
Electromyographic (EMG) analysis performed on a sample of 20 non-competitive male cyclists between the ages of 18 and 36 was utilized to compare the effect of the upright versus forward-lean position of the trunk on hamstring muscle activity during bicycle ergometry. The peak and summated EMG values, expressed as a percentage of maximal voluntary isometric contraction, were recorded continuously during a 45-second testing period in which subjects changed from the upright to forward-lean positions every 15 seconds. Paired t tests revealed significant differences between the upright and forward-lean positions (p < .001) in both the peak and summated activity levels. Pearson product correlation coefficients showed no significant correlation between angle of sacral tilt and EMG activity. It was determined that the forward-lean position significantly increased hamstring activity and that angle of sacral tilt is not noticeably correlated with EMG activity. Further research is necessary analyzing EMG activity to find optimum angle of sacral tilt for maximum hamstring output and to measure peak differences in trunk positions using different angles of sacral tilt.
AN ELECTROMYOGRAPHIC ANALYSIS OF
THE HAMSTRING MUSCLES DURING BICYCLE ERGOMETRY

A Thesis Presented
to
The Graduate Faculty
University of Wisconsin - La Crosse

In Partial Fulfillment
of the Requirements for the
Master of Science Degree

Caroline G. Nielsen
Candidate: Caroline G. Nielsen

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree: Master of Science, Physical Education - Human Performance. The candidate has completed her oral report.

Keith French
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Date

This thesis is approved for the College of Health, Physical Education, and Recreation

John C. Mitchell
Dean, College of Health, Physical Education, and Recreation

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Date
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INTRODUCTION

The development of exercise programs to meet the specific needs of the individual participants applies both to those who are trying to improve their cardiovascular fitness and patients who are recovering from injury or disease. The bicycle ergometer has frequently been used in the rehabilitation of patients with lower extremity dysfunctions and to improve cardiovascular fitness. Frequently included in these exercise programs are the goals of increased strength and endurance. The potential uses of the bicycle ergometer as a tool to achieve these goals make investigation of cycling effects on the lower extremities important.

Improving muscle strength and endurance is achieved primarily with the use of resistive exercise. Of interest is the influence of resistance and repetition on strength changes. DeLorme (1945) recommended isotonic protocols using high resistance, low repetition exercise to improve strength and low resistance, high repetition exercise to improve endurance. Several studies have been done to evaluate this recommendation (Andersen & Kearney, 1982; Stull & Clark, 1970). Cycling is generally a high repetition, low resistance exercise; however, varying
degrees of low resistance can be obtained by altering mechanical factors. Though numerous methods have been used and studied regarding isometric and isokinetic exercise (Davies, 1984; Petersen, 1960), few quantitative methods have been developed for studying muscular changes during cycling.

Electromyography (EMG) is a method frequently used to study muscle function and dysfunction in biomechanics. It is the electrical signal originating from neuromuscular activation of a contracting muscle. Surface EMG is based on the motor unit action potential train (MUAPT), which has been used to correlate such changes with muscle length, type of contraction, temporal aspects, and, to a lesser degree, fatigue (Lenman & Ritchie, 1977; Lunnen, Yack & LeVeau, 1981; Soderberg & Cook, 1984). EMG can be used as a quantitative method of evaluating the extent of muscle fiber excitation. An increase in muscle electrical activity with constant biomechanical output represents an increase in activation probably as a result of compensating for contractive fatigue (Laurig, 1976). To improve strength, a muscle must be worked to its maximum force-generating capacity, known as the overload principle (McArdle, Katch & Katch, 1981). Strength improvements depend on the intensity of the overload which produces fatigue. The utilization of the EMG signal to quantify muscle fatigue continues to be very controversial. Many studies have been done to attempt to make this quantification; however, several authors have
Described various phenomena occurring with the fatigue of continuous activity (DeLuca, 1984; Gilmore & DeLuca, 1985; Luciani, Ratino, McGrew & Suizu, 1983; Moritani, Muro & Nagata, 1986; Petrofsky, Glaser & Phillips, 1982). Basmajian (1978) maintains that quantifying fatigue of muscle fibers under voluntary activity using the EMG signal is insignificant. It is apparent, however, that muscle activity which is sustained or continuously stimulated will induce fatigue.

