Whole body vibrations on the low back using a suspension versus non-suspension seat post during off-road cycling

by Laura Michelle Stanley

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Industrial and Management Engineering
Montana State University

Abstract:
Mountain bikes were introduced nearly two decades ago and have since become the number-one type of bicycle sold in America. Nearly every major bicycle manufacturer now offers many types of suspensions systems. The rationale behind a suspension system is that it provides: (a) increased comfort levels, (b) decreased fatigue, and (c) fewer injuries. However, many of these claims are purely anecdotal and are not based on scientific evidence. Accordingly, more quantitative measures need to be taken to assess the effect of bicycle shock absorption systems on skeletal loading, muscle fatigue, and potential injury. The objective of this study was to compare the effects of a suspension and a non-suspension seat post on whole body vibration energy and muscle activity in the lumbar and abdominal muscles during off-road cycling in recreational cyclists. A randomized block ANOVA with repeated measures was used to document the effects of seat condition over one hour riding in off-road conditions. Acceleration of the seat and EMG activity of abdominal and low back muscles were recorded. The findings of this study indicate that there were no significant ($p > 0.05$) differences in muscle activity (peak amplitude, median frequency, and 95% of frequencies) between the seat post treatments. The suspension seat post did not significantly reduce total vibration energy ($p = 0.816$) or the total vibration energy ($p = 0.412$) during impact with the simulated obstacles, though the suspension seat post significantly ($p = 0.02$) reduced peak accelerations by up to 27%. Furthermore, an early indication of muscular fatigue was observed in the low back and abdominal muscle regions during the riding sessions based upon EMG frequency analysis. A 10% decrease in median frequency was observed during both riding sessions. This study suggests that the suspension seat post's ability to reduce peak accelerations will prolong the time at which the onset of muscular fatigue occurs. It is believed that muscle fatigue of the core muscles may contribute to low back pain. Any delay in the reduction in muscle power might result in less or no low back pain. Additionally, reducing peak accelerations will place less strain on the spinal structures with the anticipation of reducing any cervical, dorsal, or lumbar back pain or injury. As an off-road cyclist, the Rock Shox suspension seat post would be health beneficial because of its characteristics in reducing peak accelerations.

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APPROVAL

Of a thesis submitted by

Laura Michelle Stanley

This thesis has been read by each member of the thesis committee and has been found to be satisfactory content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Mountain bikes were introduced nearly two decades ago and have since become the number-one type of bicycle sold in America. Nearly every major bicycle manufacturer now offers many types of suspensions systems. The rationale behind a suspension system is that it provides: (a) increased comfort levels, (b) decreased fatigue, and (c) fewer injuries. However, many of these claims are purely anecdotal and are not based on scientific evidence. Accordingly, more quantitative measures need to be taken to assess the effect of bicycle shock absorption systems on skeletal loading, muscle fatigue, and potential injury. The objective of this study was to compare the effects of a suspension and a non-suspension seat post on whole body vibration energy and muscle activity in the lumbar and abdominal muscles during off-road cycling in recreational cyclists. A randomized block ANOVA with repeated measures was used to document the effects of seat condition over one hour riding in off-road conditions. Acceleration of the seat and EMG activity of abdominal and low back muscles were recorded. The findings of this study indicate that there were no significant ($p > 0.05$) differences in muscle activity (peak amplitude, median frequency, and 95% of frequencies) between the seat post treatments. The suspension seat post did not significantly reduce total vibration energy ($p = 0.816$) or the total vibration energy ($p = 0.412$) during impact with the simulated obstacles, though the suspension seat post significantly ($p = 0.02$) reduced peak accelerations by up to 27%. Furthermore, an early indication of muscular fatigue was observed in the low back and abdominal muscle regions during the riding sessions based upon EMG frequency analysis. A 10% decrease in median frequency was observed during both riding sessions. This study suggests that the suspension seat post's ability to reduce peak accelerations will prolong the time at which the onset of muscular fatigue occurs. It is believed that muscle fatigue of the core muscles may contribute to low back pain. Any delay in the reduction in muscle power might result in less or no low back pain. Additionally, reducing peak accelerations will place less strain on the spinal structures with the anticipation of reducing any cervical, dorsal, or lumbar back pain or injury. As an off-road cyclist, the *Rock Shox* suspension seat post would be health beneficial because of its characteristics in reducing peak accelerations.

