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Electromyographic Analysis of Abdominal and Low Back Musculature during Use of an Experimental Stationary Bicycle

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ELECTROMYOGRAPHIC ANALYSIS OF ABDOMINAL AND LOW BACK MUSCULATURE DURING USE OF AN EXPERIMENTAL STATIONARY BICYCLE

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This Scholarly Project, submitted by Bryce A. Kelly, Christopher L. Podoll, and Kirk R. Van Slyke in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	Electromyographic Analysis of Abdominal and Low Back Extensor Musculature during use of an Experimental Stationary Bicycle
Department	Physical Therapy
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Signatures [signatures]

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ABSTRACT

Electromyographic Analysis of Abdominal and Low Back Extensor Musculature during use of an Experimental Stationary Bicycle.

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Background and Purpose. Currently, stationary bicycles do not incorporate exercise for the abdominal and low back musculature. An experimental stationary bicycle, the Magnus Cycle, has been developed to increase trunk muscle activation and, at the same time, provide aerobic conditioning. The purpose of this study is to assess the activity of the rectus abdominus, external oblique, erector spinae, rectus femoris and biceps femoris muscles during a stationary cycling setting and during a tilt-in-space setting of the Magnus Cycle. **Subjects.** Sixteen subjects, both men and women, between the ages of 18 and 30 participated in this study. **Methods.** Surface electromyography (EMG) was used to assess muscle activity from the rectus abdominus, external oblique, erector spinae, rectus femoris, and biceps femoris muscles during each phase of stationary and oscillating exercise. The raw EMG signal was rectified, smoothed and normalized to the respective muscle maximal voluntary contraction prior to data analysis. A repeated measures t-test was utilized to assess differences in EMG activity between minutes one and three of stationary cycling. Differences in the oscillating condition for forward and backward tilt was assessed using a repeated measures ANOVA, alpha = 0.05. For trials without differences between oscillations, one way ANOVA was performed to determine differences between stationary, foot forward, and foot backward tilt conditions. **Results.** In the feet forward position, the rectus abdominis, external obliques, and rectus femoris demonstrated significantly higher EMG activation compared to both the stationary and feet backward conditions ($p<.05$). Activity of the erector spinae and biceps femoris muscles were not affected by the feet forward position. However, in the feet backward position, the erector spinae and biceps femoris muscles demonstrated significantly higher EMG activity compared to the stationary position and feet forward positions ($p<.05$). The rectus abdominis, external obliques, and rectus femoris muscles were not affected by the feet backward condition. **Discussion and Conclusion.** The tilting Magnus Cycle significantly enhances activation of the rectus abdominis, external oblique, erector spinae, rectus femoris, and biceps femoris muscles compared to stationary cycling. The enhanced trunk muscle activity may make the Magnus Cycle a better option for a quicker, more beneficial workout than standard stationary bicycles.

CHAPTER I

INTRODUCTION

Current cycle ergometers, although popular, do not address training or stability of core trunk musculature. By incorporating such training into cycling, exercise can be more efficient and possibly have more rehabilitative effects on low back pain. To this end, a new stationary bicycle has been developed. This bicycle, called the Magnus Cycle, incorporates a stationary bicycle with a seat and pedal assembly that tilts in space. The tilting of the seat and pedal assembly and the resistance for pedaling the bicycle are provided through the use of hydraulics. As the bicycle is pedaled, the seat tilts in space both forward and backward through a small arc. The tilt-in-space action of the seat and pedal assembly results in forward and backward tilting of the rider. Because the rider is stabilized at the pelvis and not at the trunk, head, and upper extremities, the forward and backward tilting should facilitate the activation of the core trunk musculature. Activation of the trunk musculature promotes stability in the spine, and may promote decreased low back pain as associations have been made between mechanical instability of the lumbar spine and low back pain.[1]

Problem Statement

Increased trunk muscle activity is expected while using the Magnus Cycle with the tilt-in-space movement as compared to stationary bicycling. However, there is no evidence for this statement. Therefore, the purpose of this study is to assess the activity of the rectus abdominus, external oblique, and erector spinae muscles during a stationary cycling setting and the tilt-in-space setting, referred from this point as the movement setting.

Significance of the Study

Currently, stationary bicycles do not incorporate exercises for the abdominal and low back musculature. An experimental stationary bicycle, the Magnus Cycle, has been developed to increase trunk muscle activation and, at the same time, provide aerobic conditioning. This study examines the activity of the abdominal and low back musculature while using the Magnus Cycle through the use of electromyographic (EMG) analysis. The Magnus Cycle may serve as a tool for persons who wish to train their abdominal and low back musculature in conjunction with an aerobic training stimulus.

Research Question

Does use of the Magnus Cycle in the movement setting cause greater muscular activity in the rectus abdominus, external oblique, erector spinae, rectus femoris, and biceps femoris than bicycling in the stationary setting?

Hypothesis

The null hypothesis states that there is no significant difference in muscular activity when operating the Magnus Cycle in the movement setting as compared to operating the Magnus Cycle in the stationary bicycle setting. The alternative hypothesis states that there is a significant difference in muscular activity when operating the Magnus Cycle in the movement setting as compared to operating the Magnus Cycle in the stationary bicycle setting.

CHAPTER II

LITERATURE REVIEW

Spinal Stabilization

A system describing spine stabilization has been proposed by Panjabi[2,3] that may be divided into three subsystems: (1) the spinal column; (2) the spinal muscles; and (3) the neural control unit. It has been shown that the spinal column, a passive osteoligamentous system, will buckle at loads less than 100 newtons.[4,5] But, with the addition of the spinal muscles, active/musculotendinous system, and neural control unit, the spine is stable under loads of several thousand newtons.[1] Therefore, the importance of trunk muscles in providing stability to the lumbar spine is great and has been established.[1,6,7]

For some time, the concept that low back pain rehabilitation should advocate activity rather that rest has been accepted. Studies involving the group of muscles referred to collectively as the paraspinal muscles have yielded information into the relationship between muscle and low back pain. In studies of patients with chronic low back pain, paraspinal muscles have been shown to be both weak,[8,9] and notably fatigable.[10-16] In addition, studies of persons who had previously been free from back pain revealed that poor paraspinal muscle endurance increases the risk for developing first-time low back pain.[10,17] This is key information demonstrating that decreased strength and endurance in paraspinal muscles may be a causative factor and not merely a symptom of disuse due to injury. At the same time, disuse should not be discounted, as the disuse plays a role in "deconditioning syndrome." Deconditioning is avoided or delayed through an appropriate exercise and rehabilitation program. The exercise and rehabilitation programs improve muscular performance and self-reported ratings of pain and disability.[18-20] Indeed, exercise therapy for chronic low back pain has been proven to be effective.[21]

Associations have been made between mechanical instability of the lumbar spine and low back pain,[1] and low back pain and muscle dysfunction.[22] Research has been conducted to investigate which muscle or muscles and, further, which program or approach is most beneficial in management of low back pain. Two areas have emerged as conceptual approaches. One approach proposes that muscles with intervertebral attachments are better suited to provide intervertebral stability as compared to the longer trunk muscles,[23] and is commonly referred to as a stabilization program. For example, the multifidus, transverse abdominus, and internal oblique muscles have intervertebral attachments and therefore should provide greater intervertebral stability than the erector spinae or rectus abdominus. The multifidus, transverse abdominus, and internal oblique muscles, then, are the target of specific training exercises. The other approach involves a general exercise program which activates trunk muscles as a whole, including the longer trunk muscles such as the erector spinae and rectus abdominus.

Stabilization programs were shown effective in subsets of patients with low back pain, spondylolysis or spondylolisthesis[22] and multifidus muscle size differences.[24,25] Also, Goldby et al.[26] demonstrated that a spinal stabilization program is more effective than manually applied therapy or an education booklet in treating chronic low back disorders over time. It is not known if the stabilization program was more effective than general exercise, as these studies did not incorporate a general exercise group as a comparison to the stabilization approach that they were investigating. Research into the stabilization approach is now endeavoring to determine a valid method of identifying the subgroups of patients with low back pain that will benefit from the stabilization approach. While research using spinal stabilization demonstrates success with some patients and not with others[27], the use of general exercises may be as effective. Danneels et. al.[28] identified comparable increases in multifidus cross sectional area when comparing a stabilization exercise against two types of general back extensor exercise. Koumantakis et al.[29] found a general exercise program reduced disability in the short term to a greater extent than a stabilization-enhanced exercise approach in patients with recurrent non-specific low back pain. Cairns et al.[30] found patients with LBP had similar levels of improvement with conventional physiotherapy consisting of general active exercise and manual therapy or conventional physiotherapy plus specific spinal stabilization exercises, suggesting there was no additional benefit of adding specific spinal stabilization exercises to a conventional physiotherapy package for patients with recurrent LBP in this study.

Some researchers have pointed out that even though specific muscles are proposed to be the target of the stabilization approach, muscle groups outside the muscles targeted are challenged in ways that promote spinal stability[27]. Also, Cholewicki et al[31] found that a single muscle could not be identified as the most important for the stability of the lumbar spine. Rather, spinal stability depends on the relative activation of all trunk muscles. Further research is needed to determine if subsets of patients with low back pain, as identified by clinical prediction models, can benefit from a stabilization program to a greater degree than through a general trunk exercise program, or if the relative activation of all trunk muscles provided by a general trunk exercise program is more beneficial.