Houtz and Fischer (1959) and Carlsoo and Molbech (1966) used EMG to identify the muscles which are activated during cycling. These and other studies (Boylls, Zomlefer & Zajac, 1984; Desipres, 1974; Gregor, Green & Garhammer, 1982) have indicated that significant activity occurs in the quadriceps femoris, hamstrings and triceps surae muscle groups during different cycling phases. It is interesting to note that muscle activity may be affected by changes in the mechanics of the bicycle and cycling technique. Factors affecting the activity of a particular muscle group are workload, pedalling rate (cadence), saddle height and usage of toe clips (Burke, 1986; Ericson, Nisell, Arborelius & Ekholm, 1985; Goto, Toyoshima & Hoshikawa, 1975). Increasing these parameters increases hamstring activity; however, they may also increase stresses at the knee and cause excessive rocking of the pelvis.

The present study investigated the postural effect of
cycling on the hamstrings, as previous studies have not compared the effects of trunk position changes on the hamstrings. It seems that having the trunk in a forward-lean position rather than upright may increase hamstring activity by placing the pelvis in an anterior tilt and slightly elongating the hamstrings. It would also eliminate or minimize those problems encountered by changing seat height, increasing workload and pedalling rate and using toe clips.

Studies have shown that cycle exercise has been very beneficial for improving muscle strength, range of motion, endurance and overall cardiovascular fitness for patients recovering from knee injuries (Campbell & Glenn, 1982; Hull & Jorge, 1985; Malone, Blackburn & Wallace, 1980). Cycling also helps to prevent knee injuries by maintaining ligamentous stability. McLeod and Blackburn (1980) have concluded that cycling serves to protect the healing ligaments while rehabilitating patients with knee injuries. This form of exercise does not create the inertial and compressive forces of the tibia gliding anteriorly on the femur as do other resistive exercises. Effective rehabilitative exercise programs are developed by determining optimal bicycle mechanics and cycling techniques to increase activity of each muscle group.

In reviewing the literature regarding cycling, most studies have dealt with cardiovascular (physiological)
changes and few with muscular strength and endurance changes. It seems that cycling is used as a low intensity exercise to improve lower extremity endurance, primarily, of the knee extensors; however, it appears that investigation of optimal techniques to improve hamstring muscle performance would be beneficial. A thorough understanding of cycling biomechanics could eliminate or prevent overuse injuries in the knee due to cycling and optimize rehabilitation programs for knee injuries.

Purpose of Study

The purpose of this study was to compare the hamstring muscle activity with the trunk in the upright versus forward-lean position during bicycle ergometry using electromyographic analysis.

Hypothesis

In regards to the hamstrings, it is hypothesized that during cycle exercise, trunk position has no effect on hamstring muscle activity.

Delimitations

1. The study was delimited to male volunteers from the University of Wisconsin-La Crosse and Gundersen Clinic, La Crosse, Wisconsin.

2. Competitive cyclists were eliminated from the study.
Limitations

1. Motor points vary between individuals; therefore, electrode placement was in the approximate area of palpated muscle belly.

2. The population consisted of volunteers; therefore, it was not a random sample.

Definition of Terms

Maximal Voluntary Isometric Contraction (MVIC): the greatest amount of effort exerted by a given muscle or muscle group during which the length of the contracting muscle remains constant.

Forward-Lean Position: the trunk inclined forward from the upright position with the upper chest resting on handlebars.

Angle of Sacral Tilt (AST): angle of the posterior sacrum in the upright versus forward-lean position as measured using a gravity inclinometer placed over the sacral spinous processes.
CHAPTER II
REVIEW OF LITERATURE

Introduction

This chapter will review articles which have investigated the effects of cycling primarily on knee flexor muscles, semimembranosus (SM), semitendinosus (ST), and biceps femoris (BF). No EMG information was found which compared the effects of trunk position changes during cycling; therefore, literature relating to the effects of resistive exercise programs on strength and endurance, physiological changes in muscle induced by cycling and length-tension relationships of two-joint muscles will also be reviewed.

The Effects of Cycling on Knee Flexor Muscle Activity

Attempts have been made to interpret the electrical activity pattern of selected lower extremity muscles during cycling, primarily on the bicycle ergometer using electromyographic analysis. The function of the hamstrings as a hip extensor in cycling has been found to be relatively inactive (Basmajian, 1978; Ericson, et al., 1985; Gregor, Cavanagh & Lafontune, 1985); therefore, emphasis will be on their function as a knee flexor.
Houtz and Fischer (1959) studied the muscular activity of 14 muscles with accompanying joint ranges on a stationary bicycle. Subjects performed two series of experiments; first, with the bicycle seat at its lowest position (21 inches) and then with the seat elevated (25 inches) with 0, 1.5, 3, 4, 4.5 and 5.0 pounds of pedalling resistance. Muscle action potentials were picked up by surface electrodes and the results of hamstring activity were as follows: the action pattern of the SM, ST and BF was short in duration building to a peak during the recovery phase then rapidly diminishing. Changing seat height did not affect the timing pattern of muscle activity, though it did influence the quantitative effect of the hamstrings activity. It was also found that the usage of the toe straps increased hamstring activity.