CHAPTER 1

INTRODUCTION

Mountain bikes were introduced nearly two decades ago and have since become the number-one type of bicycle sold in America (Berry and Woodward, 1993). This popularity has been accompanied by industry wide research and development, which has in turn produced numerous technological innovations. For example, nearly every major bicycle manufacturer now offers many types of suspensions systems. The rationale behind a suspension system is that it provides: (a) improved control of the bicycle, (b) increased comfort levels, (c) decreased fatigue, (d) fewer injuries, and (e) increased enjoyment. However, many of these claims are purely anecdotal and are not based on scientific evidence. Accordingly, more quantitative measures need to be taken to assess the effect of bicycle shock absorption systems on skeletal loading, muscle fatigue, and potential injury.

The possibility that suspension systems can prevent injuries and/or reduce fatigue is of paramount importance. According to Berry and Woodward (1993), 30-70 % of cyclists suffer from cervical, dorsal, or lumbar back pain. Although the current scientific evidence is not conclusive, a recent review of epidemiological and laboratory studies by Wilder and Pope (1996) indicates that a relationship exists between whole body vibrations and low back pain. Vibrations at lower accelerations have been suggested to cause fatigue failures in the discs of the spine, while large vertical accelerations cause spine fractures during repetitive compression (Sandover 1981, 1983). If vibration is reduced with a suspension system it may be possible to decrease the risk of low back pain and injury during cycling.

The lumbar and abdominal muscles are used to stabilize the pelvis on the bicycle seat while in a bent over position and are a crucial component to efficient power transfer between the upper and lower body during cycling. Hence, if the lumbar and abdominal muscles begin to fatigue during off-road cycling, a reduction in muscle power should result. This reduction in muscle power induces discomfort and pain, and, in the long term, is believed to contribute to low back pain, hence making the quantification of fatigue extremely relevant.

Objective Statement

The objective of this study is to compare the effects of a suspension seat post and a non-suspension seat post on whole body vibration energy and muscle activity in the lumbar and abdominal muscles during off-road cycling in recreational cyclists.

Hypotheses

The following null hypotheses will be tested:

1) There is no significant difference in whole body vibration energy of acceleration (root-mean-square) or peak acceleration during non-suspension seat post and suspension seat post use:

$$H_o: u_1=u_2$$

H_a: $u_1 \neq u_2$

Where u_i, i = seat post condition (1 = non-suspension seat post, 2 = suspension seat post).

2) There is no significant difference in whole body vibration energy of acceleration (root-mean-square) or peak acceleration during either non-suspension seat post or suspension seat post use over time:

H_o: $u_1 = u_2 = u_3 = u_4$

H_a: $u_1 \neq u_2 \neq u_3 \neq u_4$

Where u_i, i = cycling time (1 = 15 minutes of cycling duration, 2 = 30 minutes cycling duration, 3 = 45 minutes of cycling duration, 4 = 60 minutes of cycling duration).

3) There are no significant differences in EMG activity (peak amplitude, median frequency, 95% of frequencies) of the core muscles, lumbar and abdominal muscles, during non-suspension seat post and suspension seat post use:

H_o: $u_1 = u_2$

H_a: $u_1 \neq u_2$

Where u_i, i = seat post condition (1 = non-suspension seat post, 2 = suspension seat post).

4.) There are no significant differences in EMG activity (peak amplitude, median frequency, 95% of frequencies) of the core muscles, lumbar and abdominal muscles, during non-suspension seat post and suspension seat post use over time:

$$H_o: u_1=u_2=u_3=u_4$$

$$H_a: u_1 \neq u_2 \neq u_3 \neq u_4$$

Where u_i, i=cycling time (1=15 minutes of cycling duration, 2=30 minutes cycling duration, 3=45 minutes of cycling duration, 4=60 minutes of cycling duration).

Delimitations and Limitations

There are two primary delimitations to this study. First, the study was delimited to female recreational cyclists. Recreational cyclists are those who ride occasionally, approximately one to five hours per week, and are not competitive cyclists. Second, all testing was conducted under simulated conditions. These conditions were designed to simulate off-road cycling, but exact off-road conditions were near impossible to mimic. The major limitations of this study are due to the equipment used to measure muscle activity. Since the electromyogram (EMG) electrodes were applied to the surface of the skin, movement of the equipment on the skin was an inherent error, although every precaution was taken to minimize this error. Also, this study was limited to only a small group of female recreational cyclists. Other groups, such as male cyclists, professional cyclists, beginner cyclists, etc. were not included.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this study was to compare whole body vibrations sustained to the lower back during suspension seat post and non-suspension seat post use during off-road cycling. No known studies have analyzed this particular situation in the off-road cycling setting, yet many studies have been conducted on the impact of vibrations on the lower back in an occupational setting. The following presents a background of characteristics of whole body vibration in the human body, studies on whole body vibration's effects on the lower back, measurements and quantifications of vibrations, muscle activity during exposure to vibrations, and the International Standard Organization (ISO) standards and guideline recommendations.