Endurance

In most situations, only a small amount of muscular coactivation, about 10% of maximal contraction, is needed to provide stability to the spine.[32] Muscular endurance rather than strength has been related to reduction in low back pain symptoms.[10] Therefore, endurance is much more important than absolute muscle strength in most cases.[32] Iverson et al[33] demonstrated that a 12 week stationary bicycle program improved functional status and well-being of adults with chronic low back pain aged 55 years and older. This study highlighted the ability of endurance training to have a positive effect on patients with chronic low back pain.

Positioning

Research has shown that one area of particular importance may be to work on lumbar stability with a neutral spine, avoiding end ranges.[34] Much of the reasoning behind the promotion of neutral spine positioning is due to the increased intervertebral disc pressure at extreme ranges. Intervertebral disc pressure has been an area of interest since Nachemson's original work in the 1960s.[35] Newer research has corroborated Nachemson's work and brought new information to light, such as the curvilinear decrease in pressure when moving from a flexed to extended position in standing.[36] There is no such curvilinear correlation in sitting,[36] but different sitting positions do produce varying disc pressures. Muscular contraction can also increase disc pressure.[37] Sustained increases in disc pressure are generally related to injury, the rhythmic pressure changes associated with muscular contraction during exercise may promote a flow of fluid and nutrition to the disc. This research indicates that exercises that involve some changes in positioning, combined with muscular contraction provide the most benefit for intervertebral disc health.

Cycle Ergometers and EMG activity in the trunk and lower extremity

During regular cycling exercise, there is very little abdominal activity unless a sprinting or a standing posture is adopted.[38] Without sprinting or standing, the abdominal wall is activated at a low, continual level while the erector spinae activity is very low – generally less than 5% of maximal voluntary contraction.[38] Similarly, rectus abdominus activity remained relaxed in all pedaling intensities in three different road cycling postures—hands on upper bars, hands on lower bars, and forearms resting on triathlon aero bars.[39] Interestingly, paravertebral muscle activity decreased with lower hand positions but increased with pedaling intensity. The little abdominal activity that exists may be attributed to a respiratory-related function.[40]

Abraham et al[40] found that progressively increasing work during cycling caused rectus abdominus and external oblique activity to increase throughout exercise. However, when work was held constant, exercise levels increased above resting rate and remained steady throughout the duration of the exercise. Furthermore, rectus activity remained elevated after the immediate cessation of cycling, whereas external oblique activity decreased with the cessation of lower extremity movement. From these results, Abraham et al[40] postulated that abdominal muscles support ventilatory increases during heavy, constant work rate cycling. Since the external obliques cease firing when leg movement stops and rectus abdominus continues to fire strongly in accordance with ventilation, a conclusion can be made that external oblique muscle activity was related to stabilizing leg movement but rectus abdominus activity was not.

Abdominal EMG Responses

Apart from the activity related to lower extremity movement, core muscles may also fire in response to a central nervous system feed-forward connection. Hodges and Richardson[41] demonstrated that core muscles are activated before voluntary lower extremity movement. In sagittal plane movements, all abdominal muscles and the multifidus reacted before rectus femoris during hip flexion. Alternatively, movement toward hip extension resulted in the activation of only the abdominal muscles prior to the gluteus maximus contraction.[41] Extrapolating from this, it may be reasonable to expect that some of the small amount of core EMG activity during cycling is attributable to this feet forward mechanism.

The type of support, whether stable or labile, is another important factor that may contribute to the amount of abdominal activity. In a comparison of curl-ups in four different conditions—a flat surface, an exercise ball with the feet on the floor, an exercise ball with the feet on a stable chair, and an exercise ball with the feet on a wobble-board—abdominal muscle activity increased as the stability of the exercise was decreased.[42] The highest abdominal muscle EMG activity was observed when the subjects performed the curl-ups on the ball with their feet on the wobble-board. Notably, the ratio of oblique to rectus abdominus activity increased, indicating that higher levels of motor control were required to maintain spinal stabilization in the more unstable conditions.[42]

Tilting in space may also constitute a labile surface, resulting in varying levels of motor control and muscle activation. Brown, Kautz, and Dairaghi[43] had subjects pedal a cycle while strapped to a board that was tilted backwards from 0-80° in increments of 10° with respect to vertical. The experiment examined lower extremity muscle activity and joint torque while pedaling at different body orientations. In order to maintain crank angular velocity, the subjects altered activation and torque patterns. Hip flexion was greater in the vertical position while torque was similar regardless of the angle of tilt for the cycle position. Greater knee extension torque was observed in the vertical position, while knee flexion torque was elevated in the tilted position. Interestingly, peak activity was similar during the tilting maneuver, and differences in muscle activity were mainly due to changes in duration of activation.[43] This indicates an advanced level of motor control that relies on timing rather than peak muscle recruitment to maintain crank velocity.

Magnus Cycle

The Magnus Cycle is a prototype exercise bike developed to provide cardiovascular conditioning and core muscle training. While the design of the Magnus Cycle appears to support the activation of the core trunk muscles, the claims have never been studied. The Magnus Cycle is pedaled like any other upright cycle ergometer. At the same time, the novel oscillating capacity is designed to activate the core musculature while simultaneously providing a lower extremity and cardiovascular workout. It accomplishes this goal by tilting forward and backward while pedaling (Figures 1 & 2). The riding assembly of the cycle that tilts includes the seat, handles, and pedals—allowing a rider to maintain the same body position while gravity affects the body at differing angles.

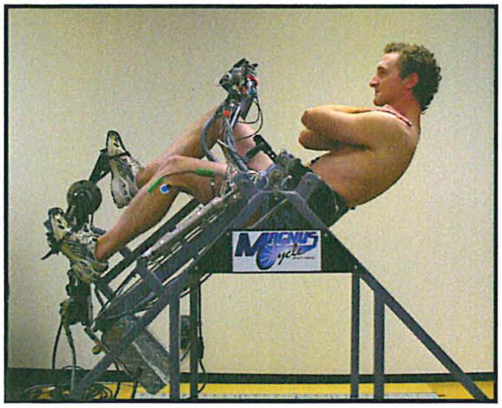

Fig. 1: The Magnus Cycle in feet forward position.

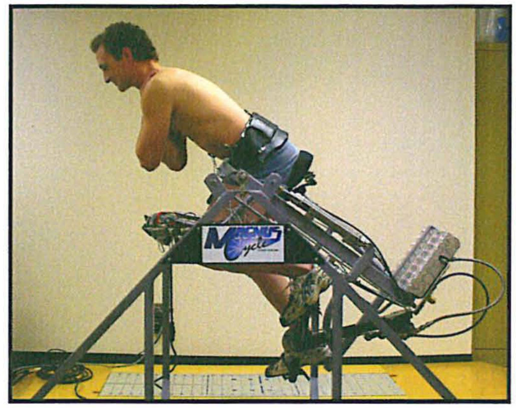

Fig. 2: The Magnus Cycle in feet backward position.

The study by Brown et al[43] also assessed muscular response to tilting while cycling, and it was similar to the Magnus Cycle in many ways, but some key differences were present. Subjects were strapped to a board, precluding a natural, flexed cycling posture; the apparatus only tilted backward,[43] whereas the Magnus Cycle tilts both directions; and a belt was used to ensure complete stability at the pelvis, while the Magnus Cycle has a safety harness at the pelvis that does not prevent all movement. Brown et al[43] found that timing of lower extremity muscular contraction, not peak activity, changed with tilting. The Magnus Cycle is also expected to produce a change in timing of muscle activation; however, without the rigid support of the pelvis and upper body, it is expected that the Magnus Cycle will result in elevated peak activity. Also, more activity is expected in the core trunk muscles than in normal cycling, which can be explained by examining the force vectors present in cycling situations on the Magnus Cycle.

In upright and unsupported bicycling, the force vector of a person's upper body weight is directed downward into the seat of the bicycle (Figure 3).

Fig.3: Stationary/Upright Position with an arrow indicating the theorized gravitational force vector.

When using the Magnus Cycle, the user is tilted either forward or backward resulting in the force vector migrating off of the seat and either in front of or behind the user, respectively (Figures 4 & 5).

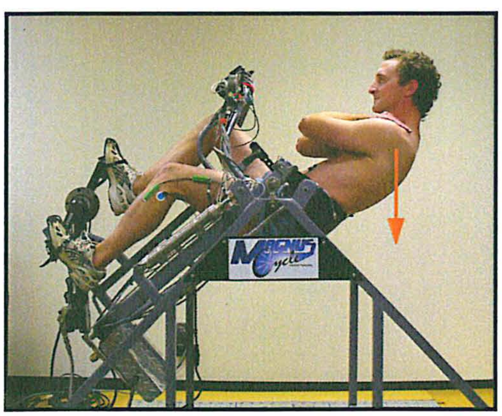

Fig. 4: Feet Forward Position with an arrow indicating the theorized gravitational force vector.

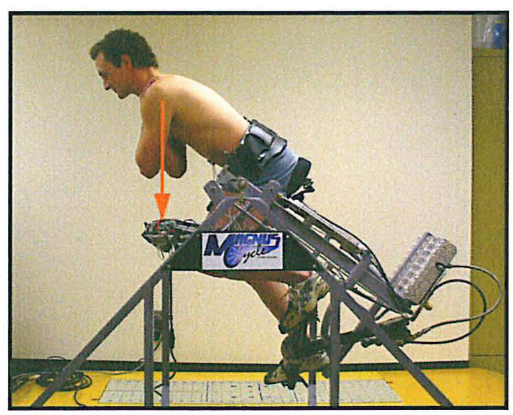

Fig. 5: Feet Backward Position with an arrow indicating the theorized gravitational vector.