Though numerous studies have been done regarding the biomechanics of cycling (Burke, 1986; Dal Monte, Manoni & Fucci, 1973; Gregor, et al., 1985; Suzuki, Watanabe & Homma, 1982), one of interest analyzed 11 lower extremity muscles during cycle ergometry comparing workload, pedalling rate, saddle height and foot position (Ericson, et al., 1985). It was found that these four parameters had the greatest influence on knee flexor muscle activity. The biceps femoris had low peak electrical activity and was active during the whole revolution; this activity only changed by a change in workload. The medial hamstrings, ST and SM, were
primarily active during the 150° - 270° crank angle (recovery phase). This activity was significantly increased with an increase in workload, pedalling rate and saddle height.

Jose and Furlani (1984) have studied the effect of foot position in BF, ST and SM during cycle ergometry. These muscles were analyzed during the movements of knee flexion with the foot in the normal, inverted and everted positions during the four phases of knee flexion. The results indicated that BF, ST and SM are all active with the foot in the normal position, BF is effective when the foot is inverted; only ST and SM are effective with the foot everted.

From these studies, it is apparent that during cycling the hamstrings function primarily as knee flexors and that muscle activity can be altered with changes in workload, seat height, pedalling cadence and foot position.

Effects of Resistive Exercise on Strength and Endurance

Since limited information is available regarding the effects of cycling on muscle strength and endurance, this section will review articles which simulate the characteristics of cycling.

DeLorme (1945) proposed that low resistance, high repetition exercise improved endurance, while high resistance, low repetition exercise increased strength. To
evaluate this theory, Stull and Clark (1970) performed a study in which 20 subjects performed high resistance, low repetition exercise three times per week for six weeks. The results showed an increase in final strength and total work, referred to as absolute endurance.

Another study conducted by Andersen and Kearney (1982) compared high resistance, low repetition; medium resistance, medium repetition; and low resistance, high repetition exercise using three treatment groups. Following training three times per week for nine weeks, results indicated that all groups improved in strength, though the high resistance, low repetition subjects improved significantly greater. Increases in absolute endurance were not significantly different between the groups.

A number of other studies (Andersen & Henriksson, 1977; DeLateur, Lehmann & Fordyce, 1968; Miller, 1984; Petersen, 1960) have found similar results regarding training for strength and endurance. Both high resistance, low repetitions and low resistance, high repetitions improve strength and endurance; however, gains are significantly greater when using the method described by DeLorme.

Changes in Muscle Induced by Cycling

This section will review those articles dealing with effects of cycling on muscle fiber types and enzyme changes.
Gollnick, Armstrong and Saltin (1973) studied changes in the vastus lateralis of six subjects during cycling. Exercise was performed four times per week for five weeks at 75 and 90 percent of the subjects' maximum aerobic power. Biopsies were performed and results showed no alteration in the percentage of slow twitch (ST) and fast twitch (FT) fibers. There was, however, an increase in relative area of the ST fibers. The authors felt this indicated that the ST fibers were used more extensively during the training program. They also found an increase in oxidative capacity of both fiber types, though anaerobic capacity increased only in the FT fibers.

Quantitative measures of enzyme activity in Type I and Type II muscle fibers were investigated by Henriksson and Reitman (1976). Two groups of subjects were trained on a cycle ergometer for seven to eight weeks. One group used interval training with maximal exercise intensity (I.T.) and the other group used continuous exercise with submaximal intensity (C.T.). No changes were noted in phosphofructokinase (PFK) activity; however, succinate dehydrogenase (SDH) activity increased 27.5% (I.T.) and 22% (C.T.) Only SDH in Type I muscle fibers increased in the C.T. group while only SDH in Type II muscle fibers increased in the I.T. group. These results indicate that the oxidative potential of each fiber type is highly adaptable. Furthermore, this adaptability appears to be related to the
pattern of muscle fiber recruitment during exercise.

Other studies (Andersen & Henriksson, 1977; Costill, Fink & Habansky, 1977; Woods & Bigland - Ritchie, 1983) have indicated this adaptability of the relative area of each fiber type, though no change in specific fiber type is noted. Endurance training increases the ST fiber area significantly and also increases SDH.

