Core Muscle Endurance and Low Back Pain in Adolescent Female Gymnasts

A thesis submitted to the Miami University
Honors Program in partial fulfillment of the
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By

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ABSTRACT

CORE MUSCLE ENDURANCE AND LOW BACK PAIN IN ADOLESCENT FEMALE GYMNASTS

By:

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The aim of this study was to determine whether an association exists between low back pain and core muscle endurance in adolescent female gymnasts. Six subjects (3 with LBP, 3 control) held seven isometric exercises while surface EMG was used to measure muscle activity and fatigue parameters. Results suggest that there is a difference in core endurance, as measured by the time subjects were able to hold exercises, however there was an insufficient number of subjects in this pilot study to prove significance. Mean values for flexion/extension and flexion/side bridge ratios did not differ between the groups.

Acknowledgments

I would like to take this opportunity to thank my advisor, Dr. Steve Dailey, providing me with guidance and support throughout the duration of this project. I would also like to thank Pat Troesch and Mark Cristel for agreeing to serve as readers for this thesis and provide input on the final product. A special thank you also goes to Dr. Jesse Eisler and Rochelle Carlonas of Wellington Orthopedics for their assistance in the experimental design phase of this project. Additionally, I owe Dr. Mark Walsh and Dr. Bill Berg of the PHS department thanks for assisting me with the technical aspects of conducting electromyography. I would also like to thank Mary Lee Tracy, Jamie Broz, and the gymnasts at Cincinnati Gymnastics Academy for volunteering to participate as subjects in this study. Lastly, I would like to thank the Miami University Honors and Scholars Program Student Initiate Fund for graciously providing the funds to conduct this research project.

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Background

Low back pain is a pervasive problem in the world of athletics, with approximately 75% of high performance athletes reporting some sort of back pain.[10] Gymnasts in particular are at a high risk for developing low back pain (LBP) due to the excessive microtrauma caused by hyperextension and rotational movements that are inherent to the sport.[22] Additionally, the large volume (15-20 hr./wk) of training time required by the sport exceeds the level of 15 hr/wk that Goldstein[11] reported increased the risk of injury from 13% to 57%. Typically back pain in gymnasts is attributed to a variety of causes, ranging from hyperlordotic back pain, and pars interarticularis defects to vertebral body fractures and intervertebral disc disorders,[22] with the vast majority (68%)[7] occurring in the lumbarsacral region. A study conducted in Germany found that 64% of competitive artistic gymnasts experienced LBP during their competitive careers, and 61% reported pain even after retiring from the sport.[33] It was also discovered upon radiological examination that 51.4% of these gymnasts showed evidence of degenerative changes in the lumbar spine following their competitive careers.[33] Similarly, Goldstein[19] also reported degenerative changes present in the intervertebral discs of gymnasts at incidence rates of 11% in pre-elite, 43% in elite, and 63% in Olympic gymnasts. With incidence rates of low back pain that far exceed the normal population, it is important to address the issue of stability and how it impacts the spine of an athletic population.

Traditionally, low back exercises have aimed at increasing or restoring spinal strength and range of motion. However, evidence suggests that hypermobility of the spine actually increases risk for future back trouble, and that muscle endurance, not strength is related to reduced symptoms.[3] In fact, compromised endurance appears to be involved in many injuries that occur during submaximal tasks.[19] Recently a trend has emerged in rehabilitation and performance enhancement that focuses on lumbar stabilization and core stability. The underlying concept of stability suggests that a spine must first be stable before forces and moments can be used to enhance performance.[20] The major stabilizers, or core muscles, of the lumbar spine have been identified as the abdominal wall, consisting of the internal oblique, external oblique, and transverse abdominis, the lumbar multifidii, the quadratus lumborum, the longissimus, and the iliocostalis. Cholewicki and McGill[5] showed that in most people, a moderate level of co-activation (2-3% of maximum voluntary contraction)[4] of paraspinal and abdominal wall muscles is sufficient to produce lumbar stability in an undeviated spine. Increased levels of co-contraction (approximately 6% of MVC) are needed to achieve adequate stability in those individuals with injured spines because they have lost some of the passive stiffness that aids in structural stability.[9] Focusing on muscle endurance and maintaining a neutral spine posture when under a load encourages abdominal co-contraction and bracing in a functional manner.[20] A few studies are even available which suggest that muscle endurance has a higher prophylactic value than strength in regards to injury.[15]

Many studies have documented an association between low back pain and suboptimal back muscle function, manifested as disturbances in muscle activation during free dynamic movements, reduced muscle strength, increased muscle fatigability, and alterations in muscles' size and internal structure.[17] Although there is some evidence to support a role for some of these factors in the development of LBP, the general consensus is that these dysfunctions arise as a consequence of the pain, associated inactivity, and subsequent onset of the disuse process.[17] Nonetheless, there are a number of studies that have repeatedly documented significant differences in the fatigability of trunk muscles between individuals with and without LBP.[3,12,13,23,27,28,30,32] The vast majority of these studies have been conducted with adults and consequently there is little research that pertains to the spines of children. Little evidence exists to demonstrate whether or not adolescents exhibit the same types of fatigue patterns in the trunk musculature as adults.

