

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

EFFECT OF TRUNK ENDURANCE TRAINING ON LOW BACK ENDURANCE &  
INJURY IN COLLEGIATE GYMNASTS

A Chapter Style Thesis Submitted in Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Clinical Exercise Physiology

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## ABSTRACT

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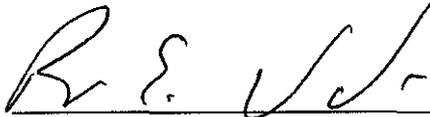
Collegiate level gymnastics creates extreme amounts of load and stress on the trunk musculature of athletes. Therefore, low back injuries are prevalent during practice competition hours. This clinical investigation aimed to administer and evaluate the effect of an 8-week trunk endurance training protocol on the low back endurance and injury rates in collegiate gymnasts compared to a control group. Data will be collaborated with results from previous and future investigation in order to strengthen the association between trunk endurance and decreased injury rates. The training protocol focused on the trunk extensor and lateral flexor muscles through prone opposite arm and leg raises and lateral double leg lifts with lateral trunk flexion. Trunk endurance was evaluated pre- and post- 8 weeks training using four static hold tests; Biering-Sorenson, right and left side-bridge, and trunk flexor. The results of the study showed the training group of gymnasts made significant improvements in trunk extensor endurance compared to the control group. No significant differences were found in lateral flexor improvements between the two groups, indicating the lateral flexor muscles were not adequately challenged during training. Injury rates were relatively low in comparison to previous seasons without the supplemental training protocol. Only one new episode of low back pain was reported as well as two recurrent episodes.

EFFECT OF TRUNK ENDURANCE TRAINING ON LOW BACK ENDURANCE &  
INJURY IN COLLEGIATE GYMNASTS

By Leah Creager

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of the Master of Science in Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.



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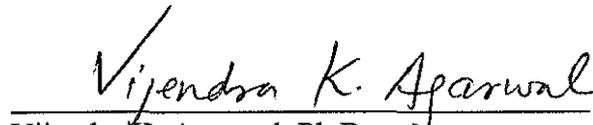


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## INTRODUCTION

Training, practice and competition in advanced level activities and sports result in stress and extreme loads on the musculoskeletal structures of athletes. As with many elite level athletics, injuries are prevalent in gymnasts (1,3). Incidence rates have been found to be between 1.08 (1) and 22.7 (20) injuries per 1000 hours of participation. Repetitive stress syndrome has been reported as a contributor to gymnastic ailments (3). The National Collegiate Athletic Association (NCAA) results of an injury surveillance system of gymnastic seasons 1988-1989 through 2003-2004, found the overall injury rate during competition has decreased annually yet the injury rate during practice hours has remained constant. The percentages of trunk and back injuries amid competition and practice were 9.5% and 19.1% respectively; placing trunk injuries third in prevalence (13). These results are consistent with subsequent studies finding trunk and back injuries to comprise 22.2% (1) and 28.5% (8) of injuries. Furthermore, studies have reported that 75% (10) and 89% (9) of gymnasts experience low back pain (LBP) during their participation in the sport. The repetitive bending, twisting and extreme extension of the trunk during gymnastics exposes athletes to a high incidence of LBP (6,9).

LBP can vary greatly in regards to severity of injury. The pain felt by the individual may be caused by a simple strain to numerous lower back structures. Intervertebral disc injury, herniated vertebral disk, vertebral growth plate injury, Scheuermann's disease, spondylolysis, spondylolisthesis, facet syndrome, and scoliosis are all possible contributors to LBP among gymnasts (10). While LBP is often multifactorial, the performance of the trunk musculature has been postulated as a significant factor (2,4,17,19). Trunk extensor muscle fatigue may increase risk of LBP (2) by

consequently imposing greater or unaccustomed loads on passive low back structures (12,18,23) or relying on secondary muscle recruitment and therefore loading the structure in a new way (18). Prevention to this common ailment in gymnastics is under investigation. Pre-season gymnastics training protocols have been observed to focus on the trunk flexors and include little to no targeted trunk extension or lateral flexor training (4). Therefore, the effects of increasing endurance of trunk extensor and lateral flexor muscles have interested some researchers (4). In one such study, Durall and colleagues reported that the addition of trunk extensor and lateral flexor exercises to a preseason gymnastics training protocol was associated with an apparent reduction in incidences of LBP. None of the gymnasts who completed the 10-week training protocol had new episodes of LBP during the subsequent competitive season, which was in contrast to previous seasons (4).

Due to the potential relationship of trunk extensor muscle endurance and the incidence of LBP as well as that between spinal stability and lateral flexor muscles (2,4,5), the purpose of this study was to further examine the influence of the following comprehensive trunk muscle endurance training on trunk endurance capabilities. Furthermore, the association between the endurance training and the occurrence of LBP in female collegiate gymnasts was studied. Data from this investigation, together with previous data, should provide additional insight into the strength of the association between these variables.