A study done by Costill (1977) observed two groups of patients recovering from knee surgery who exercised in a cycling training program. One group performed the conventional strengthening program with weights. The other group supplemented the weight program with 30 minutes of one-legged cycling. Following the training program for five times per week for six weeks, biopsies taken indicated that in the weight-trained group SDH activity had not increased, while in the combination-trained group SDH was significantly increased, even greater than the leg which was not exercised.

Endurance training involving long intervals stresses ST fibers; therefore, oxidative capacity of the muscle cells is improved. FT fibers, which are low in myoglobin and mitochondrial concentration, fatigue easily. They, however, function at a very high intensity during work periods. By cycling at high intensity workloads while incorporating short periods of work and recovery, the work can be performed with only comparatively slight increases in blood
lactic-acid concentration while still improving strength
(Faria & Cavanagh, 1978).

**Length-Tension Relationships of Two-Joint Muscles**

Limited information is available regarding
length-tension relationships of two-joint muscles because
muscle length and moment arms relating to joint position
cannot be quantified by EMG (Basmajian, 1978; Gregor, et al.
regarding Lomard's Paradox; i.e. the activity of a two-joint
muscle when the required moment at one end of the joint is
in the opposite direction to that caused by the muscle. The
function of two-joint muscles was studied by having five
subjects perform a cycling task against a constant load.
Results indicated a clear difference in hip and knee action
during the propulsive phase of pedalling. The hip moment is
always extensor and the knee moment is first extensor then
flexor. Two principles regarding any two-joint muscles are
as follows: (a) a muscle must have a certain amount of
elongation to produce satisfactory tension; (b) maximal
muscle tension is produced when a muscle is slightly
elongated beyond its resting length; i.e. when a muscle
fiber is unstiumulated and no external forces are acting
upon it (Brunnostrom, 1972). The hamstrings are two-joint
muscles which are primarily postural, acting on both the hip
and knee joints (Carlsoo & Molbech, 1966).
The activity of two-joint muscles influences both joints. If a muscle functions as a stabilizer of one joint, the actual kinetic effect would be limited on another joint. Activation of two-joint muscles may require additional energy expenditure since opposing muscle groups work against each other at each joint; therefore, cocontraction is necessary to stabilize the joint. During hip flexion with forward inclination of the trunk, the hamstrings function more actively during cocontraction of the hip (Gregor, et al., 1982).

**Summary**

This chapter reviewed literature in four areas: the effects of cycling on knee flexor muscle activity, resistive exercise on strength and endurance, muscular changes induced by cycling and length-tension relationships of two-joint muscles.

No literature was available regarding the effects of trunk position changes on hamstring activity during cycle ergometry. Limited studies involving other biomechanical aspects of cycling investigated workload, seat height and foot position. Extensive information was available regarding resistive exercise programs; however, this review was limited to investigations involving low resistance protocols, as cycling is generally of this type. Briefly reviewed were studies involving principles of strength.
training, also. Since strength improvements generally depend on the overload principle, studies involving fatigue and use of the EMG signal to quantify fatigue were reviewed.
CHAPTER III

METHODOLOGY

Introduction

Twenty male subjects from a local university and a local clinic each performed three consecutive tests of 15 second duration in the upright, forward-lean and upright positions on a stationary bicycle. The peak and summated EMG values were recorded continuously during the 45-second testing period. Data were analyzed using paired t tests and correlation coefficients were computed between EMG activity levels and angle of sacral tilt (AST).

Subject selection is described followed by testing procedures and data analysis.

Subject Selection

Subjects were male volunteers with no observable musculoskeletal deficits between the ages of 18 and 36. Subjects who biked more than 100 miles per week or were involved in cycling competition during the past year were eliminated from this study.

Procedures

The purpose and procedures of the study were explained to the participants. Prior to testing, questionnaires were
completed (Appendix A) and informed consent was obtained (Appendix B). Figures 1 and 2 show the test set up in the upright and forward-lean positions. The following measurements were taken and settings were incorporated. Seat height, measured from the posterior aspect of the saddle to the center of the pedal spindle in the down position with the crank parallel to the seat tube, was set at 107% of pubic symphysis height, measured from the point of heel-floor contact to the tip of the pubic symphysis while standing (Burke, 1986; Faria & Cavanagh, 1978; Hamley & Thomas, 1967; Nordeen-Snyder, 1977). Handlebar height was set for each subject according to comfort. The AST was recorded in the upright position (UP) and forward-lean position (FP) using a gravity goniometer with the subject sitting on the bicycle at his predetermined seat height. The AST was recorded with the upper notch of the goniometer on the posterior aspect of sacrum at the L₅S₆ interspace. Toe clips were used on the ergometer to stabilize foot position. Workload was arbitrarily set constant at 900 kilopoundmeters per minute (kpdm/m). After reducing the skin impedance with rubbing alcohol, Beckman-type surface electrodes for electromyographic (EMG) recording were placed over a motor point of the right hamstrings (Chusid, 1979) 2.5 cm apart on a line parallel with the muscle fibers, and the ground electrode placed medially between the active electrodes.
Figure 1. Test set-up in the upright position