The purpose of this pilot study is to examine a young, athletic population that has a high incidence of low back pain and compare these results to those of an older population. The notion of core muscles is relatively new, and subsequently little research has looked at these deep trunk muscles. Three lumbar stabilization exercises rarely used in the literature are included in this study to provide clinicians with baseline endurance times for young, athletic patients. Overall, the goal of this study is to fill the void in the current research and disseminate information to clinicians in regards to core muscle endurance and low back pain in an athletic, adolescent population.

Methods

Subjects. The criteria for inclusion in this study was restricted to 6 female patients between the ages of 12 and 18 (mean age = 14.67 years, SD = 1.86, range = 12-17; mean height = 157.70 cm, SD = 7.64, range = 147.32-166.37; mean weight = 53.07 kg, SD = 10.47, range = 38.10-67.13). All subjects were currently training a minimum of twelve hours per week as high-level (USAG Level 7 and above) competitive gymnasts at a local gymnastics club. Approximately half of the subjects presented with a history of low back pain with concurrent clinical signs. The other half served as a control, with no clinical presentation of LBP. Parental consent was obtained along with child assent before initiating participation in this project. Ethical approval for this study was granted by the Institutional Review Board for Human Subjects Research of Miami University, Oxford, Ohio.

Table 1. Subject Characteristics

Characteristic	Control Group	LBP Group
N	3	3
Age (yr.)	14.3 (2.1)	15 (2)
Height (cm)	162.1 (4.5)	153.2 (8.2)
Weight (kg)	57.9 (9.8)	48.2 (10.4)
Competition Experience (yr.)	6.3 (2.5)	7.7 (1.5)
Training Time (hr/wk)	18.0 (3.5)	20.0 (0)

Note: Values are mean (SD)

Instrumentation. Eight pairs of Noraxon bipolar dual disposable silver-silver chloride surface electromyography (EMG) electrodes (with center to center distance of 2cm) were applied to the skin bilaterally over the following muscles: external oblique, approximately 12 cm lateral to the umbilicus; internal oblique, below the external oblique electrodes and just superior to the inguinal ligament; multifidus, 3 cm lateral to the L-5 spinous process; and lumbar erector spinae, 3 cm lateral to the L-3 spinous process. The erector spinae location was used to detect muscle activity of the quadratus lumborum, as indicated by McGill, Juker and Kropf.[21] Noraxon MyoResearch 2.02 was used to collect all EMG data. Prior to data collection, all subjects performed maximum voluntary contractions (MVCs) for all muscles to be tested. Procedures for obtaining maximum EMG activity for normalization have been explained previously by McGill.[18] Briefly, four tasks were used to elicit maximum EMG activity from the 8 recorded sites. The trunk extensors were activated by cantilevering the trunk over the edge of a mat and maintaining a horizontal position against resistance. A resisted bent-knee sit-up with a slow twisting motion was used to activate the abdominal musculature. Additionally, a side bridge was also performed on both the left and right side to elicit maximum activity from the quadratus lumborum. The raw EMG signals were collected at a frequency of 20Hz, rectified and normalized against the MVC values collected.

Data Collection. All data collection took place at Cincinnati Gymnastics Academy. Subjects were first asked to fill out a short questionnaire (see appendix) detailing their involvement in gymnastics, hand dominance, and history of low back pain. Following the questionnaire, subjects underwent a brief physical exam that consisted of 6 orthopedic special tests specific to spinal pathology, as well as a brief postural screen. The special tests (unilateral and bilateral straight leg raise, with and without ankle dorsiflexion and neck flexion, and the march or one-leg standing lumbar extension test) attempted to identify those subjects who presented with any type of disc involvement, sacroiliac joint pain, or posterior element (i.e. pars interarticularis) dysfunction. The principal investigator reviewed both the questionnaire and the physical exam results prior to subjects beginning any of the isometric exercise testing. Subjects then performed the following seven isometric endurance exercises, with the order randomized among subjects: the isometric flexor exercise, the isometric extensor exercise, a prone bridge, an isometric side bridge on both the left and right side, and the isometric "bird dog" exercise on both the left and right side. If patients experienced pain during any test, those results were excluded from calculations in order to measure the subject's capability, unprovoked by pain.[13] EMG data was recorded for each exercise along with the time (in seconds) that each exercise was performed. Exercises were held for a maximum of 300 seconds, after which point the test was discontinued. Five minutes time was allotted between efforts to facilitate muscle recovery.

Exercise 1 (fig 1) consisted of a bent-knee sit-up that tested trunk flexor endurance. Subjects sat on the floor (carpeted and padded surface), with feet unrestrained and both knees and hips bent to 90 degrees. The arms were extended forward with the fingertips touching the inferior border of the patella. Subjects were instructed to maintain this position for as long as possible. Verbal encouragement was provided throughout the duration of the test. The test ended when subjects were no longer able to hold the position, and the fingertips were no longer in contact with the patella.