## **METHODS**

### **Subjects**

The training group for this investigation consisted of 16 members of the University of Wisconsin- La Crosse women's gymnastic team. The control group consisted of 12 non-athlete collegiate females (Table 1). All subjects participated voluntarily in the study and provided written informed consent. The study was approved by the Institutional Review Board of the University of Wisconsin- La Crosse.

### **Testing Procedures**

The testing protocol was modified from a protocol described by Durall and colleagues (4). Subjects were asked to perform four static hold tests; the Biering-Sorenson trunk extensor test, right and left lateral side support tests, and a trunk flexor test. Reliability coefficients have been found to range from 0.97 to 0.99 for all four tests. (11,14,15,16,21). Tests were held until fatigue as determined by test administrators. Digital stopwatches were used to measure the duration of each test. The test administrators were experienced clinicians who offered verbal cues to maintain correct body alignment for each task. Testing order was randomly determined. The subjects were not informed of their results in order to reduce testing bias. Throughout the study period and during the remainder of the gymnastics season, low back pain or injuries were recorded by the athletic training staff.

### **Biering-Sorenson Test**

The Biering-Sorenson trunk extensor test was administered with subjects in a prone position; their anterior-superior iliac spines aligned with the edge of the testing surface as the subjects were manually secured at their ankles by an examiner. Subjects supported their upper body using a chair in front of the testing surface until their legs were stabilized. As the test time started, subjects were asked to hold their upper body horizontal to the floor with their arms crossed on their chest as long as possible. When the subject's torso dropped below the horizontal start position or the subject lowered their hands to the chair, the test was terminated and the time recorded.

### **Trunk Flexor Test**

The flexor endurance test was performed with subjects sitting on the floor with their knees bent at a 90 degree angle. The feet were secured by one examiner while another examiner positioned the subject's torso 60 degree from the support surface using a standard goniometer. With arms crossed on their chest, subjects were instructed to hold their body position until as long as possible. The test was terminated and time recorded when the upper body dropped below 60 degrees.

### **Lateral Side Bridge Tests**

The lateral side bridge static hold tests were conducted on both the left and right sides separately. In preparation for the test, the subject lay on their side with their legs extended. While supporting their body on one elbow and forearm, the subject was instructed to raise their pelvis off the testing surface maintain a straight line from their torso to lower extremities. Subjects were verbally cued to not flex or extend their trunk or hips in the sagittal plane. The hand of the arm not supporting the body was crossed

and placed on the weight-bearing shoulder for support of the joint. The test was terminated when the body lowered toward the testing surface.

### **Training Procedures**

The training group performed the opposite arm and leg raises and sidelying double leg lifts with lateral trunk flexion three times each week for eight consecutive weeks along with their normal exercise and training habits. Since the present gymnast's training protocol contained a substantial volume of trunk flexor exercise, the supplemental program was intended to balance in trunk musculature by targeting posterior and lateral muscle groups. Subjects were taught proper technique for all exercises performed.

Arm and opposite leg raises were performed with subjects prone on a gymnastics mat. With arms extended forward, subjects lifted one arm and the collateral leg to a level parallel to the floor. Each repetition was held for five seconds, alternating sides. Subjects completed the exercise for the duration of four minutes. To perform the sidelying double leg lift with lateral trunk flexion, subjects raised both legs as well as their upper torso off the training surface to a comfortable height. Each repetition was held for five seconds and the exercise was performed for two minutes on each side. This exercise was selected in lieu of the side-bridge since the authors found in a previous investigation that the side bridge was associated with upper extremity discomfort that occasionally impaired exercise performance.

### **Statistical Analysis**

The endurance test times of both the control and training groups for each of the tests were analyzed in four separate ANOVA calculations using *time* and *protocol* as

independent variables. The variable *time* determined if significant differences existed between pre- and post testing of all subjects. *Protocol* was used to determine if there were significant differences between the control and training groups during the pre-training endurance tests. The *protocol x time* interaction of both independent variables determined if there was a significant difference in the performance of the training group compared to the control group.

## RESULTS

A total of twenty-nine participants completed the study, twelve in the control group and seventeen in the training group. Three subjects withdrew from the training group due to injury not related to the training protocol.

Table 1. Demographics of Control Group and Training Group Participants

	Control	Training
Number	12	17
Age (yr)	22.3 ± 1.7	19.4 ± 1.4
Height (cm)	164.7 ± 7.3	160.7 ± 6.8
Weight (kg)	57.4 ± 5.7	57.8 ± 5.1

Test means and standard deviations are reported in Table 2. The training group showed significantly greater improvement in the Biering-Sorenson and trunk flexion tests from pre-testing to post-testing than the control group ( $p=0.04$ ,  $p=0.01$ ). Pre-post changes in right and left side-bridge endurance were not significantly different between groups ( $p= 0.18$ ,  $p=0.53$ ).