Figure 2. Test set-up in the forward-lean position
First stage amplifiers were secured to the anterior aspect of the thigh with a velcro strap to reduce movement artifact. Instructions given to the subjects are presented in Appendix C.

Following a two-minute warm-up period of pedalling at 60 rpm, 300 kpd/m, a standard EMG isometric contraction recording procedure (Basmajian, 1978; Hull & Jorge, 1985; Nemeth, Ikholm, Arborelius, Schudlt & Harms-Ringdahl, 1984; Perry & Bekey, 1981) was performed to normalize the electrical activity of the hamstrings among subjects. All test-related EMG activity was then expressed as a percentage of this pretest activity identified as the maximal voluntary isometric contraction (MVIC).

The EMG was recorded in the following manner for all subjects: (a) subjects performed a maximal voluntary isometric contraction for five seconds on the stationary bicycle with the right pedal in the downward fixed position with the trunk in the upright position; (b) subjects pedalled at 60 rpm and 900 kpd/m for 15 seconds with the trunk in the upright position, switching within one second to the forward-lean position for 15 seconds upon command; and (c) returning within one second to the upright position for 15 seconds. Timing was done by the researcher using a digital stopwatch.
**Instrumentation**

**Bicycle Ergometer**

The testing procedure used the Fitron (Cybex, division of Lumex Corporation, Ronkonkoma, New York) cycle ergometer, a constant velocity cycle with an internal hydraulic braking system to achieve a preselected rpm value. The braking mechanism accommodates to the increase or decrease in force the subject applies to the pedals; therefore, the resistance varies and pedal velocity is kept constant, allowing the subject to develop maximal dynamic muscle tension throughout full range of motion.

**Electromyographic Instrumentation**

The TECA TE-4 (TECA, White Plains, New York) electromyograph with two AAGMKII amplifiers and integrator was used to record muscle activity. Muscle activity levels were determined by customized computer software (Rowinski, Personal Communications). A WPI 121 (WP Instruments, New Haven, Connecticut) window discriminator was used to count integrated data EMG level resets within successive 70.2 msec data intervals. This sampling bin width was the minimal interval allowed by the software program and is consistent with Norman, Nelson & Cavanagh (1978), who suggested sampling times of 50-75 msec. All equipment was calibrated by certified technicians from the manufacturers prior to testing.
Statistical Analysis

Paired t tests (SPSSX, Academic Computing Services - UWL, La Crosse, Wisconsin) were performed using the mean values obtained for percent MVIC for each of the test positions. Pearson product correlation coefficients were calculated using AST and differences in EMG activity levels in each trunk position.

Analysis of Data

Calculations were done according to summated and peak EMG activity. Due to the large volume of data generated during the 45-second testing period, summated values were obtained by adding the value of every fifth interval in each sample bin of 10.9 seconds. This sample bin represents a testing period allowing for transition time between tests. Peak values were obtained by analyzing the highest five values in each sample bin of the summated activity. Values of muscle activity, expressed as a percentage of MVIC, were analyzed from a sampling at every fifth interval, each interval being 70.2 msec. Therefore, a sample of 70.2 msec of activity was taken every 0.351 seconds.

The mean and standard deviation of the summated and peak activity levels were calculated from each sample bin of 10.9 seconds, allowing for transition time between position changes. This resulted in values selected from the sampling procedure presented in Table 1.
Table 1. Sampling procedure for determining transition and EMG activity periods.

