment. The experiment identified that a sitting posture (90 degrees) is more optimal than (60-degrees) regarding fatigue reduction. The vibration and non-vibration state plays an essential role in muscle fatigue as fatigue readings recorded during vibration were higher than the non-vibration state.

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Biographies

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