The extensor exercise (fig 2) was modified from the Biering-Sorensen test,[3] which has been shown to be consistently reliable as a measure of back extensor endurance.[1] Subjects laid prone on a mat (approximately 30cm high) with the anterior superior iliac spine on the edge of the mat and the lower body fixed to the mat at the ankles, knees and hips. The upper body was cantilevered off the edge of the mat with the upper body resting on the floor until the test began. At the beginning of exertion the arms were held across the chest and the upper body was lifted until the upper torso was horizontal to the floor. Subjects were instructed to maintain this horizontal position as long as possible, with encouragement being provided throughout the test. The test was ended when subjects could no longer maintain a horizontal position despite repeated verbal cues from the investigator.

The prone bridge (fig 3) entailed subjects lying prone on the floor with their body weight supported on their toes and forearms. At the beginning of the test, subjects raised their body off the ground so that only their toes and forearms were in contact with the floor, with the trunk extended such that the body was in a straight line and their spine in a neutral position. Again, subjects were instructed to hold the position as long as possible with the test ending when subjects could no longer maintain proper body position.

The side bridge (fig 4) consisted of subjects laying on the floor on their sides with legs extended. The top foot was placed in front of the lower foot on the floor for support. Subjects were instructed to support themselves lifting their hips off the floor to maintain a straight line over their full body length, and support themselves on one elbow and their feet. The uninvolved arm was placed on the hip or grabbed the support arm at the wrist to assist with balance. The test ended when the hips returned to the floor. This exercise was performed on both the left and right sides.

Fig. 1. Trunk Flexion Exercise

Fig 2. Modified Biering-Sorensen Test for Extensor Endurance

Fig. 3. Prone Bridge Exercise

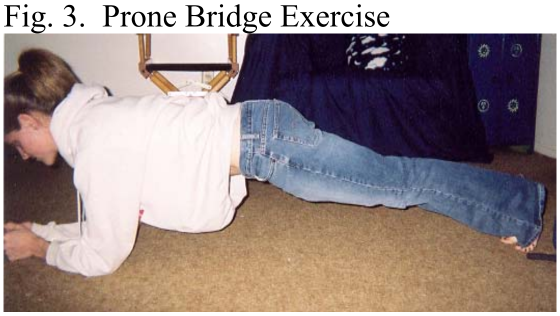

Fig. 4. Side Bridge Exercise

Fig. 5. Bird Dog Exercise

The bird dog exercise (fig. 5) required subjects to be positioned on their hands and knees. At the start of the exercise, one leg was extended out horizontally, while the contralateral arm was raised to horizontal as well. Subjects were instructed to maintain this straight line from their foot to the opposite arm for as long as possible. Right bird dog was the term used to denote the position when the right arm and left leg were extended, while left bird dog was used to describe the position of left arm and right leg extended. The test was stopped when subjects could no longer maintain proper body position.

Statistics. Statistical analysis consisted of student t-tests ($p < .05$) to assess the differences in endurance times for each exercise between the two groups.

Results

Results of the physical exam revealed two abnormal postural screens in the control group. One subject presented with minimal rotating scoliosis (<10 degrees), and another displayed paraspinal hypertrophy and a slight buckling of the spine at L3. Both of these subjects were clinically asymptomatic and had no previous history of low back pain. No postural abnormalities were present in the LBP group. The LBP group consisted of two subjects who had a history of posterior element pain (spondylolysis or spondylytic-type pain) and both presented with a positive march test. The other symptomatic subject had a history of neurologic symptoms and exhibited pain during straight leg raising tests, indicating the presence of possible intervertebral disc pathology.

Mean endurance times and ratios for the exercises are listed in Table 2. The ratios of endurance times were normalized to the trunk flexion exercise, as subjects were able to hold this position the longest. There is insufficient evidence to demonstrate whether a significant difference exists between the endurance times of the two groups for all but one of the exercises due to a small sample size. No significant comparison can be made between the ratios for the same reason. Only the right bird-dog exercise demonstrated a significant difference ($p<0.05$) between the LBP and control groups. Due to technical difficulties with the EMG system, no meaningful, fatigue-related EMG data (iEMG, median frequency slopes, etc.) was obtained.

Table 2. Mean Endurance Times (sec) With Standard Deviation and Ratios Normalized to Flexion Exercise

	Control			LBP		
Task	Mean	SD	Ratio	Mean	SD	Ratio
Back Extension	146.33	21.2	0.57	113	50.9	0.63
Trunk Flexion	256	76.2	1	178.3	74.3	1
Prone Bridge	131.7	56.6	0.51	127.3	47.5	0.71
Rt. Side Bridge	88.3	12.2	0.34	72.3	27.4	0.41
Lt. Side Bridge	103.7	15.9	0.41	74	35.2	0.42
Rt. Bird Dog	224.7*	66.5	0.87	118.7*	46.1	0.67
Lt. Bird Dog	188.7	26.4	0.74	142.7	46.5	0.8

* Denotes significance of $p<0.05$

Discussion

First, it is important to note that this is a pilot study, and therefore there are an insufficient number of subjects to determine whether or not these results are truly significant. Additional subjects need to be tested to confirm the validity of these preliminary results. The following interpretation is being made assuming that the results are significant.