Characteristics of Whole Body Vibration in the Human Body

Whole-body vibration is known to affect human performance, health, and safety; so far, research is lacking a clear source of which outcome variables to measure when assessing whole-body vibration exposure. Current literature on the effect of prolonged exposure to whole-body vibration demonstrates the increased risk of developing back disorders. In the occupational setting, whole-body vibration usually occurs in combination with other risk factors, such as poor posture and prolonged sitting.

The following vibration factors influence the potential for injury to the human: frequency, amplitude, acceleration, duration and direction of vibration, contact of vibration to body, body posture and muscle tension. Of these, the main parameters are the frequency acceleration, velocity, and displacement of the vibration. When the human body is exposed to vibration some kinetic and potential energy is absorbed by the body's mechanized system, resulting in a dampening and loss of potential energy. When the transfer of kinetic energy to potential energy occurs, dampening by the body's tissues and organs and the muscle surrounding the tissues and organs compensates by causing voluntary and involuntary contractions, potentially leading to localized muscle fatigue (Chaffin and Anderson, 1991).

When the frequency of excitation coincides with the natural frequency of the system or person amplitudes add together and create large oscillations, called resonance. Resonance can create potentially harmful stresses to the body, by increasing the spinal load, which results in fatigue injury of the passive spinal structures (Hansson and Holm, 1991) and a nutritional deficiency in the intervertebral discs (Dickerson, 1991). When the body is positioned vertically, vertical vibrations in the 5-10 Hz range generally cause resonance in the thoracic-abdominal system. Panjabi (1986) found that vibrations in the 2-30 Hz range are where most body tissue resonance occurs and that the average resonant frequency of the lumbar vertebrae is 4.4 Hz. Furthermore, it has been determined that vibrations between 2.5 and 5 Hz generate strong resonance in the vertebra of the neck and lumbar region with amplification of up to 240%. Between 4 and 6 Hz resonances are set up in the trunk with amplification of up to 200% (Ergonomics Technologies, http://www.ergotech.co.za/vib_wbv.htm, accessed April 2002). For other postures, different resonance frequencies are expected, but little is known.

The importance of resonance can be found in the situation of driving a vehicle, where spectral components of 4-8 Hz frequencies occur; these vibrations reach the operator's spine via the driver's seat, then the spine will most likely involuntarily respond by actually amplifying and exacerbating the effects of the whole body vibration exposure. Our body has the ability to compensate the exposure by selecting, accepting, and amplifying certain vibration frequencies over others. When the body proceeds to select, accept, or amplify certain vibration frequencies an exacerbation effect can occur, resulting in more harm to the body. Beyond resonance, whole-body vibration exposure can cause horizontal shifting, rotation, and torsional movements in the spinal segments resulting in wear and tear of the outer ring of the intervertebral discs. From years of exposure early degeneration of the discs can result.

Studies on Whole Body Vibration's Effects on the Lower Back

A study conducted at Projekt-WELLCOM in Germany found that the lower back is the most vulnerable part of the human body while riding a bicycle (Project-WELLCOM, http://www.projekt-wellcom.de/, accessed April 2002). Their data collection during the *Transalp Challenge R*ace, included 620 kilometers of 20,300 meters of vertical gain in eight days where they measured the gravitational forces (1 g = 9.8 m / sec^2) while riding on a fully suspended bicycle (suspension on front and rear) and a hard-tail bicycle (front suspension and no rear suspension). The researchers found that the full suspension bike reduced accelerations by 23.3 % compared to the hard-tail bicycle over the entire race. Furthermore, the subjects were experiencing shock impacts of 13.4 *g*'s while riding a hard-tail bike. In addition to measuring acceleration, the researchers split the body into two parts: upper body and the back. The researchers found that the upper body, including the arms, shoulders and neck, demonstrates a very strong support system of tissue and muscles resulting in a better suspension absorption system than the back. In the back, they found the erector spinae was used only to keep the spine straight while demonstrating no support of the vertebra. Because of the lack in support by the erector spinae, vibrations traveled directly into the lower back.