By maintaining upper body position in relation to the riding assembly, the turning moment is maintained and increased as the angle of tilt becomes greater. Ligamentous and muscle activity is required behind the center of rotation in order to maintain the upright position, just as in any other rotational situation in the back.[44]

Analysis of force vectors reveals that the tilting motion of the Magnus Cycle can activate core trunk musculature. Furthermore, the length of time to complete a full oscillation on the Magnus Cycle may produce isometric muscle contractions of the trunk throughout the duration of the tilt (approximately 40 seconds). Prolonging the duration of isometric contractions increases strength and cross sectional area of the muscles involved.[45] Although this phenomenon was examined specifically in the quadriceps, where training with longer duration contractions (4 repetitions of 30 seconds versus 4 sets of 10 repetitions with a 3 second hold) increased isometric strength and muscle cross sectional area,[45] the results may be extrapolated to trunk musculature.

An isometric strength increase, as a result of tilting, is not the only means of increased muscle activity expected from the Magnus Cycle. Considering the feed-forward mechanism postulated by Hodges and Richardson[41], it is possible that the Magnus Cycle will also elicit core muscle activity in a dynamic context of concentric and eccentric activity to stabilize the continuous lower extremity movement.[40] This mechanism may lead to higher levels of motor control, which is evidenced by a higher oblique to rectus abdominus ratio.[42]

Abdominal strength is important because of the role it plays in low back pain.[1] Mechanical instability of the lumbar spine and low back pain are strongly associated,[1] and stability of the trunk depends on activation of all trunk muscles.[31] Although stabilization of the spine is effective in treating chronic low back pain,[26] general back and abdominal exercises may be of equal or greater benefit.[29,30] The Magnus Cycle addresses spinal stability through the latter theory of general exercise, without requiring conscious contractions of specific muscles. The Magnus Cycle does this partly because the cycling motion independently activates the core trunk musculature,[40] but more importantly, a combination of prolonged isometric contractions and the muscle activation associated with cycling suggest that the Magnus Cycle may be effective during rehabilitation of the trunk and core musculature.

Aside from stability, the Magnus Cycle may address the increased risk of low back pain identified in subjects with decreased paraspinal muscle endurance.[10,17] In addition, cycling itself can improve functional status in clients with chronic low back pain.[33] Therefore, combining core muscle activation with cycling should address the strength, endurance, and functional aspects that can contribute to back pain relief.

Muscular causes and cures for back pain are certainly relevant, but the spinal column itself should be addressed, especially changes in intervertebral disc pressure. Extreme end range positioning should be avoided when working on lumbar stability,[34] but changes in pressure may actually be healthy for the disc.[37] The Magnus Cycle will force riders to move from sitting relaxed without a backrest, to active straightening of the back, and to sitting with flexion. Disc pressures in these positions have been demonstrated as 0.46 MPa, 0.55 MPa, and 0.83 MPa, respectively.[37] Muscular contractions themselves may change disc pressure,[37] which may occur throughout the oscillations of the Magnus Cycle.

Although the Magnus Cycle has never been studied, many assumptions can be made as to its effects. Cycling alone has many proven cardiovascular benefits and can improve back pain.[33] Abdominal and back exercises have demonstrated effectiveness in treating back pain through improved spinal stabilization and paraspinal endurance.[1,10,17,26,29-31] In terms of quality of core strengthening exercises, the postulated effects on muscle activation, motor control, and strength gains,[41,42,45] combined with the benefit of cardiovascular effort from cycling, may make the Magnus Cycle one of the most effective exercises available.

To determine the effect of riding the Magnus Cycle on activation of the core trunk musculature, EMG activity of the core trunk muscles and major thigh muscles will be compared to cycling in a stationary, non-tilting manner, and while oscillating on the Magnus Cycle. The first hypothesis is that the tilting Magnus Cycle will show significant increases in EMG activity compared to non-tilting, stationary cycling. A further hypothesis is that backward tilting will increase the activity of the abdominal musculature (rectus abdominus and external oblique) and rectus femoris, and forward tilting will increase the activity of the erector spinae and biceps femoris. These hypotheses develop from known muscle actions of the muscles in question: The rectus abdominus and external oblique resist trunk extension, and the rectus femoris resists posterior pelvic rotation—which can be caused by trunk extension. The erector spinae resists trunk flexion, and the biceps femoris can resist anterior pelvic rotation—which can be caused by trunk flexion.

CHAPTER III

METHODS

This project was reviewed and approved by the University of North Dakota Institutional Review Board prior to the initiation of the study (See Appendix A).

Subjects

Participants were recruited by means of fliers at the University of North Dakota School of Medicine and Health Sciences building and personal communication with physical therapy students currently enrolled in the program, members of other health professions within UNDSOMHS, and the general public. At the time potential subjects were recruited, the selection criteria were communicated. Prospective subjects were healthy adults age 18-60 years with the ability to give consent to participate in research. Prospective subjects were excluded for the following reasons: diagnosed or undiagnosed musculoskeletal disorders, two or more risk factors as assessed by the PAR-Q,[46] previous total joint arthroplasty, cardiovascular disease or greater than two cardiovascular risk factors as defined by the American College of Sports Medicine guidelines,[46] pulmonary disease, history of abdominal or back pain, women who were pregnant or had given birth in the previous 6 months, or the inability to perform exercises. Persons allergic to latex, rubbing alcohol, or adhesives, and persons with any medical condition that presented potential risks or confounding variables were also excluded.

The novelty of the Magnus Cycle results in limited research on the cardiovascular and musculoskeletal response when utilizing the device. Therefore, to minimize the risk of adverse consequences, the exclusion criteria were rather rigorous. Individuals with musculoskeletal disorders, previous total joint arthroplasty, and history of abdominal or back pain had the potential of introducing undesired confounding variables. Due to the novelty of the Magnus Cycle exercise, subjects with known cardiovascular and pulmonary disease and/or more than one risk factor could introduce a potentially hazardous health situation and were therefore excluded. The morphological and hormonal changes associated with pregnancy may alter the fit of the Magnus Cycle and therefore could have introduced undesired confounding variables. Allergies to material used in the study, such as adhesives for the EMG electrodes, would have presented undesirable reactions for the subjects.

Procedure

Research was conducted in the Physical Therapy Department in the School of Medicine and Health Sciences building at the University of North Dakota. Upon arrival, each participant completed a consent form and reviewed a physical activity questionnaire PAR-Q.[46] Upon successful screening, the participant was prepared for participation.

Subject Preparation

Self-adhesive, pre-gelled Ag/AgCl snap EMG surface electrodes (Model #272, Noraxon USA, Scottsdale, AZ) with an inter-electrode distance of 2.0 cm were placed unilaterally on the left side of each subject's body over the rectus abdominus, external oblique, erector spinae, biceps femoris, and rectus femoris musculature. Measurements for electrode placement were: rectus abdominus, 2 centimeters superior and 2 centimeters lateral to umbilicus; erector spinae, horizontally aligned with the L3-4 interspace and 4 cm lateral to midline; external oblique, 5 centimeters superior to the anterior superior iliac spine (ASIS); biceps femoris, midpoint of a line from the ischial tuberosity to the lateral femoral condyle; and rectus femoris, midpoint of a line from the ASIS to the superior pole of the patella (minimum of 10 cm above the patella) (Figures 6 & 7). Prior to placement, the electrode sites were prepared by clipping excess hair, rubbing with 400 grit sandpaper, and vigorously wiping the skin with an isopropyl alcohol soaked towel. Surface electrode impedance levels were measured at 5 kOhms or less using an impedance checker (Noraxon USA, Scottsdale, AZ).

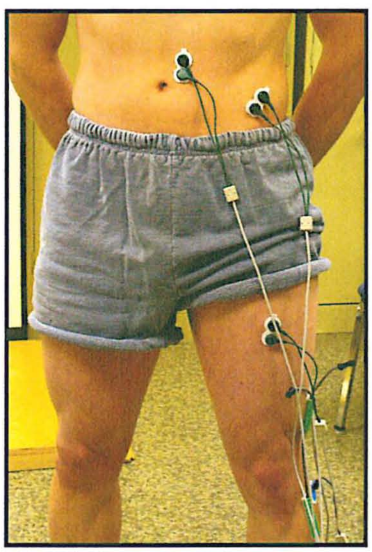

Fig. 6: Electrode placement for the rectus abdominus, external oblique, and rectus femoris.

Fig. 7: Electrode placement for the erector spinae and biceps femoris.

Equipment Instruction and Familiarization

The subjects were instructed on the use of the Magnus Cycle and allowed to ride in stationary mode (Figure 8) for 2 minutes and in movement mode (Figures 1 & 2) for one complete cycle from upright position to feet forward to feet backward and return to upright position—approximately 1 minute. In the latter setting, the Magnus Cycle tilts 50° from vertical in each direction.