Results from this pilot study suggest that comparable trends in trunk endurance exist in adolescent female gymnasts as in the larger adult population most frequently studied by others. Similar to studies conducted within an adult population, back extensor and trunk flexor muscle endurance is decreased in subjects with LBP.[3,12,13,16,23,24,27,30,32] Evidence exists to suggest an association between excessive back muscle fatigue and high pre-contraction metabolite levels that result from persistent muscle spasm and prolonged muscle tension.[2] Typically, when a person stands in full flexion, the back muscles are placed in a state of total relaxation. This is known as the flexion-relaxation phenomenon and has been extensively studied.[4,8,17,25,29] However, people with LBP usually cannot achieve full relaxation upon flexion, as there is constant activity in the lumbar musculature that serves as a protective mechanism. This observation fits with what Lund et al.[14] described as the "chronic pain-adaptation model." Perhaps this continual firing leads to greater fatigue rates when muscles are asked to perform tasks because they have not had time to regenerate energy stores. Additionally, the constant firing may also cause muscles to be incapable of reaching the 6% MVC necessary to maintain lumbar stability.[9] This may in turn actually predispose these individuals to further injury, and subsequent declines in muscle endurance.

A number of theories exist to try and explain the endurance deficit seen in individuals with LBP. Holmstrom[12] demonstrated that people with LBP used a higher percentage of their maximum trunk extensor strength during the endurance test than the control group. Upon analysis though, only 8% of the variation in endurance time could be attributed to this increased contraction percentage. Pain is another reason that might be responsible for the decreased endurance times seen in patients with LBP. However, pain should not have been a factor in this study as tests that produced pain were excluded from the results.

It has been suggested that discrepancies in trunk extensor endurance times between control and LBP groups are due to differences in muscle fiber type proportions. The generally held notion that postural muscles consist primarily of fatigue-resistant, Type I fibers may not apply to the erector spinae, one of the major trunk extensors. Biopsy has revealed that the erector spinae is composed of 60% Type I fibers, and 40% Type II, or fast-twitch fibers,[31] and is therefore not as endurant as many may have believed. Additionally, it is theorized that people suffering from LBP have higher proportions of Type II fibers, and therefore they do not have the same inherent endurance capacity as those without LBP.[27,32] It should be assumed that these differences in muscle fiber type proportions apply not only to the trunk extensors, as decreases in trunk flexor and side bridging endurance were observed as well.

Lastly, one other aspect that needs to be taken into account is the true objectivity of strictly using time as a measure of endurance. In addition to the muscle's intrinsic fatigability, factors such as pain tolerance, competitiveness/determination, and boredom must also be acknowledged as having an impact on a person's ability to hold an isometric exercise to fatigue.[17] Therefore, muscle endurance as measured by time adopts a psychological dimension in addition to the physical one being targeted. This subsequently limits its objectivity as a test of muscle function, particularly in patients with LBP, as there is often a psychological component that accompanies this type of ailment. This psychological component was seen in one of the LBP subjects, as her times were significantly lower than those of her peers were, and it is questionable as to whether her times should be included in the results. For this reason, it is important to have a more objective measure of muscle fatigue (i.e. EMG) to use along with endurance times in order to help minimize erroneous interpretation of results. Unfortunately, due to unexpected systems errors, we were unable to gather meaningful fatigue-related EMG data to use concurrently with the endurance times collected.

In addition to endurance times, ratios of trunk flexor endurance to extensor and side bridge endurance were also used to compare the two groups. As in previous studies[12,24,28,30] there was no difference in the ratios of endurance times between subjects with LBP and those without. However, it is interesting to note that unlike studies conducted in adults,[12,13,24,30] the gymnasts demonstrated greater endurance in the trunk flexors than the extensors. This is consistent with the findings of Saliminen et al.[28] that examined 15 year-old Scandinavian schoolchildren. This trend might possibly be attributed to the fact that back extensor endurance time increases with age.[26] If the same subjects were followed, perhaps the ratio would be reversed as the subjects mature. Another possible explanation stems from the fact that gymnasts tend to perform a greater number of abdominal strengthening exercises compared to exercises targeting the lumbar musculature. The imbalance in strength between the abdominals and the back extensors may be reflected in the endurance capacity of each of these muscle groups, and may potentially contribute to injury.

Further research is needed to confirm the hypothesis that core muscle endurance is significantly decreased in gymnasts with low back pain as compared to those with no clinical presentation. EMG data would greatly enhance knowledge as to which core muscles fatigue fastest, and at what portion of the MVC fatigue occurs. Additionally, with the high incidence of LBP in this population, research is also needed to test whether an interventional core muscle endurance program could help reduce the overall incidence of LBP in gymnasts. Hopefully by gaining a greater understanding of the core muscles and their role in stabilizing the spine, preventative exercise programs can be constructed and instituted to help reduce the incidence of debilitating low back pain.

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Appendix A

Research Description for the Committee on the use of Human Subjects in Research (Final)

Title of Research Project: Core Muscle Endurance and Low Back Pain in Adolescent Female Gymnasts

Principal Investigator: Kelly A. Buchanan, undergraduate student, Department of Physical Education, Health and Sport Studies

1. Personnel

Kelly A. Buchanan (Principal Investigator). Kelly Buchanan will design and execute the study. This includes testing and operating experimental equipment, resolving any problems with equipment (in collaboration with consultants), recruiting a minimum of forty potential participants, as well as data collection and reduction.