When comparing the *Rock Shox* suspension seat post and a fully suspended bicycle (suspension on front and rear) to a hard tail, Project-WELLCOM researchers found that the suspension seat post reduced shocks by up to 24% and 33%, respectively. On the downhill portions, where the riders were mostly standing and the legs do most of the shock absorption, the researchers saw a 20% reduction of vibration in the full-suspension versus the hard-tail. Furthermore, based on health-standards for shock forces, the hard-tail design exceeded recommendations by up to 30%.

The literature concerning the effects of whole-body vibration on the human body in an occupational setting are more numerous than in the sports setting. Frymoyer et al. (1980) found that patients experiencing low back pain tend to be employed in occupations that involve whole-body vibration exposure. Wilder and Pope (1996) also found a clear relationship between exposure to vibration and low-back disorders. Drivers of trucks (Kelsey and Hardy, 1975; Gruber, 1976; Frymoyer et al., 1980), of tractors

(Dupuis and Christ, 1972; Bovenzi and Betta, 1994), of heavy-equipment (Spear and Keller, 1976), of buses (Gruber and Ziperman, 1974; Kelsey and Hardy, 1975; Bpvenzi and Zadini, 1992), and airplane pilots (Fitzgerald and Crotty, 1972) have all experienced an increased risk of low back pain due to various frequencies and peak accelerations during vibration exposure.

Studies done by Kitazak and Griffin (1998), found a decrease in resonance frequency when subjects switched from an erect position to a slouching position, suggesting that the greater risk of back problems may be from the bending deformation of the spine when it is subjected to vibrations less than the 10 Hz range. Furthermore, it is well known that large vertical accelerations cause spine fractures, while smaller accelerations have been suggested to cause fatigue failures in the discs of the spine; these vibrations interfere with the nutrition of the disc, ultimately resulting in premature degenerative changes (Sandover 1981, 1983).

Dupuis and Zerlett (1987) reported that two-thirds of operators of earth-moving vehicles complained about spinal discomfort. Further examining these operators they found that operators with at least ten years of vibration exposure showed the occurrence of morphological changes in the lumbar spine much earlier than in non-exposed persons. Troup (1988) reviewed epidemiological and clinical studies and found that those who spend more than half of their working lives driving a motor vehicle were three times more likely to suffer back trouble than the rest of the population. Seidel and Heide (1996) further established that there is an increase in musculoskeletal disorders of the back after intense long-term exposure to whole-body vibrations.

Additional studies have been conducted in the attempts to reduce vibration exposure. Griffin (1978) reported that factors such as the suspension characteristics of the vehicle, nature of the road/track surface, vehicle speeds and the vibration attenuation characteristics of the seat influence vibration levels experienced by vehicle operators. Wasserman (1995) concluded that proper use of newer technologies such as active vibration control in conjunction with an improved seat design could substantially reduce the vibration exposure experienced by vehicle operators. The results of these reports indicated the resonance of the human body depended on various factors: posture, the materials of the seat surface, vibration magnitude and frequency.

Measurement and Quantification of Vibrations

The most widely used standard in assessing whole-body vibration exposure is the ISO 2631 (1985) document prepared by the International Organization for Standardization. The need to standardize whole-body vibration measurement and evaluation techniques led to the development of the ISO 2631. The standard provides acceptable exposure limits based on four physical factors of primary importance in determining the human body's response to whole-body vibration: intensity, frequency, direction, and duration of vibration exposure. The document provides a tri-axial coordinate system to measure whole-body vibrations, using assumptions that human tolerance to vibration differs for vibrations of different frequencies, and that within a 24-hour time span human tolerance decreases. The standard sets three exposure limits according to three criteria: (1) reduced comfort boundary (preserving comfort), (2) fatigue-decreased proficiency or FDP boundary (working efficiency); and (3) exposure limit (health and safety). The guidelines recommend quantifying frequency analysis using a third octave bandwidth with spectrum frequencies 1 to 80 HZ. The levels for the fatigue-decreased proficiency limits for various vibration exposures are given in diagrams of vertical acceleration versus frequency diagrams, as shown in Figure 1.