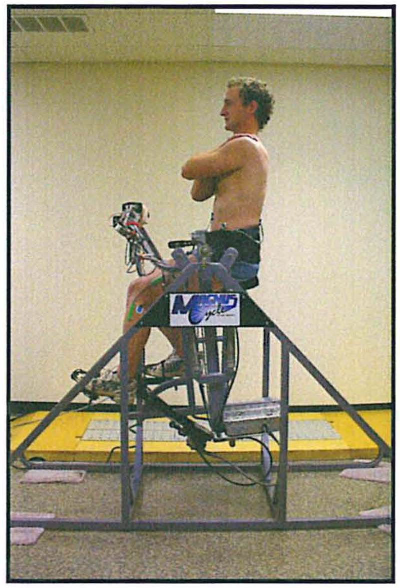

Fig.8: The Magnus Cycle in the stationary/upright position.

A metronome, set at 1Hz, was used to pace a subject's cycling rate at 60 revolutions per minute. During this time, participants were instructed in the use of the Borg Rate of Perceived Exertion (RPE) scale[46] to be utilized as a subjective measure of exercise intensity on the Magnus cycle.

Data Collection

Baseline measurements of heart rate, blood pressure, and RPE were recorded using a heart rate monitor (Polar A3 Heart Rate Monitor, Kempele, Finland), manual sphygmomanometer, and the Borg RPE scale, respectively. Vital sign measurements were repeated at 1, 3, and 5 minutes during the oscillation exercise sessions and at 2 minutes during stationary cycling.

Maximal Voluntary Contractions

The EMG leads were connected to the electrodes and verification of an appropriate signal was determined through visual inspection. The EMG activity was transmitted from the telemetry transmitter to a TeleMyo 900 (Noraxon USA, Scottsdale, AZ) receiver, which was interfaced with an analog to digital interface card (Noraxon USA), and viewed on a standard laptop computer monitor prior to saving to the hard-drive (HP Pavilion ZV5000, Pentium 4 2.80 GHz processor). In order to normalize EMG data, five second maximal voluntary contractions (MVC) of the rectus abdominus, external oblique, erector spinae, rectus femoris, and biceps femoris were conducted using standardized positions.[47] The participant then rested until physiological variables returned to baseline levels.

Bicycle Usage

Randomization of the experimental conditions (movement or stationary) was accomplished by alternating the order of testing so that half of the subjects began with the stationary setting while the remaining subjects began with the oscillating setting. The participants rode the Magnus Cycle in the stationary setting at 60 rpm for 3 minutes and the movement setting at 60 rpm for 5 oscillation cycles. Between testing conditions, participants were given a rest break of 3-5 minutes allowing their heart rates to return to baseline.

Physiological stopping points for the exercise sessions included: drop in systolic blood pressure of greater than 10 mm Hg from baseline blood pressure despite an increase in workload; fatigue, shortness of breath, wheezing; leg cramps, or claudication; systolic blood pressure greater than 225 mm Hg and/or diastolic blood pressure greater than 115 mm Hg; participant desire to stop; exercise heart rate greater than 85% of age adjusted maximum heart rate; or rate of perceived exertion (RPE) greater than 16.

Data Analysis

Data analysis was performed using the MyoResearch XP (Noraxon, USA) software program. To compare EMG data between subjects, signals were rendered as a percentage of maximal voluntary contraction for each subject. Using the MyoResearch XP (Noraxon, USA) software program, the raw EMG signals were rectified, smoothed (RMS 50ms), and normalized to the maximal 1000 contiguous points of EMG activity that occurred within the maximal voluntary contraction of each muscle. However, external oblique was normalized to the maximal activity observed during the rectus abdominus MVC test position.

Statistical Comparisons

Data are presented as Mean±standard deviation. Data utilized for statistical comparisons are averages of five, consecutive pedal revolutions as subjects were cycling at 60 rpm. Pedal revolutions were determined from electrogoniometer (Model SG 150, Biometrics, Ltd., Ladysmith, VA) data received from the knee movement. In the stationary setting, data utilized for analyzing was collected at 30 seconds and 150 seconds of cycling. Oscillating data was collected from the five revolutions prior to the point of maximal backward tilting (feet forward) and maximal forward tilting (feet backward) for each of the five oscillations.

A repeated measures t-test was utilized to assess differences in EMG activity between minutes one and three of stationary cycling. Differences in the oscillating condition for forward and backward tilt across all five oscillations was determined using a repeated measures ANOVA, with an alpha level set at 0.05. To compare stationary cycling to the movement setting, stationary trials, feet forward trials, and feet backward trials without significant differences were compared using a one way ANOVA. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software program (Version 11.0.1, SPSS Inc., Chicago, IL). Post hoc analysis was performed using the Bonferroni method for multiple significances.

CHAPTER IV

RESULTS

Subjects

Sixteen persons (5 male and 11 female) between the ages of 18 and 35 years participated in the study. No potential subjects were required to be excluded based upon the exclusion criteria or PAR-Q[46] questions. The average of baseline heart rates for all participants was 82 beats per minute (bpm) (range = 49-99). The average of heart rates for all participants was 115 bpm (range = 81-160) during use in the stationary setting, and 126 bpm (range = 88-168) during use in the movement setting. The average of baseline rate of perceived exertion (RPE) for all participants was 6 (range = 6). The average RPE for all participants was 9 (range = 7-11) during use in the stationary setting, and 12 (range = 7-16) during use in the movement setting. No participants required the study to be stopped due to exceeding any of the physiological stopping points, no participants experienced physiological symptoms causing stoppage of the study, and no participants asked to cease participation during activity.

Stationary Cycling Comparisons

The paired samples t-test revealed no significant difference ($p>.1$) in EMG activity for any muscle (rectus abdominus, external oblique, erector spinae, rectus femoris, or biceps femoris) between the first and third minute of the stationary cycling (Table 1).

Table 1. Paired Samples t-test for stationary trials at 30 seconds and 150 seconds.

	Trial	n	M (% MVC)	SD	t	df	Sig. (2-tailed)
Rectus Abdominus	1	15	4.4	2.3	0.165	14	0.872
	2	15	4.4	2.3			
External Oblique	1	15	5.5	3.9	0.518	14	0.612
	2	15	5.4	3.8			
Erector Spinae	1	16	3.3	3.7	0.156	15	0.878
	2	16	3.4	3.4			
Rectus Femoris	1	16	15.9	11.7	1.603	15	0.130
	2	16	14.7	10.6			
Biceps Femoris	1	16	6.6	3.9	0.741	15	0.470
	2	16	6.2	3.9			

Oscillating Cycling Comparisons

The repeated measures ANOVA revealed no significant difference between the five trials in the mean EMG activity of rectus abdominus, external oblique, rectus femoris, or biceps femoris during the feet forward position (Table 2). The repeated measures ANOVA revealed no significant difference between the five trials in the mean

EMG activity of rectus abdominus, external oblique, rectus femoris, or biceps femoris during the feet backward position (Table 3).

Table 2. Repeated measures ANOVA for movement trials in the feet forward position.

	Trial	n	M (% MVC)	SD	F	df	p	eta	power
Rectus Abdominus	1	16	29.7	22.9					
	2	16	32.5	18.9					
	3	16	30.5	18.5	0.214	1,15	0.650	0.014	0.072
	4	16	29.8	16.0					
	5	16	30.8	16.8					
External Oblique	1	15	64.4	38.5					
	2	15	75.7	60.4					
	3	15	72.8	46.9	1.293	1,14	0.275	0.085	0.185
	4	15	71.5	48.9					
	5	15	72.9	48.3					
Erector Spinae	1	15	3.0	1.2					
	2	15	3.8	1.8					
	3	15	4.1	1.8	10.730	1,14	0.006*	0.434	0.861
	4	15	4.2	1.8					
	5	15	4.6	1.9					
Rectus Femoris	1	14	34.8	10.7					
	2	14	41.0	14.2					
	3	14	44.3	17.4	2.275	1,13	0.155	0.149	0.287
	4	14	48.1	28.5					
	5	14	46.8	18.7					
Biceps Femoris	1	15	5.8	6.3					
	2	15	5.4	4.0					
	3	15	4.8	3.6	0.200	1,14	0.661	0.014	0.070
	4	15	5.0	4.9					
	5	15	5.3	5.2					

*Significant Difference identified between oscillating trials.
Values for F, df, p, eta, and power reflect analysis between all five trials for each muscle.

Table 3: Repeated measures ANOVA for movement trials in the feet backward position.

	Trial	n	M (% MVC)	SD	F	df	p	eta	power
Rectus Abdominus	1	16	9.3	9.9					
	2	16	8.3	7.5					
	3	16	8.2	7.8	1.337	1,15	0.266	0.082	0.191
	4	16	9.9	13.5					
	5	16	11.4	12.9					
External Oblique	1	14	16.5	20.3					
	2	14	23.8	27.4					
	3	14	19.4	21.5	1.673	1,13	0.218	0.114	0.224
	4	14	17.5	20.4					
	5	14	19.0	23.5					
Erector Spinae	1	16	24.4	7.9					
	2	16	21.4	8.6					
	3	16	20.7	8.0	9.157	1,15	0.009*	0.379	0.807
	4	16	20.1	8.3					
	5	16	20.5	8.1					
Rectus Femoris	1	15	14.5	9.9					
	2	15	12.2	6.3					
	3	15	17.4	25.2	1.059	1,14	0.321	0.070	0.160
	4	15	10.2	5.9					
	5	15	10.5	5.4					
Biceps Femoris	1	15	25.7	21.4					
	2	15	21.4	13.6					
	3	15	21.3	13.0	0.839	1,14	0.375	0.057	0.137
	4	15	22.3	16.5					
	5	15	24.9	19.0					

*Significant Difference identified between oscillating trials.
Values for F, df, p, eta, and power reflect analysis between all five trials for each muscle.