Dr. Stephen Dailey MD (faculty advisor). Dr. Dailey will supervise Kelly Buchanan as well as engage in data collection and reduction. He will assume ultimate responsibility for this study.

Dr. Jesse Eisler MD Dr. Eisler will assist with experimental design and data reduction. He will not have direct contact with the study participants.

Rochelle Carlonas. Ms. Carlonas will assist with experimental design and data reduction. She will not have direct contact with study participants.

2. Purpose

Low back pain is a pervasive problem in the world of athletics, with approximately seventy-five percent of high performance athletes reporting some sort of back pain (Gerbino & Micheli,1995). Gymnasts in particular are at a high risk for developing back pain because of the excessive hyperextension and rotational movements that are inherent to the sport. Spinal injuries seen in gymnasts range from muscle spasms to stress reactions (spondylolysis and spondylolisthesis), to pathologic and degenerative discs. Many of the protocols used in the rehabilitation of low back injuries focus on improving core strength and low back stability. Recently McGill (2001) has suggested that core muscle endurance is more important to low back stability than is core muscle strength. Therefore, it is the attempt of this study to determine whether gymnasts with poor core muscle endurance are the ones who experience back pain. A positive correlation between back pain and poor core muscle endurance may confirm a need to implement core endurance programs into the daily training efforts of individuals at high risk for developing low back pain.

3. Subject Population

Approximately forty adolescent competitive female gymnasts, age 12-18 from Cincinnati Gymnastics Academy and Queen City Gymnastics will serve as participants for this study. Participants will be non-smokers, in good physical condition, currently training at a competitive level, and may or may not experience back pain. Parental or guardian consent must be obtained before a subject may participate in the study.

4. Recruitment and Selection of Subjects

Participants will be recruited by a) announcements read by coaches at participating gymnastics clubs to their competitive gymnasts, and b) letters distributed by coaches to the parents of their competitive gymnasts. All recruitment efforts will avoid coercion or the impression of coercion.

5. Informed Consent

Prior to data collection, participants and their guardian will be read a research description by the principal investigator or faculty advisor in which each learns what participation in the study entails, and that they are free to ask questions or change their mind about participating at any time. Each parent or guardian will then read and sign the Informed Consent Form. Each gymnast will also be read a research description and will then sign an Assent Form to document their willingness to participate.

6. Research Procedures

a. Each subject will complete a brief questionnaire regarding age, participation in gymnastics, training habits, and history of back pain. This questionnaire will be thoroughly reviewed by Dr. Stephen Dailey prior to engaging in any further portions of this research study. Then, participants will undergo a brief, noninvasive physical examination where orthopedic testing specific to spine pathology will be conducted. Tests being used include, Lasegue's test, Brudzinski's sign, Bragard's test, bilateral straight leg raise, crossover test, march test, and a brief postural screen. After the physical exam each subject will be instructed in the proper positions that will be held during the muscle endurance testing portion of this study. Participants will be asked to wear a sports bra and spandex shorts so electrodes can be placed in the appropriate places for accurate electromyography (EMG) data collection. Kelly Buchanan will conduct all EMG testing. Following electrode placement, maximal voluntary contractions (MVCs) for each of the muscles being tested will be elicited when participants perform a resisted sit-up with lateral twisting. This information will be used to normalize the EMG data obtained later in the session. Each participant will then be asked to perform seven isometric exercises, holding each one until fatigue. Only one trial for each position will be required. The positions to be held are: trunk flexion at 60 degrees, trunk extension (holding a horizontal position against gravity), a side bridge with body weight supported on left and right side, a prone bridge, and the "bird-dog" position with each arm and the contralateral leg extended. EMG data for the quadratus lumborum, transverse abdominis, and internal and external obliques will be recorded during these exercises along with the time each exercise is held.

b. Data collection will take place at Cincinnati Gymnastics Academy and Queen City Gymnastics.

c. EMG data will be collected using an eight-lead Noraxon electromyography machine and disposable electrodes. Subjects will also complete the attached questionnaire. Physical exam data will be gathered through observation of the principal investigator or faculty advisor and recorded on the attached form.

d. Questionnaire, physical exam and EMG study will all be conducted in a single session. Participants will be allowed adequate time to warm-up prior to commencement of the EMG portion of the experiment. Approximately five minutes of rest will be allotted between each exercise of the EMG portion to allow for adequate recovery. Estimated time involvement for participants is ninety minutes.

e. Both principal investigator and faculty advisor have training in physical exam skills as well as the other data collection procedures including participant preparation, operation of EMG equipment, and control of experiment conditions. Miami University faculty members Dr. William Berg and Dr. Mark Walsh will provide training in the use of EMG equipment to the principal investigator.

f. To ensure safety of participants, all equipment will be checked prior to testing, and subjects will be constantly monitored during testing for signs of injury or discomfort. Any contraindicating sign, including a participant's desire to quit, will result in discontinuing data collection. If an emergency arises, the faculty advisor is a medical doctor and will assess the situation and provide direction for the course of action to be taken.