<table>
<thead>
<tr>
<th>Time (sec.)</th>
<th>Periods</th>
<th>Abbreviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1.9</td>
<td>Transition #1</td>
<td>T1</td>
</tr>
<tr>
<td>2.0 - 12.9</td>
<td>Upright position #1</td>
<td>UP1</td>
</tr>
<tr>
<td>13.0 - 16.9</td>
<td>Transition #2</td>
<td>T2</td>
</tr>
<tr>
<td>17.0 - 27.9</td>
<td>Forward-lean position</td>
<td>FP</td>
</tr>
<tr>
<td>28.0 - 30.9</td>
<td>Transition #3</td>
<td>T3</td>
</tr>
<tr>
<td>31.0 - 41.9</td>
<td>Upright position #2</td>
<td>UP2</td>
</tr>
</tbody>
</table>
CHAPTER IV
RESULTS AND DISCUSSION

Introduction

Twenty male subjects from a local university and a local clinic each performed three consecutive tests of 15 second duration in the upright, forward-lean and upright positions on a stationary bicycle. The peak and summated EMG values were recorded continuously during the 45-second testing period. Data were analyzed using paired t tests and correlation coefficients were computed between EMG activity levels and angle of sacral tilt (AST).

The results are presented and discussed in this chapter. Subject characteristics are given followed by a discussion of the analysis of data.

Subject Characteristics

The physical characteristics of the subjects are presented in Table 2, and the individual data for each subject is in Appendix D.

Test Results

Calculations of the mean and standard deviation of the summated EMG activity levels are given in Table 3. The increase in summated activity indicated that more motor
Table 2. Means and Standard Deviation of Subject Characteristics (N=20)

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>28.45</td>
<td>182.15</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.82</td>
<td>5.18</td>
</tr>
<tr>
<td>Range</td>
<td>18-36</td>
<td>173-190.5</td>
</tr>
</tbody>
</table>
Table 3. Means and Standard Deviation for Summated EMG Activity Levels

<table>
<thead>
<tr>
<th>Position</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP 1</td>
<td>10.4624</td>
<td>10.1557</td>
</tr>
<tr>
<td>FP</td>
<td>14.7474</td>
<td>11.4954</td>
</tr>
<tr>
<td>UP 2</td>
<td>10.1206</td>
<td>9.4939</td>
</tr>
<tr>
<td>FP-UP1</td>
<td>4.2850</td>
<td>3.8531</td>
</tr>
<tr>
<td>FP-UP2</td>
<td>4.6268</td>
<td>4.3366</td>
</tr>
<tr>
<td>UP1-UP2</td>
<td>0.3418</td>
<td>3.1397</td>
</tr>
</tbody>
</table>
units are firing in the FP than in UP 1 or UP 2. The results of the mean and standard deviation of the peak activity levels are given in Table 4. This increase in peak activity suggests that not only is the firing rate increased but the firing intensity is also higher. Figure 3 shows a sample EMG recording of a MVIC. The recording in Figure 4 is representative of the changes in summated and peak EMG activity during the 45-second testing period.

Paired t tests as shown in Table 5 revealed significant differences between the upright and forward-lean positions (p < .001) in both summated and peak activity levels. No significant difference was noted between UP 1 and UP 2 (p > .05). Therefore, the significant differences in EMG activity between FP - UP 1 and FP - UP 2 can be attributed to trunk position change and not as a result of testing order.

A Pearson correlation coefficient was obtained comparing degree of AST and the amount of EMG activity. Results are given in Table 6. Scatterplots in Figures 5 and 6 show the correlation coefficients of the differences in summated EMG activity between Positions B-A and B-C with AST. There was no significant correlation between AST and EMG activity for either the upright to forward-lean or forward-lean to upright conditions.
Table 4. Means and Standard Deviation of Peak EMG Activity Levels

<table>
<thead>
<tr>
<th>Position</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP1</td>
<td>20.2</td>
<td>13.27</td>
</tr>
<tr>
<td>FP</td>
<td>28.65</td>
<td>19.1577</td>
</tr>
<tr>
<td>UP2</td>
<td>18.86</td>
<td>12.8635</td>
</tr>
<tr>
<td>FP-UP1</td>
<td>8.45</td>
<td>10.1684</td>
</tr>
<tr>
<td>FP-UP2</td>
<td>9.79</td>
<td>10.7348</td>
</tr>
<tr>
<td>UP1-UP2</td>
<td>1.34</td>
<td>5.4426</td>
</tr>
</tbody>
</table>
Figure 3. Sample EMG recording of a MVIC as performed with the trunk in the upright position.
Figure 4. Sample EMG recording of the 45-second test period showing representative changes in peak and summated EMG activity.
Table 5. Results of paired t tests for summated and peak EMG activity levels.