Therefore, trial one for rectus abdominus, external oblique, rectus femoris, and biceps femoris in feet forward and feet backward were used to compare to the stationary trial. Notably, the erector spinae muscles displayed significantly different activity during the first oscillating trial (lower in feet forward, $p<.049$; higher in feet backward, $p<.023$) (Tables 2 & 3), but the remaining four oscillations were not significantly different from one another (Table 4). Therefore, trial 2, which was not different from trials 3, 4, and 5, was utilized when comparing EMG activity of the erector spinae between the stationary and oscillating conditions (Table 4).

Table 4. Pairwise comparison of the erector spinae movement trials.

Feet Back				Feet Forward			
Trial	**Trial**	**Sig.**	**Std. Error**	**Trial**	**Trial**	**Sig.**	**Std. Error**
2	1	0.023	0.807	2	1	0.049	0.224
	3	1.000	0.714		3	0.991	0.174
	4	0.306	0.539		4	0.761	0.209
	5	1.000	0.975		5	0.208	0.320

Stationary vs. Feet Forward vs. Feet Backward

For all five muscles examined (rectus abdominus, external oblique, erector spinae, rectus femoris, and biceps femoris), there was a significant difference in percent MVC between the position variables (Figure 9). In the feet forward position, the rectus abdominus, external obliques, and rectus femoris demonstrated a significantly higher percentage of MVC from the stationary position (rectus abdominus $p<.002$; external oblique $p<.001$; rectus femoris $p<.002$).

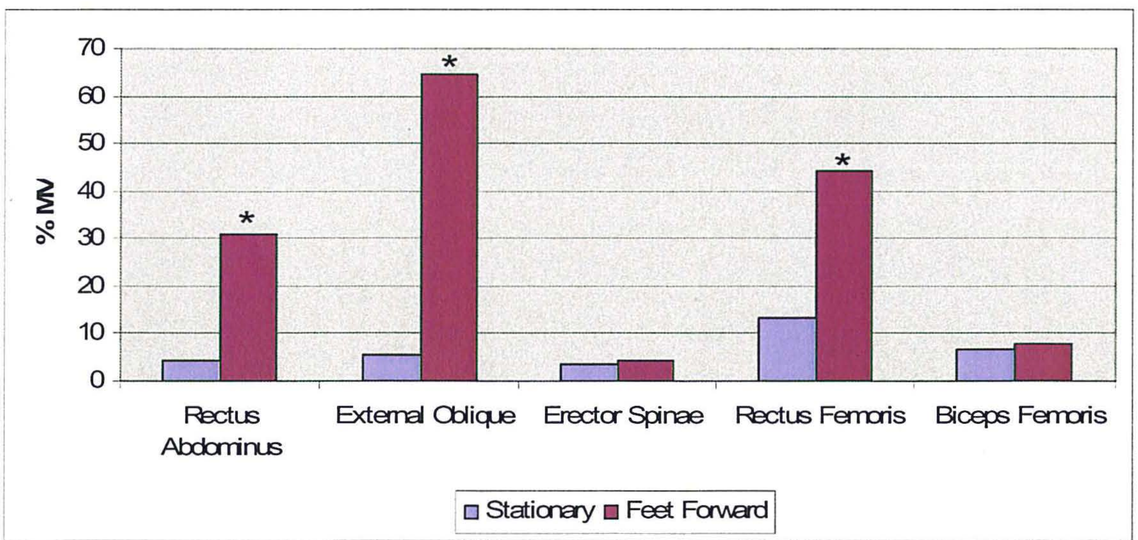

Fig 9. Comparison of muscle activity (percentage of MVC) between the stationary setting and movement setting during the feet forward position.
*Significant difference in muscle activity was identified.

In the feet backward position, the EMG activity of erector spinae and biceps femoris showed a significantly higher percentage of MVC from the stationary position (erector spinae p<.001; biceps femoris p<.01); rectus abdominus, external obliques, and rectus femoris were not significantly different (Figure 10). Pair-wise comparison of stationary to feet backward cycling in Trial 1 for erector spinae revealed significance at p<.001 - a similar significance to the comparison of stationary to Trial 2 (p<.001).

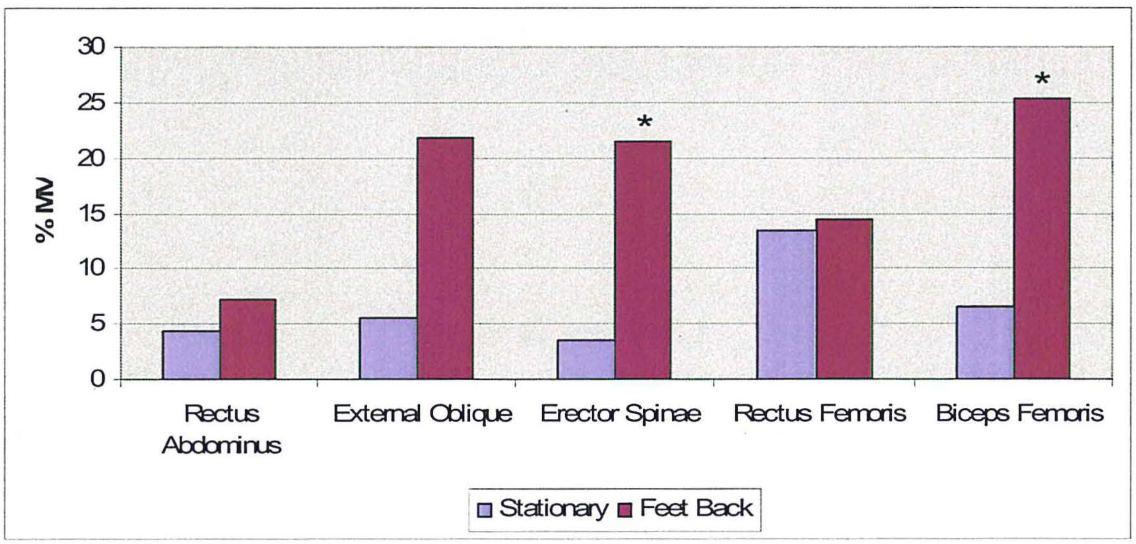

Fig 10. Comparison of muscle activity (percentage of MVC) between the stationary setting and movement setting during the feet backward position.
*Significant difference in muscle activity was identified.

CHAPTER IV

DISCUSSION

The Magnus Cycle is a novel exercise device proposed to activate core trunk muscles in addition to providing cardiovascular exercise. The purpose of this study was to ascertain whether the oscillating condition of the Magnus Cycle augments EMG activity of core muscles compared to stationary cycling. The lower extremity muscles, rectus femoris and biceps femoris were also examined for changes in EMG activity. The oscillating condition of the Magnus Cycle resulted in significantly greater EMG activity. Specifically, when tilting with the feet forward, the Magnus Cycle elicits greater EMG activity in the rectus abdominus (675%), external obliques (966%), and rectus femoris (238%), when compared to stationary cycling. While feet back tilting produces 600% and 257% greater EMG activity in the erector spinae and biceps femoris, respectively.

Stationary Trials

Comparisons of stationary cycling at 30 seconds and 150 seconds of steady state exercise revealed no difference, meaning that subjects had attained a steady state of EMG activity, and stationary data from 30 seconds could be used to compare against oscillating results. Three minutes was chosen as the optimal duration for this activity because it is sufficient enough to obtain a steady state of activity[48] and not long enough to produce fatigue,[49] which may have confounded results. Furthermore, stationary cycling was performed on the Magnus Cycle itself, rather than another stationary bicycle. This was done in order to ensure that resistance at the pedals remained constant, that the subjects' position relative to the bicycle remained constant, and because less movement between stations allowed for a more controlled environment with less chance for EMG interference. By limiting variability, all significant differences can be attributed to position, as confounding variables are greatly decreased. The implications of the study were not limited by constructing the experiment in this way because posture in the stationary setting of the Magnus Cycle is similar to other bicycles and exercise bicycles, allowing extrapolation of comparisons to any other cycle. Results from this setting were very similar to those found by Juker et al[38], where abdominal and erector spinae activity was approximately 5% MVC or less. The congruity of these results indicates that a comparison can be made between the Magnus Cycle and cycle ergometers.

Comparison of 5 Oscillations

Due to the novel nature of the Magnus Cycle, five consecutive oscillations were used to minimize the potential for learning to occur and obfuscate results in the initial trials. The oscillating mode of the Magnus Cycle results in core trunk muscle isometric contractions, of approximately 40 seconds in each direction (feet forward and feet back), to maintain position in relation to the bike. Prolonged isometric contractions can result in fatigue of the core trunk musculature.[50] To minimize the potential for fatigue, the present study limited oscillations to five and analyzed EMG activity between repetitions of the oscillations. A comparison of all trials indicated there was no difference between oscillating trials in any of the muscles except erector spinae.