7. Potential Risks and Discomforts

The experiment proposed presents minimal risk to participants. All participants are in good physical condition being competitive athletes, and thus possess adequate physical fitness to perform the isometric exercises in the EMG portion of the study. A warm-up will be done to minimize the risk of injury during this study. In the case that any of the exercises elicits pain, subjects will be instructed to stop the exercise immediately. Subjects will also be informed of the possibility that mild muscle soreness may occur one to three days following data collection. Some of the orthopedic tests performed during the physical examination may elicit pain in those subjects with low back pain. Pain is the indication of a positive test for certain pathologies, and is temporary. If pain is experienced, the test is promptly stopped. Again participants will be informed of this possibility before commencement of the physical exam.

8. Potential Benefits

Aside from the intrinsic satisfaction gained from contributing to a research project, there are few potential benefits to the participants. Each participant, even if they decide to withdraw from the study before data collection is complete, will receive a free movie pass as compensation for their time.

The importance of the knowledge that may result from this study is considerable. The theory that core muscle endurance is necessary for proper spine stabilization is implied, and this theory is put into practice in many spine rehabilitation protocols. However, no one has yet investigated whether poor core muscle endurance is a potential risk factor for developing low back pain. It is the attempt of this study to determine whether a link exists between the two. If a positive correlation between core muscle endurance and low back pain is found, this may have a profound impact of preventative exercises that may be instituted to combat low back pain in high risk populations.

9. Procedure for Safeguarding Confidentiality of Information

All participants will be identified by a code number to ensure confidentiality. Data will be stored indefinitely under lock and key in the apartment of the principal investigator. Only the individuals listed in the personnel section of this proposal will have access to any data that potentially identifies subjects.

10. Project Dates

This project should take approximately five months to complete data collection and reduction. Further analysis of the data in preparation for publication may be made after April 15, 2003, however at that time, all data will have been stripped of identifying links and markers.

11. Deception

No deception is involved in this study.

Appendix B

Questionnaire

Age:_______________ Do you smoke? _____________

Gymnastics Involvement:

1. How many years have you been involved in gymnastics of any kind? ________
2. How many years have you been competing in gymnastics? ________________
3. What level are you currently competing at? ____________________________
4. What is your current training schedule? (hours/day, days/week)

   ____
5. Which hand is your dominant hand (for both writing and in gymnastics)?

   ____
6. Which direction do you twist? (right or left) _____________________________

Back Pain:

1. Do you have a previous history of back pain? (problems you had a while ago, but do not have trouble with now) ___________________________________
2. When did you have the pain, and how long did it last? ___________________

   ____
3. Did you seek medical attention for the pain, and if so, what was the diagnosis?

   ____
4. Do you currently experience back pain (at rest or while training)? __________

   ____
5. How long have you been having back pain (duration)? __________________

   ____
6. What moves/skills/activities cause you pain? __________________________

   ____
7. Have you missed training time within the last two weeks? If so, how much time have you missed? ____

Appendix C

Physical Exam Form

Height _______________ Weight ________________

1. *Postural Screen*

   Comments: ____

   ____

   ____

2. *Lasegue's Test* Positive _________ Negative __________

   Comments: ____

   ____

3. *Brudzinski's Sign* Positive _________ Negative __________

   Comments: ____

   ____

4. *Bragard's Test* Positive _________ Negative __________

   Comments: ____

   ____

5. *Bilateral SLR* Positive _________ Negative __________

   Comments: ____

   ____

6. *Crossover Test* Positive _________ Negative __________

   Comments: ____

   ____

7. *March Test* Positive _________ Negative __________

   Comments: ____

8. *Neurologic Symptoms?* ____

Appendix D

Research Description for Participants

Title of Research Project: Core Muscle Endurance and Low Back Pain in Adolescent Female Gymnasts

Principal Investigator: Kelly A. Buchanan, undergraduate student, Department of Physical Education, Health and Sport Studies

Faculty Advisor: Dr. Stephen Dailey MD, Head Team Physician for Miami University Athletics

Your child is invited to participate in a study that will investigate low back pain and its possible relationship to poor stomach and back muscle endurance (how long you can contract your muscle). Back injuries are common in gymnastics, so this study is trying to determine whether there is a link between poor muscle endurance and low back pain. Depending on the outcome of the study, future research may try to find preventative measures for athletes, such as gymnasts, who are at high risk for back injuries.

If your child chooses to participate, she will fill out a short questionnaire that asks about her participation in gymnastics, and any history of low back pain. Next, she will undergo a short physical evaluation where we will evaluate her posture, and do six orthopedic special tests (i.e. a straight leg raise while lying on your back, etc.), which are noninvasive, that look for signs of back injury. Lastly, we will place eight electrodes over her stomach and back muscles that are connected to a machine that measures muscle activity. She will then hold seven different positions (i.e. bird-dog position – on her hands and knees with one arm and one leg extended outward) for as long as possible. Your child will hold each position one time and will receive five minutes of rest in between each exercise. The entire session (questionnaire, physical evaluation, and muscle testing) will be completed within two hours.