<table>
<thead>
<tr>
<th>Variable</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference between:</td>
<td></td>
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<tr>
<td>Summated FP-UP1</td>
<td>4.97</td>
<td>0.0001***</td>
</tr>
<tr>
<td>FP-UP2</td>
<td>4.77</td>
<td>0.0001***</td>
</tr>
<tr>
<td>UP1-UP2</td>
<td>0.49</td>
<td>0.6319</td>
</tr>
<tr>
<td>Peak</td>
<td></td>
<td></td>
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<tr>
<td>FP-UP1</td>
<td>3.72</td>
<td>0.0015**</td>
</tr>
<tr>
<td>FP-UP2</td>
<td>4.08</td>
<td>0.0006***</td>
</tr>
<tr>
<td>UP1-UP2</td>
<td>1.10</td>
<td>0.2846</td>
</tr>
</tbody>
</table>

**significant at the < .01 level
*** significant at the < .001 level

FP = Forward-lean position
UP1 = First upright position
UP2 = Second upright position
Table 6. Correlation test of AST with muscle activity levels.

<table>
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<tr>
<th>Variable</th>
<th>F-value</th>
<th>P-value</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference between:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Summated FP-UP1</td>
<td>0.026</td>
<td>0.8727</td>
<td>.04</td>
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<tr>
<td>FP-UP2</td>
<td>0.006</td>
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<td>.02</td>
</tr>
<tr>
<td>Peak FP-UP1</td>
<td>1.089</td>
<td>0.3104</td>
<td>.24</td>
</tr>
<tr>
<td>FP-UP2</td>
<td>0.805</td>
<td>0.3814</td>
<td>.21</td>
</tr>
</tbody>
</table>

FP = Forward-lean position
UP1 = First upright position
UP2 = Second upright position
Figure 5. Scatterplots of the differences in summated EMG activity between forward position-upright position 1 and forward position-upright position 2.
Figure 6. Scatterplots of the differences in peak EMG activity between forward position-upright position 1 and forward position-upright position 2.
Discussion

Few comparisons with previous studies can be made because measurements previously reported were from different test populations and most analyzed the EMG activity of the lower extremity muscles during various phases of the crank revolution.

A few studies, however, have been done which analyzed the effects of seat height, workload, pedalling rate and foot position on selected lower extremity muscles. Houtz and Fischer (1959) found that decreasing seat height by four inches resulted in a 11 percent increase in knee flexor activity as well as a 24 percent increase in knee extensor activity. Despires (1954) found that increasing seat height by 10 percent resulted in a 16 percent increase in hamstring activity with a 80 percent average increase in quadriceps activity.

Studies done by Ericson, et al. (1985) have shown that increasing workload, pedal rate, saddle height and using toe clips results in increased hamstring activity, though they also result in a proportionate increase in quadriceps activity up to 96 percent and gluteal activity up to 98 percent.

Jose and Furlani (1984) found that the medial hamstrings are active with both foot inversion and eversion; however, the lateral hamstrings are more active with the foot inverted. This shows that perhaps changing foot
position may be a method to increase hamstring activity during training.

It is apparent from these studies that changes in seat height, workload, foot position and pedal cadence result in increased hamstring activity; however, it is always accompanied by a much greater increase in quadriceps activity. Because previous studies have shown sufficient evidence regarding the quadriceps during cycle ergometry, the present study was limited to the analysis of the hamstrings only. Therefore, no conclusions can be made regarding the quadriceps activity in the forward-lean position.

The results of the present study show an increase of 30 percent in both mean summated and peak activity of the hamstrings. This suggests that changing trunk position to at least 40 degrees of sacral tilt may increase hamstring activity more effectively than changing other factors. This also eliminates the problems incurred by changing seat height and workload such as excessive pelvic rocking and increased compressive forces at the knee.

The correlation analysis determined that between 40°-55° of AST the hamstrings are placed on sufficient amount of stretch to significantly increase muscle activity. The absolute amount of sacral tilt within this range has no noticeable effect on the amount of increased activity. Although there was no statistically significant
correlation, of practical importance is noting that the angle of sacral tilt is more closely correlated with peak EMG activity than with summated activity. It can, therefore, be postulated that varying degrees of sacral tilt may change the motor unit firing intensity more than it will change the firing rate.
Twenty male volunteer subjects from a local university and clinic each performed three continuous stationary cycling tests: trunk in the upright position, changing to forward-lean position and returning to the upright position. Seat height was individually adjusted according to pubic symphysis height. Workload was constant at 900 kpd/m and pedal rate was 60 rpm. Toe clips were used and handlebar height was adjusted for comfort.

Data collected included EMG activity values expressed as a percentage of MVIC with the trunk in the upright and forward-lean positions and angle of sacral tilt.

Mean peak and summated activity levels were recorded by an in-house computer program. Data were analyzed using paired t tests measured with significance established at the .05 level. Correlation coefficients were obtained to compare degree of AST and the EMG activity levels.