Erector spinae demonstrated a significant difference in feet forward and feet back for the first trial compared to trials 2 through 5; there was no other difference between trials. Possible explanations include a training effect in the first trial and subject alterations of posture. It was observed that some subjects did not initially maintain their position relative to the Magnus Cycle but tried to maintain a more vertical orientation. This may have been due to apprehension and unfamiliarity, despite performing a practice oscillation. Ostensibly, a change in erector spinae EMG activity due to posture would have produced a difference in other muscles as well. However, no other muscle showed a significant difference. The theoretical value of this premise remains because the muscles may not have been activated differentially by the indicated change in posture. As an example, the abdominal muscles may not have been affected by trunk posture because they still had the role of stabilizing pelvic motion to allow effective lower extremity movement.

Neuromuscular adaptation may have also played a role in decreasing the hysteresis in erector spinae activity. The first trial exhibited significantly lower EMG activity in foot forward and higher EMG activity in foot backward than the subsequent four trials. Decreasing and increasing activity, respectively, may have been accomplished by recruiting other muscles—such as multifidus—to prevent early fatigue of erector spinae.

Stationary Compared to Oscillating Cycling

Rectus abdominus was largely activated by the same means as a typical sit-up, meaning that a downward gravity vector outside of the center of gravity forced activation of the rectus abdominus to maintain body position. As well, there is a possibility that respiration caused an increase in activity,[40] but this was not seen in stationary cycling, nor did subjects appear to be working overly hard—all were able to speak easily during exercise and none registered a rate of perceived exertion greater than 16 on the Borg RPE scale.[46]

External oblique activity increased by the same means as rectus abdominus. Additionally, the obliques have demonstrated increased activity with lower extremity movement,[40] which is likely due to a role in pelvic stabilization. Two explanations can account for this: first, when lower extremity movement causes forward pelvic rotation, the length tension curve of the obliques may place them in a mechanically advantageous position to contract and stabilize; second, a feed-forward mechanism may have caused contractions to stabilize the pelvis in anticipation of perturbation caused by lower extremity movement.[41] In any case, the level of neuromuscular control in the present study is evidenced by the oblique to rectus abdominus ratio that increased from 1.25 in stationary to 2.08 in feet forward and 3.03 in feet backward pedaling.[42]

The stabilizing effect of the oblique musculature during lower extremity movement also accounts for the high amount of oblique activity in feet backward pedaling. The sagittal plane effect of gravity in this position will not require a contraction of anterior musculature, but when the gravity induced anterior pelvic rotation (controlled by posterior muscles) is combined with movement of the lower extremities, the pelvis must also be stabilized in the transverse plane—necessitating oblique activity, either through length tension relationships or feed-forward anticipation. Notably the external oblique: rectus abdominus ratio was higher in the feet back position. However, the absence of an antigravity effect in this position resulted in statistically similar EMG activity of the rectus abdominus and external oblique muscles.

Leg movement, whose stabilization affected oblique activity, did not contribute to erector spinae. The attachments of erector spinae allow it to perform sagittal pelvic rotation and trunk side-bending,[51] but the erector spinae does not have the mechanical pull necessary to control transverse rotation of the pelvis. Therefore, erector spinae muscles' significant activity in a feet backward position was based solely on gravity, which worked in the same manner as rectus abdominus did in the feet forward position.

Muscles of the thigh, particularly rectus femoris and biceps femoris, extend from the pelvis to the leg and have dual responsibilities of knee extension/flexion, and hip flexion/extension, respectively. Typically, the movement at the hip causes osteokinematic actions seen in the lower extremity, however, when the leg is fixed the action of the muscles results in pelvic and trunk action. Although the lower extremities are not fixed, they maintain a stabilized position and axes of motion by virtue of their placement in the pedals, allowing the thigh muscles to control both pelvic and knee movement.

The rectus femoris demonstrated increased activity in the feet forward position. Stronger contractions were elicited because this position forced the knee to extend the weight of the leg against gravity, which was not the case in stationary and feet backward pedaling. Second, the rectus femoris may provide pelvic stabilization through its attachment to the pelvis, thus increasing activation in order to maintain a relatively neutral pelvic position and counteract the effect of gravity pulling the pelvis, through the trunk position, toward posterior rotation.

The biceps femoris had anti-gravity activity that was similar to rectus femoris, but occurred in the opposite position (feet backward) and had to flex the weight of the leg against gravity. In this position, it also had a similar effect on pelvic rotation, but it assisted with posterior sagittal stabilization of the pelvis. Biceps femoris has the benefit of large gluteal muscles that act in the same manner[52], for these reasons biceps femoris did not have the level of activity seen in rectus femoris (25.3% MVC vs. 44.2% MVC, respectively).

In contrast with the lower extremity results found in this study, Brown, Kautz, and Dairaghi[43] saw greater muscle activity in knee extensors while vertical and knee flexors when tilted back into a feet forward position. The greater values obtained in Brown, Kautz, and Dairaghi,[43] however, were a result of activity duration not peak intensity, as was the case with the Magnus Cycle. Furthermore, the study designs varied in pelvic/trunk stabilization and pedal location to an extent that makes direct comparisons impractical. Brown et al[43] used belts to ensure complete pelvic stability and subjects were on a board with pedals directly below the hips; the lack of a dynamic pelvis and a natural pedaling posture are likely the reasons for the differences in results.

Clinical Relevance

The Magnus Cycle provides a method of training trunk muscles as well as muscles of the thigh by forcing the user to hold a trunk position relative to the tilt in space of the seat and pedal assembly. Trunk muscles play an important role in providing stability to the lumbar spine[1,4,7] as part of the spinal stabilization system described by Panjabi.[2,3] A failure in an area of the stabilization system causes a person to become susceptible to injury. Research has shown that the paraspinal muscles of patients with chronic low back pain are both weak[8,9] and fatigable.[10-16] Studies of persons who had previously been free from back pain reveal that poor paraspinal muscle endurance increases the risk for developing first-time low back pain.[10,17] Therefore, the Magnus Cycle may prove to be a beneficial tool in treatment of chronic low back pain and in prevention of episodes of low back pain by providing a training stimulus to the paraspinal muscles and other muscles involved in core strength, namely rectus abdominus, external oblique, rectus femoris, and biceps femoris.

In addition, a systematic review of literature indicated that exercise therapy for chronic low back pain has been proven to be effective.[21] Research also indicates that addressing deconditioning through exercise in a rehabilitation program can result in improvements in muscular performance and an individual's ratings of their perceived pain and disability.[18-20] Bicycling itself has been shown to be effective for low back pain patients.[33] A 12 week bicycle program improved functional status and well-being of adults with chronic low back pain. The Magnus Cycle, then, may prove to be a more effective tool for exercise-base rehabilitation for patients with low back pain.

Limitations

This was the first study performed on the Magnus Cycle and did not have the benefit of previous studies to guide its direction. For this reason, the subject sample was kept to a homogeneous group of healthy people in order to ascertain the EMG effects without introducing confounding variables. Although sample size provided sufficient statistical power, a larger, more heterogeneous subject group would have allowed for broader conclusions.

Most results supported the hypotheses, with the exception of the significant difference shown in trial one of erector spinae. The possibility of a training effect could have been diminished if a training day had been set up. This would ideally occur a few days prior to the experimental day, and participants could have practiced the exercise enough to become fully comfortable with the Magnus Cycle and still not present any issues concerning fatigue.

Some limitations involved problems inherent with surface electrodes. Interference caused by unknown factors affected some data to the extent that it was rendered useless. As well, the adhesive on some electrodes did not stand up to the combination of movement and sweat, making them fall off during some trials. Fortunately, neither of these issues affected statistical power when affected data was discarded.

Perhaps the largest limitation concerning surface electrodes was that they could not be placed on all desired muscles (such as internal oblique, gluteus maximus, and multifidus) because of the Magnus Cycle's harness system. This problem may have been precluded with intramuscular electrodes—which would have also provided more exact data.

The Magnus Cycle also presented pedal resistance problems inherent in a prototype machine. Resistance was adjusted to a low level that all participants considered easy in the stationary position. The average resistance remained at this level for all subjects and was not adjusted for body mass. Due to hydraulic control, the resistance was not consistent through all parts of the pedal stroke leading to a somewhat jerky feel. Resistance adjustment and consistent braking should be addressed in future models.

Future Study

Further EMG studies, particularly intramuscular EMG, should examine a wider range of muscles, including vastus medialis oblique, vastus lateralis, gluteus maximus, multifidus, quadratus lumborum, internal oblique, triceps surae, and tibialis anterior. Additionally, the Magnus Cycle was only examined at the full tilt setting, but has a setting that tilts to only 40° (as opposed to 50°) that was not examined. The tilting of the Magnus Cycle is 50° in each direction, but a motion analysis study would reveal whether pelvic tilt changes throughout the full oscillation. This information could provide more insight into the pelvic stabilization role of hip flexors and extensors.

The level of effort require by the Magnus Cycle was higher as demonstrated by increased average heart rate (115 bpm in stationary and 126 bpm in movement) and RPE (9 in stationary and 12 in movement) as compared to stationary. Possible implications of potential increased effort indicate that calorimetry studies may be beneficial. Calorimetry studies would allow comparison of the cardiovascular stimulus of the Magnus Cycle to various ergometers. The amount of muscle recruitment on the Magnus Cycle, in combination with cycling, suggests that VO2 max would be reached sooner and that the cardiovascular workout would be greater than other cycle ergometers at an equivalent level of pedal resistance. All tests, EMG, motion analysis, and calorimetric, could be completed at increased levels of resistance and for longer durations to test the effects and onset of fatigue.