Both the reduced comfort and exposure health limits are based on the fatigue-decreased-proficiency limits; by dividing the fatigue-decreased-proficiency limits by 3.15, reduced comfort boundary can be determined; multiplying the proficiency limits by two, the exposure limit can be obtained. For example, if the whole body vibration energy of vertical acceleration (m/s^2) for a particular task was measured to be 4 m/s^2 at a frequency of 2 Hz, then based on the diagram shown in Figure 1, the limit for the fatigued-decreased-performance proficiency would be for no longer than one minute of whole body vibration exposure for that particular task. To obtain the exposure health limit, the proficiency limit of one-minute would be multiplied by two, resulting in an exposure limit of two minutes. Furthermore, by dividing the fatigue-decreased-proficiency limits by 3.15 (1 minute / 3.15 = 19 seconds) the reduced comfort limit equals 19 seconds of exposure.

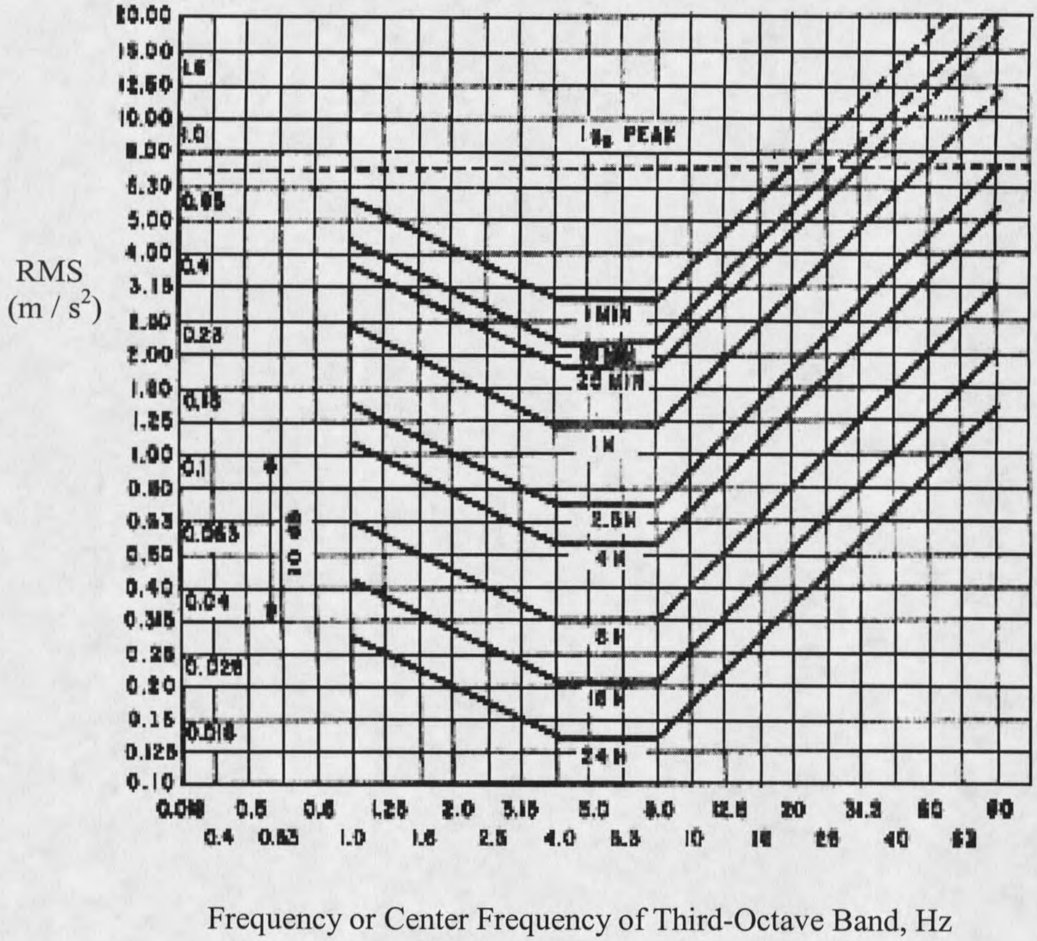

Figure 1. Limits for equal fatigue-decreased-performance proficiency. For vertical vibrations in third-of-an octave band (Hz) (From ISO 2631).