This experimental task presents minimal risk to your child. It is possible that your child will experience some muscle soreness 1-3 days after participating. If the soreness is severe enough to cause you concern you are strongly encouraged to call Kelly Buchanan at 513-664-6547 or Dr. Stephen Dailey at 513-245-2500 for advice. Additionally, you and your child are strongly encouraged to consult with the research staff about any discomfort or concerns you experience during the session. If your child experiences any undue discomfort while holding the positions, she should stop and tell the research staff. If a physical injury does result from the research procedures, financial compensation is not available, and medical treatment is not provided free of charge.

By participating in this study, you and your child have an opportunity to help researchers understand some of the risk factors for low back pain in gymnasts. We encourage your cooperation throughout the session, however, your participation is voluntary and you and your child are free to refuse to participate and/or withdraw from the study at any time without being penalized in any way.

Any information obtained in connection with this study that can be identified with your child will remain confidential and will be disclosed only with your permission. In any written reports, publications or presentation of the data, no participant will be identified by name.

Do you have any questions about your child's participation in the study?

In the future, if you have any questions or concerns about the study, please contact Kelly Buchanan at 513-664-6547, or buchanka@muohio.edu, or Dr. Stephen Dailey at 513-245-2500 or daileysw@muohio.edu. If you have general questions about your child's rights as a research participant, you may also call the Office for the Advancement of Scholarship and Teaching at 513-529-3734.

You will be provided with a copy of this form to keep.

Appendix E

Informed Consent Form

Title of Research Project: Core Muscle Endurance and Low Back Pain in Adolescent Female Gymnasts

Principal Investigator: Kelly A. Buchanan, undergraduate student, Department of Physical Education, Health and Sport Studies

Faculty Advisor: Dr. Stephen Dailey, MD, Head Team Physician for Miami University Athletics

This is to certify that I, ___________________________, hereby give my consent for my child, ___________________________ to volunteer in a scientific investigation as an authorized part of the education and research program of Miami University under the supervision of Kelly Buchanan and Dr. Stephen Dailey, MD

The investigation and my child's part in the investigation have been defined and fully explained to my child and I, and we understand the explanation. A copy of the procedures of this investigation has been provided to me and has been discussed with me in detail.

My child and I have been given the opportunity to ask questions and all such questions and inquiries have been answered to my satisfaction.

I understand that my child is free to deny answers to specific questions in interviews and questionnaires.

I understand that participation does not change the availability of clinical or other services at Miami University.

I understand that in the event of physical injury resulting from the research procedures, financial compensation is not available and medical treatment is not provided free of charge.

I FURTHER UNDERSTAND THAT I AM FREE TO WITHDRAW MY CONSENT AND TERMINATE MY CHILD'S PARTICIPATION AT ANY TIME.

________________ ____________________________________

Date Parent/Guardian's Signature

I, the undersigned, have defined and fully explained the investigation to the above parent or guardian.

________________ ____________________________________

Date Investigator's Signature

Appendix F

Assent Form for Children

Title of Research Project: Core Muscle Endurance and Low Back Pain in Adolescent Female Gymnasts

Principal Investigator: Kelly A. Buchanan, undergraduate student, Department of Physical Education, Health and Sport Studies

Faculty Advisor: Dr. Stephen Dailey, MD, Head Team Physician for Miami University Athletics

You are invited to take part in a research study on low back pain and stomach and back muscle strength. If you want to participate in the study you will fill out a form with questions that ask you about gymnastics and if you've ever hurt your back. Then, we are going to look at your posture, and do a couple quick tests to see if you have any back pain. Lastly we want to see how long you can hold different positions, and how your muscles react while you do seven exercises. You will get to rest five minutes in between each exercise. During this part we will put sticky pads on your stomach and back that will be hooked up to a machine that tells us how active your muscles are.

This study shouldn't cause you any pain, however, you may be a little sore 1-3 days afterwards. This would be similar to how your muscles feel after a hard workout. If anything during the session causes you pain, you should stop the exercise and tell the researcher.

It is totally up to you if you want to participate in this study. You do not have to answer any questions that you do not want to, and you can stop at any time, even if you haven't finished everything. You will not be penalized in any way if you decide to stop.

All of the information that we get from this study that can be linked to you will be confidential (no one but the researchers will know your name). When the results of this study get written, or presented to other people, your name won't be linked to any of the results.

I, ______________________________ understand everything that has been explained to me, and all of my questions have been answered in a way that I can understand.

I am willing to participate in the study that has been described to me.

_________________ ____

Date Participant's Signature

I have explained the experiment to the above participant and answered their questions.

_______________ ____

Date Investigator's Signature

Appendix G

Letter to Coaches

Dear Coaches,

My name is Kelly Buchanan and I am an undergraduate Honors student at Miami University. I am currently working on a research project in conjunction with Dr. Steve Dailey of Wellington Orthopedics Inc. that aims to explore the relationship between core muscle (stomach and back muscles) endurance and low back pain in gymnasts. As you know, low back pain/injuries are increasingly prevalent in young gymnasts, and our goal is to examine whether or not a relationship exists between muscle endurance and low back pain. This is the first step in what may spawn follow-up studies to further examine if a causal relationship exists, and possibly what types of preventative measures may be taken to reduce the overall incidence of low back pain/injuries in this population.