Beyond tests with healthy subjects, different patient populations, including a variety of ages should be examined. A long-term treatment program for chronic low back pain could verify the postulated benefits for this clients with low back pain. Other long-term studies should address muscle strength and cardiovascular benefits of the Magnus Cycle. A variety of exercise protocols could be incorporated into long term studies – including interval training with varying speed, resistance, or tilt; cycling with handheld weights held in various shoulder positions; and combining Magnus Cycle training with sport specific exercise.

Conclusions

The tilting Magnus Cycle produces significantly greater muscle activity in the rectus abdominus, external oblique, erector spinae, rectus femoris, and biceps femoris muscles than stationary cycling. The trunk exercise makes the Magnus Cycle a better option for a quicker, more beneficial workout than standard stationary bicycles. The potential value of the Magnus Cycle for the young, healthy population is without question, but its application to elderly populations has not been established. The exercise provided by the Magnus Cycle has strong, theoretical potential for people with chronic low back pain, but this must be substantiated through further study.

APPENDIX

University of North Dakota Human Subjects Review Form

All research with human participants conducted by faculty, staff, and students associated with the University of North Dakota, must be reviewed and approved as prescribed by the University's policies and procedures governing the use of human subjects. It is the intent of the University of North Dakota (UND), through the Institutional Review Board (IRB) and Research Development and Compliance (RD&C), to assist investigators engaged in human subject research to conduct their research along ethical guidelines reflecting professional as well as community standards. The University has an obligation to ensure that all research involving human subjects meets regulations established by the United States Code of Federal Regulations (CFR). When completing the Human Subjects Review Form, use the "IRB Checklist" for additional guidance.

Please provide the information requested below:

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School/College: University of North Dakota Department: Physical Therapy

Project Title: Electromyographic Analysis of Abdominal and Low Back Extensor Musculature with use of an Experimental Stationary Bicycle

Proposed Project Dates: Beginning Date: June 1, 2006 Completion Date: May 31, 2007
(Including data analysis)

Funding agencies supporting this research: N/A

Did the contract with the funding entity go through UND Grants and Contracts Administration? N/A.
Attach a copy of the contact. Do not include the any budgetary information. The IRB will not be able to review the study without a copy of the contract with the funding agency.

___ YES or _X_ NO Does the Principal Investigator or any researcher associated with this project have a Financial Interests Disclosure Document on file in the RD&C office? If not, submit one along with this application. If any researcher associated with this project has a financial interest in the results of this project, submit, on a separate piece of paper, an additional explanation of the financial interest.

___ YES or _X_ NO Will research subjects be recruited at another organization (e.g., hospitals, schools, YMCA) or will assistance with the data collection be obtained from another organization?

If yes, list all institutions: ________________

Letters from each organization must accompany this proposal. Each letter must illustrate that the organization understands their involvement in that study, and agrees to participate in the study. Letters must include the name and title of the individual signing the letter and should be printed on letterhead.

Does any external site where the research will be conducted have its own IRB? N/A.

If yes, does the external site plan to rely on UND's IRB for approval of this study? N/A.
(If yes, contact the UND IRB at 701 777-4278 for additional requirements)

If your project has been or will be submitted to other IRBs, list those Boards below, along with the status of each proposal.

________________ Date submitted: ________ Status: ___ Approved ___ Pending
________________ Date submitted: ________ Status: ___ Approved ___ Pending

(include the name and address of the IRB, contact person at the IRB, and a phone number for that person)

Type of Project: Check "Yes" or "No" for each of the following.

X YES or ___ NO	New Project	___ YES or X NO	Dissertation/Thesis/Independent Study
___ YES or X NO	Continuation/Renewal	X YES or ___ NO	Student Research Project

___ YES or X NO Is this a Protocol Change for previously approved project? If yes, submit a signed copy of this form with the changes bolded or highlighted.

___ YES or X NO Does your project involve medical record information? If yes, complete the HIPAA Compliance Application and submit it with this form.

___ YES or X NO Does your project include Genetic Research?

___ YES or X NO Does your project include Internet Research?

Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

______ Children (< 18 years)	X UND Students
______ Prisoners	______ Pregnant Women/Fetuses

______ Persons with impaired ability to understand their involvement and/or consequences of participation in this research

______ Other ______________________________

Please use appropriate checklist when children, prisoners, pregnant women, or people who are unable to consent will be involved in the research.

This study will involve: Check all that apply.

______ Deception		______ Stem Cells
______ Radiation		______ Discarded Tissue
______ New Drugs (IND) IND # ____________	Attach Approval	______ Fetal Tissue
______ Non-approved Use of Drug(s)		______ Human Blood or Fluids
______ Recombinant DNA		Other
X None of the above will be involved in this study		______________________

I. Project Overview

The purpose of the study is to compare the efficacy of the Magnus Cycle—a prototype exercise device for improving aerobic endurance and core (abdominal and low back) muscle strength—to a stationary exercise bicycle. The comparison will be performed by monitoring the abdominal and low back muscles with electromyography (EMG). The significance of the study lies in the fact that current exercise bicycles do not incorporate abdominal and low back musculature. There has been no research to determine the efficacy of the Magnus Cycle's effects in abdominal and low back extensor musculature training. If a significant involvement of the abdominal and low back musculature is found, then the Magnus Cycle may be recommended for use with clients, such as individuals with low back pain, who require aerobic training and core strengthening. Human subjects are necessary to properly examine muscular involvement during bicycling.

II. Protocol Description

1. Subject Selection.

a) Subjects will be recruited from physical therapy students currently enrolled in the UND Physical Therapy program by the research team through word of mouth and fliers at the physical therapy department. Fliers will also be place in the the UND School of Medicine and Health Sciences where members of other health professions or the general public may be recruited.. (See attached flier).

b) At the time potential subjects are recruited, either by word of mouth or flier, the selection criteria described below will be communicated. Also, prior to participating in the study, subjects will be screened for the criteria via verbal questioning. Prospective subjects will be healthy adults age 18-60 years with the ability to give consent to participate in research.

c) Prospective subjects will be excluded for the following reasons: current diagnosed or undiagnosed musculoskeletal disorders, previous total joint arthroplasty, cardiovascular disease or greater than two cardiovascular risk factors, pulmonary disease, history of abdominal or back pain, women who are pregnant or have given birth in the previous 6 months, inability to perform exercises, the elderly, and minors. Persons allergic to latex, rubbing alcohol, or adhesives, and persons with any medical condition that may represent risks or present confounding variables, will also be excluded. Musculoskeletal disorders, previous total joint arthroplasty, and history of abdominal or back pain may introduce undesired confounding variables. Because exercise is involved, subjects with cardiovascular and pulmonary disease and/or more than one risk factor could introduce a potentially hazardous health situation, these groups will also be excluded. Pregnant women may have difficulty with the bicycle, and recent history of birth may introduce undesired confounding variables because of possible increased lumbopelvic laxity. Allergies to material used in the study, such as adhesives for the EMG electrodes, may present undesired reaction in the subject.

d) It is anticipated that approximately 40 subjects will participate in this study. This number was chosen to increase the power and validity of the statistical analysis of results.

e) This is a preliminary study, and no data exists to predict a specific magnitude of EMG increase. Current literature suggests that abdominals and back muscles are only minimally active during standard bicycling. Based on the design on the Magnus Cycle, and the fact that it necessitates muscular contraction in order to maintain the upright position while the bicycle tilts, we anticipate a significant difference over standard bicycling.

2. **Description of Methodology.**

a) Subjects will sign an Informed Consent document before participating in the study.

b) Research will be conducted in the Physical Therapy Department in the School of Medicine and Health Sciences building at the University of North Dakota.

c) Research will be conducted by David Relling, PT, PhD, and three graduate Physical Therapy Students trained in the use of the EMG equipment and Magnus cycle: Bryce A. Kelly, Christopher L. Podoll, and Kirk R. Van Slyke.

d) EMG data will be collected for maximal voluntary contractions (used to normalize data), during stationary cycling, and while cycling during the movement setting of the Magnus Cycle. EMG signals will be transmitted to the receiver unit and into a computer for display and analysis. Skin-fold measurements will be collected to calculate percent body fat (Skin folds used for Men: chest, abdomen, and thigh; for Women: triceps, suprailiac, abdomen). Subjects will then be prepared for electrode placement by clipping excess hair from areas of electrode placement followed bycleaning the area with isopropyl alcohol. A felt tip marker will be used to mark areas of electrode placement, and adhesive EMG electrodes will be placed over target muscles. Subjects will then be instructed on use of the Magnus Cycle. Participants will use the Magnus Cycle to warm up for 3 minutes (at 60 RPM) in the stationary setting and for 1 minute (at 60 rpm) in the movement setting. The EMG leads will then be connected to the electrodes. Maximal voluntary contractions of the target muscles will be conducted. Subjects then ride the Magnus Cycle in the stationary setting and the movement setting; the order will be randomized for each subject, and a three to five minute break will be given between exercises. At the conclusion of data collection, the EMG leads will be disconnected, the electrodes will be removed, the skin will be cleaned with alcohol, and the subject is free to leave. The study will require no longer than 1 hour time from each subject.

e) Digital photographs and videotaping will be taken for illustration purposes only. Consent will be received for use of any pictures and videos prior to the procedure. All electronic data (computer files/video tapes) will be stored in a separate, locked file cabinet in the Department of Physical Therapy for a period of three years, at which time the data will be erased.

f) The principal investigators are either faculty or graduate students in the Doctorate of Physical Therapy program at the University of North Dakota. They will conduct all procedures, and have been trained in the proper use of Electromyography equipment.

g) Subjects will not receive any compensation for participating in this study.