Of the four main parameters for quantifying vibration, acceleration is almost exclusively used to quantify magnitudes of vibration. The following equation, using the first derivative of the velocity function, gives the acceleration function:

$$a(t) = \omega^2 X \sin(\omega t + \pi)$$

where, X = Peak amplitude (in meters), ω = angular frequency = $2\pi f$ (in radians per second), and t = time in seconds

Frequently, the total amount of energy of the vibration is calculated as the Root-Mean-Square (RMS) of acceleration, where:

$$X_{RMS} = \sqrt{\frac{1}{T}\int_0^T X^2(t)dt}$$

where: T=cycle time, X= instantaneous amplitude of vibration

<u>Muscle Activity During Vibration Exposure</u>

Surface electromyogram (EMG) is often used in assessing muscular fatigue in occupational field studies (Luttman, Jager, and Laurig, 1999). EMG is used to examine muscular reactions as a conventional non-invasive method because direct measurement of the back and abdominal muscle activity is impossible. Muscle fatigue is defined as "any reduction in the ability to exert force in response to voluntary effort" (Edwards, 1981: Bigland-Ritchie et. al. 1995). Since muscle fatigue reduces muscle power, induces discomfort and pain, and, in the long term, is believed to contribute to low back pain, it is important to quantify fatigue. Thus, if the muscles used to support the back, i.e. abdominals and erector spinae, during off-road cycling begin to demonstrate a fatigued state, then a possibility of acute or long-term low back pain might result.

During sustained or repetitive muscle contractions, as needed in off-road cycling, typical changes in EMG, including an increase in amplitude and/or shift in the frequency spectrum towards lower frequencies, can be observed. Ergonomists agree that the onset of fatigue occurs at a minimum of 10% shift in the median frequency (Chaffin, 1999). In occupational electromyography, such EMG changes are commonly interpreted as indicators of muscular fatigue (Chaffin, 1973; Herberts, Kadefors, & Broman, 1980; Hagberg, 1981; Hansson et al., 1992; Kim Oberg et al., 1994). When a muscle is rested, the mean frequency of the myoelectric signal may be twice that found when the muscle is fatigued (Stulen & de Luca, 1979; Lindstrom, Kadefors, & Pertersen, 1977). The most often used measures to characterize EMG power spectral distributions are the median (Stulen & De Luca, 1981) and the mean power frequencies (Kwatny et al., 1970).

Studies performed by Seroussi et al. (1987); Pope et al. (1988); Zimmerman and Cook, (1997) found that specific trunk muscles demonstrate a cyclic EMG activity. They also found that significantly higher EMG activities existed during vibration as opposed to static moment loads on the torso. Furthermore, Magnuss et al. (1988) and Hansson et al. (1991) found an increase in erector spinae fatigue during whole-body vibrations. These studies were conducted in laboratory conditions where subjects were placed on a platform designed to study whole-body vibration effects while seated. Furthermore, a 10-percent decrease in the surface EMG spectrum median frequency obtained during sub-maximal isometric contractions of the erector spinae muscles has also been associated with the risk of developing low back pain (Mannion, 1997).

Siedel's (1988) studies demonstrated that during vertical sinusoidal vibration at very low frequencies (0.315-5 Hz), as in bicycling, there is a synchronized response in EMG of the erector spinae muscle at the lumbar level. Bonger et al. (1990) further suggested that the cyclic response of the erector spinae in response to whole-body vibration might lead to muscle fatigue, causing low-back pain in such occupations as helicopter pilots. During off-road cycling, in order to maintain a steady state of contact with the bicycle seat, the cyclist must continuously contract core muscles at various amplitudes and frequencies as they cycle over varying terrain. This continuous contraction of the muscles might result in a cyclic response of the erector spinae. This continuous contraction in response to the whole-body vibration can lead to muscle fatigue, which might lead to low-back pain. No published studies to date have dealt with EMG responses to vibration while off-road cycling.

Another hypothesis for low-back pain is based on asymmetric postures that many occupations require, such as helicopter pilots; this may lead to different intensities in the EMG of the right and left erector spinae, as observed by van Dieen (1996) and Pope et. al. (1986) in sitting with a rotated trunk. It is unclear at this point if cycling involves asymmetric postures, no studies to date have analyzed this particular situation.

Summary

Current research in the area of whole body vibration's effects on the lower back has been heavily researched within the occupational setting, but little has been devoted to off-road cycling. With the growing number of off-road cyclists today and with 30 - 70% of these cyclists suffering from cervical, dorsal, or lumbar back pain, it is important to develop a scientific analysis of manufacturer's claims on suspension systems "decreasing fatigue, hence fewer injuries". The purpose of this study is to develop more quantitative measures to assess the effects of suspension seat post absorption systems on skeletal loading and muscle fatigue.