The following findings were reached on the basis of the subject sample selected:

1. There were significant differences in EMG activity
between the upright to forward-lean and the forward-lean to upright positions \( p < .001 \).

2. There were no significant differences in EMG activity related to testing order of the different trunk positions \( p > .05 \).

3. There was no significant correlation between the angle of sacral tilt and the changes in muscle activity in each position \( p > .05 \).

**Conclusion**

In the forward-lean position as compared to the upright position, an angle of sacral tilt between 40° and 55° places the hamstring muscles on sufficient stretch to increase muscle activity significantly.

**Suggestions for Further Research**

1. Analyze EMG activity to find the optimum AST for maximum hamstring output.

2. Perform a training study to compare trunk position with changes in hamstring strength to determine most effective position for strengthening and effect on hamstring flexibility.

3. Measure peak differences in different trunk positions using different AST.

4. Studies with percutaneous electrode recordings to detect motor unit firing patterns would specifically address
the mechanism of EMG activity increase detected in the present study.

Clinical Implications

The quadriceps are generally thought to be the primary muscle group involved in cycling; however, the results of the present study indicate that assuming a forward-lean position of the trunk will significantly increase hamstring activity. This suggests that strength training would be more effective in this position as both the rate and intensity of the electrical activity are increased. The primary benefit of this position is applicable in knee rehabilitation programs where both muscle strength and endurance is desirable. Previous studies have shown that an increase in hamstring activity using other methods is usually accompanied by a significant increase in quadriceps activity which is not always desirable in training programs. It may be possible that by putting the quadriceps on slack in the forward-lean position most of the increase is in the hamstrings only. The results of this study also show that the forward-lean position increases EMG activity by 30 percent, whereas other methods such as changing seat height, workload and foot position result in an increase of 5 to 10 percent (Despires, 1954; Ericson, et al., 1985). Since this study was limited to the hamstrings only, further research is necessary to determine the effect of the forward-lean position on the quadriceps.
REFERENCES CITED


APPENDIX A

Questionnaire for Subject Selection
Questionnaire for Subject Selection

Name ____________________________
Birthdate _________________________
Phone ____________________________

(1) Do you ride a bicycle or stationary bicycle on a regular basis? ________
If so, how many miles per week? ________ or
How many minutes per session: ________
How many times per week? ________

(2) Does the bicycle you ride have toe clips or straps? ________

(3) Do you go on bicycle rides longer than twenty miles or ride a stationary bike longer than 60 minutes? ______
If so, how often? ______

(4) Have you ever been involved with bicycle racing competition? ______

_________________________

Seat height measurement: no. of holes showing ______
Sacral tilt: forward-lean ______ degrees
APPENDIX B

Informed Consent Form
Informed Consent

I, ________________________, being of sound mind and years of age, do hereby consent to voluntarily participate in electromyographic testing on the bicycle ergometer.

I understand that the tests will be administered by Caroline Nielsen and an assistant and will be done as part of a research project involving electromyograph analysis on a bicycle ergometer.

I understand that I will have surface EMG electrodes attached to the involved muscle groups and perform three 15-second pedalling tests. I understand that there exists the possibility of adverse changes during the test; e.g. leg, arm or back pain. Every effort will be made to minimize any discomfort or risk.

I understand that I may withdraw from the procedure at any time.

I have read the above document and have been fully advised of the nature of the procedure and possible risks, all of which risks I hereby assume voluntarily.

I hereby acknowledge that no representations, warranties, guarantees or assurances of any kind pertaining to the procedure have been made to me by the University of Wisconsin-La Crosse, the officers, administration, employees or by anyone acting on behalf of any of them.

Signed this _____ day of ___________, 198___, in the presence of the witness whose signature appears below.

(Signature) ___________________________ (Witness) ___________________________
APPENDIX C

Subject Instructions
Subject Instructions

You will be pedalling the bicycle ergometer for a two-minute warm-up period at 60 rpm, keeping the workload at 600 kpd/m as indicated by the red line. A 10-second maximal voluntary isometric contraction recording will be taken. You will then pedal at 60 rpm and 900 kpd/m with your trunk in the upright position, switching to the forward-lean position and returning to the upright position when indicated. In the forward-lean position, lean with chest resting on the handlebars. You will pedal for 15 seconds in each testing position. Your feet will be secured in toe clips. Be sure to use these on the upstroke of the revolution. Please inform me if you develop any discomfort in your legs.
APPENDIX D

Subject Characteristics
### Subject Characteristics

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<th>Height (cm)</th>
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