3. **Risk Identification.**

a) The risks involved in this study are minimal. The EMG testing equipment monitors skeletal muscle electrical activity. The EMG equipment does not stimulate or alter the subject's motion, therefore no discomfort to the subjects is expected.

Anticipated risks involve those associated with routine physical activity; these include, but are not limited to, fatigue, muscle cramping, and soreness. There is also a small risk of skin irritation from the electrodes. Due to the exposure of the back, abdomen, and thigh during electrode placement, there is a slight risk to the modesty of the subjects. Modesty will be controlled with the use of sheets, and by placing subjects in a private room during electrode placement.

In the event that this research activity results in a physical injury, medical treatment will be readily available, including first aid, emergency treatment and follow-up care as it is to any member of the general public in similar circumstances. The subject or the subject's third party payer, if applicable, must provide payment for any treatment.

b) No subject's names will be used in any reports of this study. Any information that is obtained in this study and can be identified with any subjects will remain confidential and will only be disclosed with permission from the subject. The research data and subjects consent forms will be connected by a single number, which will only be known by the investigators conducting this study. The identifying number is required to assure EMG data is coordinated and processed from the appropriate subject. At the completion of this research project, all research data and subject consent forms will be stored in separate, locked locations in the Physical Therapy Department for a minimum of 3 years, at which time they will be shredded. All data will be reported in aggregate form only.

4. **Subject Protection.**

a) Subjects will be informed of the activity expected of them prior to their participation in the study. They will acknowledge they have received and understand their role in the study by signing the Informed Consent form. Subjects that are at risk for possible physical complications due to exercise will be excluded from the study—as listed in the Protocol Description (II, 1, c).
All participants will be closely supervised throughout the testing procedure, and the experiment may be stopped at any time if the participant experiences discomfort, pain, fatigue, or any other symptoms deemed hazardous to the subject's health.
All electrodes will be disposable and given to each subject for their personal use only.

b) No subject names will be used in any results of this study. Any information that is obtained in this study and can identify any subjects will remain confidential and will only be disclosed with permission for the subject. The research data and subjects' consent forms will be connected by a single number, which will only be known by the investigators conducting this study.

c) Each participant will be provided with a copy of the consent form for their personal records.

d) Research data and consent forms from this study will be retained in separate, locked locations at the UND Physical Therapy department for a minimum of three years following the completion of the study. The principal investigators will have access to the research data during this time. Data and consent forms will be shredded after a minimum of three years. All electronic data (computer files, digital imagery) will be stored in the Department of Physical Therapy for a period of three years, at which time the data will be erased.

e) Investigators or subjects may stop the experiment at any time if the subject experiences discomfort, pain, fatigue, or any other symptoms that may be detrimental to his or her health. Any decision to participate or not participate in the study will not prejudice the individual's future relationship with the Department of Physical Therapy or the School of Medicine at the University of North Dakota.

f) Potential problems include adverse reactions to physical exercise and physical trauma. In the unlikely event that this research activity results in injury, medical treatment will be provided, including first aid, emergency treatment, and follow-up care, as it is to the general public in similar circumstances. The person and their third party payer must provide payment for any such treatment.

III. Benefits of the Study

Subjects will not benefit personally from being in this study. However, we hope that, in the future, others may benefit from this study because this bicycle exercises abdominal and low back muscles in a way others do not. This type of exercise is important to therapy in several disorders.

IV. Consent Form

A copy of the consent form must be attached to this proposal. If no consent form is to be used, document the procedures to be used to protect human subjects, and complete the Application for Waiver or Alteration of Informed Consent Requirements. Refer to form IC 701-A, Informed Consent Checklist, and make sure that all the required elements are included. **Please note:** All records attained must be retained for a period of time sufficient to meet federal, state, and local regulations; sponsor requirements; and organizational policies. The consent form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. **The consent form should be written at no higher than an 8th grade reading level**, and it is recommended that it be written in the third person (please see the example on the RD&C website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp.

By signing below, you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.

Signatures:

(Principal Investigator) Date:

June 15, 2006

(Student Adviser) Date:

Requirements for submitting proposals:
Additional information can be found on the IRB web site at **www.und.nodak.edu/dept/orpd/regucomm/IRB/index.html.**

Original Proposals and all attachments should be submitted to Research Development and Compliance, P.O. Box 7134, Grand Forks, ND 58202-7134, or brought to Room 105, Twamley Hall.

Prior to receiving IRB approval, researchers must complete the required IRB human subjects' education. Please go to http://www.und.nodak.edu/dept/orpd/regucomm/IRB/IRBEducation.htm for more information.

The criteria for determining what category your proposal will be reviewed under is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require full Board review, you will need to provide additional copies. Further information can be found on the RD&C website regarding required copies and IRB review categories, or you may call the RD&C office at 701 777-4279.

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

Please Note: Student Researchers must complete the "Student Consent to Release of Educational Record".

INFORMED CONSENT

TITLE:	Electromyographic Analysis of Abdominal and Low Back Extensor Musculature during use of an Experimental Stationary Bicycle
PROJECT DIRECTOR:	Dr. David Relling, Bryce Kelly, Christopher Podoll, and Kirk Van Slyke
PHONE #	777-4091; Physical Therapy Department: 701 777-2831
DEPARTMENT:	Physical Therapy

A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask.

You are invited to participate in a research study investigating how abdominal, back, and leg muscles work when riding an experimental stationary exercise bicycle. You were selected because you are a healthy adult between the ages of 18 and 60 years. You will need to visit the research lab one time. Your participation in the study will last about 60 minutes.

The purpose of this research study is to compare the muscle activity of the abdominals, back, and legs while riding a stationary bicycle and a bicycle that tilts while pedaling.

When you arrive for the study, a member of the research team will use calipers to collect skin-fold measurements and calculate body composition. Males will be measured at the chest, thigh, and abdomen. Females will be measured at the triceps, suprailiac region, and abdomen. You will then be prepared for electrode placement. During the experiment, we will be recording the amount of muscle activity in the muscles described below by use of electrodes. Electrodes are sticky, self-adhesive receivers that are placed on the skin. Preparation involves removal of excess hair by shaving with an electric clipper and rubbing of skin with alcohol on the areas where electrodes will be placed. A marker will also be used to mark the spot of electrode placement. Electrodes will be attached to abdominal, low back, and thigh muscles. Heart rate and blood pressure will be monitored at rest, and heart rate, blood pressure and rate of perceived exertion will be monitored during exercise.

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You will be instructed on the use of the bicycle. You will practice riding the bicycle for about 4 minutes to become familiar with how it works. Your muscle strength will then be tested so that we can compare the activity while on the bicycle to your maximum muscle activity. You will be asked to hold a position while a member of the research team presses you in the opposite direction. You will then ride the bicycle for approximately 5 minutes.

The electrodes and adhesive will be removed. After the electrodes are removed, the skin under the areas may possibly be red due to the self-stick adhesives. This is considered normal. You will then be free to leave.

The investigators in this study feel that the risk of injury or discomfort is minimal, similar to participation in an ordinary, light exercise activity. Possible adverse effects may be muscle fatigue, cramping, and soreness, skin irritation, or allergic reaction. You or the investigators may stop the experiment at any time if any discomfort, pain, fatigue, or other symptoms that may be harmful to your health are identified. In the unlikely event that this research activity results in injury, medical treatment will be available, including first aid, emergency treatment and follow-up care as it is to the general public in similar circumstances. You and your third party payor, if any, must provide payment for such treatment.

Your participation is voluntary. Your decision whether or not to participate will not damage your future relationship with the Physical Therapy Department or the University of North Dakota.

You will not be paid for being in this research study, and you will not have any costs for being in this research study. You will not benefit personally from being in this study. However, we hope that, in the future, others may benefit from this study because this bicycle exercises abdominal and low back muscles in a way others do not. This type of exercise is important to therapy in several disorders including low back pain.

The University of North Dakota and the research team are receiving no payments from other agencies, organizations, or companies to conduct this research study.

The records of this study will be kept private to the extent permitted by law. Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. If we write a report or article about this study, we will describe the study results in a summarized manner so that you cannot be identified. Government agencies, the UND Research Development and Compliance office, and the University of North Dakota Institutional Review Board may review your study record. Confidentiality will be maintained by means of storing consent forms separately from data collected using separate, locked file cabinets in the Physical Therapy Department at the University of North Dakota. The data and consent forms will be retained for a period of 3 years from the date of completion of the study. After this time, the information will be shredded.

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The computer files are kept in a separate locked cabinet in the Physical Therapy Department at the University of North Dakota for a period of 3 years. After that time, all electronic media will be erased.

The researchers conducting this study are Bryce Kelly, Christopher L. Podoll, and Kirk Van Slyke all of whom are graduate students in the Physical Therapy program. You may ask any questions that you may have now. If you later have questions, concerns, or complaints about the research please contact the students' advisor, Dr. David Relling, at (701) 777-4091, or researchers Bryce Kelly at (701) 777-9748, Christopher L. Podoll at (701) 775-7802, or Kirk Van Slyke at (701) 772-1659. A copy of the consent form is available to all participants in the study.

If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach research staff, or you wish to talk with someone else.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name: ____

______________________________ ____________________

Signature of Subject Date

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