We are currently looking for approximately forty competitive female gymnasts (preferably Level 7 and up) between the ages of twelve and eighteen to participate in our study. We encourage both gymnasts with and without back pain to participate. Involvement is completely voluntary and requires one session that is approximately two hours long. All of the procedures are non-invasive and should not cause pain in the participants. Gymnasts who choose to participate will fill out a short questionnaire, undergo a brief physical exam that includes a postural screen and a couple of orthopedic tests which look for low back injury, and then perform approximately seven exercises that are similar to ones found in a back rehabilitation protocol while their muscle activity is measured.

If you would read the following announcement to your competitive female gymnasts that would be greatly appreciated:

Gymnasts, you have a chance to become involved in a research study that is looking at stomach an back muscle endurance and how it relates to low back pain in gymnasts. We need approximately 40 competitive female gymnasts between the ages of twelve and eighteen to participate. We need both gymnasts with and without back pain to perform about 7 conditioning type exercises while we measure your muscle activity. There is also a short questionnaire to fill out and a brief physical exam where we'll look at your posture and check to see if you have back pain. Nothing in this study should cause you pain. Your involvement is strictly voluntary, so there is no pressure or punishment from your coaches or us if you do not want to get involved. Overall, if you want to participate, we would need to schedule one appointment that would last about two hours total. Sessions will be conducted at the gym where hopefully it is most convenient for you. If you have any questions about this study please contact either Kelly Buchanan at 513-664-6547 or buchanka@muohio.edu or Dr. Steve Dailey MD at 513-245-2500 or daileysw@muohio.edu. Thanks for your cooperation!

Coaches, a letter has also been provided with similar information to be sent home to the parents. Thank you very much for your cooperation.

Kelly Buchanan
513-664-6547
buchanka@muohio.edu

Appendix H

Letter to Parents and Gymnasts

Dear Parents and Gymnasts,

My name is Kelly Buchanan and I am an undergraduate Honors student at Miami University. I am currently working on a research project in conjunction with Dr. Steve Dailey of Wellington Orthopedics Inc. that aims to explore the relationship between core muscle (stomach and back muscles) endurance and low back pain in gymnasts. As you know, low back pain/injuries are increasingly prevalent in young gymnasts, and our goal is to examine whether or not a relationship exists between muscle endurance and low back pain. This is the first step in what may spawn follow-up studies to further examine if a causal relationship exists, and possibly what types of preventative measures may be taken to reduce the overall incidence of low back pain/injuries in gymnasts.

I would like to take this opportunity to invite your child to participate in this study as we strive to understand low back pain in gymnasts and ways that we can possibly try to prevent it. We are currently looking for approximately forty competitive female gymnasts between the ages of twelve and eighteen to take part in the study. Gymnasts with and without back pain are encouraged to participate, however, if your child does have back pain, we require that participants not have missed more than one week of practice (i.e. no activity whatsoever) due to this injury. Your child's participation in this study is completely voluntary, and there is no pressure to participate either from us the researchers, or your child's coaches. If your child does become involved in the study they will come to the gym for one session that will last approximately two hours. She will fill out a short questionnaire regarding her participation in gymnastics and any history of low back pain. Next she will undergo a brief physical examination that will include a postural evaluation as well as a couple orthopedic tests that screen for back pain. Lastly, your child will be asked to hold seven different positions that are common in back rehabilitation programs while their muscle activity is measured. All of the tests are noninvasive and should not cause your child any pain.

If you have any questions at all, please feel free to contact me, Kelly Buchanan at 513-664-6547 or buchanka@muohio.edu or Dr. Steve Dailey at 513-245-2500 or daileysw@muohio.edu.

Please return the attached sheet to your child's coach by January 8, 2003 to indicate your decision regarding participation in this study.

Thank you for your cooperation.

Kelly Buchanan

Appendix I

Research Participation

Child's Name ____________________________ *Phone Number* _________________

Address (include zip) ____

______ ***NO,*** I am not interested in participating in this study

______ ***YES,*** I would like to participate in this study on core muscle endurance and low back pain. Below indicate three dates and times that would best fit your schedule.

	Date:	Time:		Date:	Time:
_____	January 11, 2003	___________	____	February 2, 2003	__________
_____	January 12, 2003	___________	____	February 8, 2003	__________
_____	January 18, 2003	___________	____	February 9, 2003	__________
_____	January 19, 2003	___________	____	February 15, 2003	__________
_____	January 25, 2003	___________	____	February 16, 2003	__________
_____	January 26, 2003	___________	____	February 22, 2003	__________
_____	February 1, 2003	___________	____	February 23, 2003	__________

If none of these times work for you, please indicate when would be a good time _____________________________

Once we get the responses back, we will call you to confirm your appointment time as well as send you a reminder in the mail.

Thank you,

Kelly Buchanan
513-664-6547
buchanka@muohio.edu