CHAPTER 3

METHODS

Description of Subjects

Five adult females volunteered for this study. All subjects reported having no history of lower-back pain, musculoskeletal or neuromuscular disorders, or spinal or abdominal surgery, and were in good physical condition. All subjects were recreational cyclists who rode their bicycles a minimum of 30 minutes per week and not more than three hours per week. Subjects were not competitive athletes in other sports and did not take part in strength training exercises any time during the year preceding testing. The Human Subject Committee at Montana State University approved the study and all subjects signed an informed consent form (Appendix A and Appendix B).

Procedures

Each subject completed two experimental sessions, for a total of three hours in duration. The weather conditions during all experimental sessions included dry conditions with temperatures between 4.4-12.8° C. The first session involved familiarization with the bicycle, suspension and non-suspension seat posts, accelerometer, EMG surface electrodes, and an introduction to the simulated off-road track. After the familiarization period, collection of the subjects' height, mass, and grip strength data were recorded. Grip strength was obtained using a *JAMAR* hand dynamometer; the maximum value of two trials with one-minute rest periods between efforts was recorded.

Prior to actual data collection, each subject was given proper bike fit. Bike fit consisted of adjusting the saddle according to the conventional mountain bicycle setup where the subject's legs are nearly extended at the bottom of the pedal cycle (approximately 20-degree bend in the knee) (Burke, 1989). Each subject's knee measurements, using a goniometer, were recorded at the first trial and maintained for subsequent trials. Once preliminary data were collected and equipment was set-up, subjects were given a warm-up period of 10-minutes or longer depending on the comfort status of the subject. Following the warm-up period, each subject was asked to cycle on the simulated off-road track for one hour at a constant cadence of 55 rpm in a gear of 44 X 24, yielding a speed of 3.49 m/s. The simulated track consisted of a flat gravel path having a width of .914 m and a length of 800 m with .038 m X .01 m wooden boards loosely placed every 6.1 meters.

Predetermined by random assignment, each subject's first treatment was either a suspension or a non-suspension seat post (Appendix C). Data were collected every fifteen minutes for one hour through a portable data acquisition system. Following the data collection period, a cool-down period of 10 minutes was provided. The subjects were asked to return a minimum of 48 hours later for the second test session where they repeated the same protocol as in the first; this session subjects rode the other seat post treatment. Forty-eight hours was chosen to minimize possible fatigue effects of the muscles between test sessions. Both test sessions lasted approximately 1.5 hours each.

Under both experimental sessions, subjects were asked to avoid strenuous physical activity 24 hours prior to each session and to wear tight fitting shorts (i.e. bicycling shorts) or pants and a tight-fitting cycling jersey or long sleeve shirt and their own shoes so the equipment could be properly fitted to them.

Data Collection and Instrumentation

The data collection protocol was identical during both test sessions. The saddle acceleration measured in volts and erector spinae and abdominal EMG measured in microvolts data were collected. The electrodes and accelerometer were connected to a 68LP Connector Block (National Instruments, Austin TX), which was connected via a cable to a 12-bit 6024E Data Acquisition Card (National Instruments, Austin TX). The 6024E Data Acquisition Card was placed into a Gateway Solo 2500 Laptop (Gateway, North Sioux City SD) that was secured to a rear bicycle rack, for a total approximate weight of 17.26 kg.

EMG signals of the six muscles under investigation and the acceleration data were sampled at 1000 Hz. Data were collected at minutes 15, 30, 45 and 60 for 15 seconds, for a total of 60,000 samples per minute per channel. Data collection at minute 15 lasted 15 seconds and was denoted as "Time Period 1" in later analyses. The same denotation was used for successive data collection periods, i.e. data collection at minute 30 was denoted as "Time Period 2". The accelerometer required three channels on the 68LP Connector Block for acceleration data in the x, y, z – direction, two channels for left and right rectus abdominis and four channels for the left and right erector spinae muscles (longissimus and iliocostalis). All data acquisition was programmed through the data acquisition system - *Labview 5.1* (National Instruments, Austin TX) and data were not electronically filtered (Appendix D). Furthermore, the six electrodes were powered through 9-volt batteries and the accelerometer was powered through the computer's battery source. Equipment set-up is shown in Figure 2.