Table 2. Trunk Endurance Test Scores

	Control		Training	
	Pre	Post	Pre	Post
Biering-Sorenson	101.5 ± 40.7	94.6 ± 34.8	80.1 ± 23.0	95.8 ± 21.0*
Right Side Bridge	59.8 ± 25.9	58.5 ± 16.6	74.4 ± 18.4	81.9 ± 23.9
Left Side Bridge	54.8 ± 21.2	59.7 ± 23.5	72.9 ± 17.3	82.2 ± 20.9
Trunk Flexion	125.3 ± 56.6	128.2 ± 49.2	157.8 ± 61.9	220.9 ± 121.8*

\* indicates significant difference

There was a significant difference between the pre-test means of the trunk flexion test between groups with the training group showing significantly longer times ( $p=0.00$ ). This would indicate the weaker group may make greater gains, however, since the training group made greater improvement; this is not a concern.

Injury data obtained from the athletic training staff indicated that one new low back injury occurred during the subsequent season. The injury was diagnosed as a muscle strain with possible intervertebral disc injury. There were also two reoccurrences of LBP in gymnasts who had had previous LBP. One was diagnosed as sacroiliac joint injury and the other spondylolysis of the 5<sup>th</sup> lumbar vertebrae with fracture of the articular facet S1.

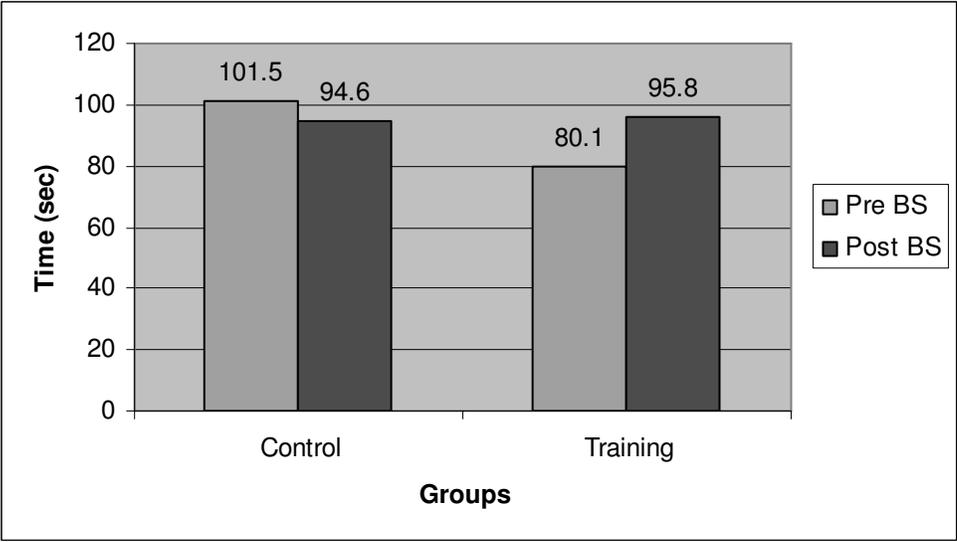


Figure 1. Biering-Sorenson Test Results

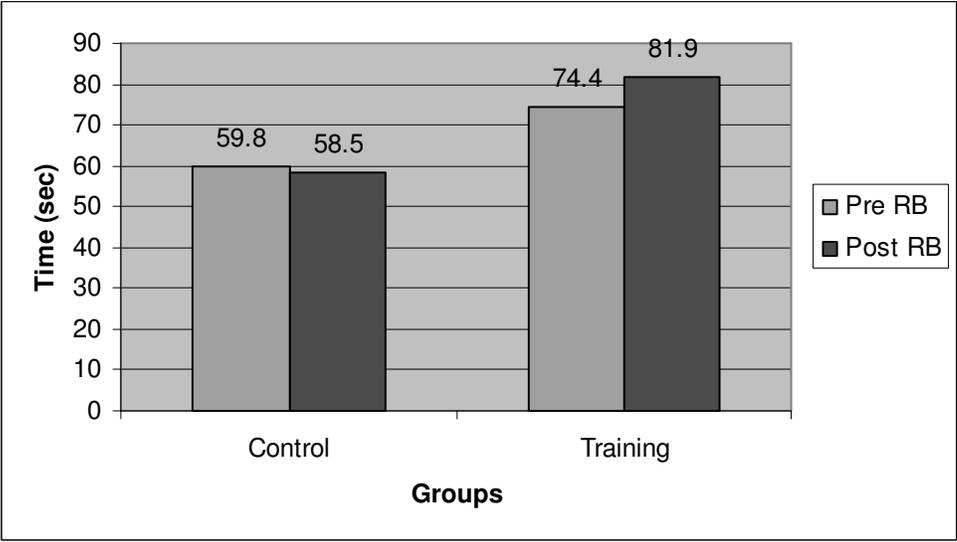


Figure 2. Right Side-Bridge Test Results

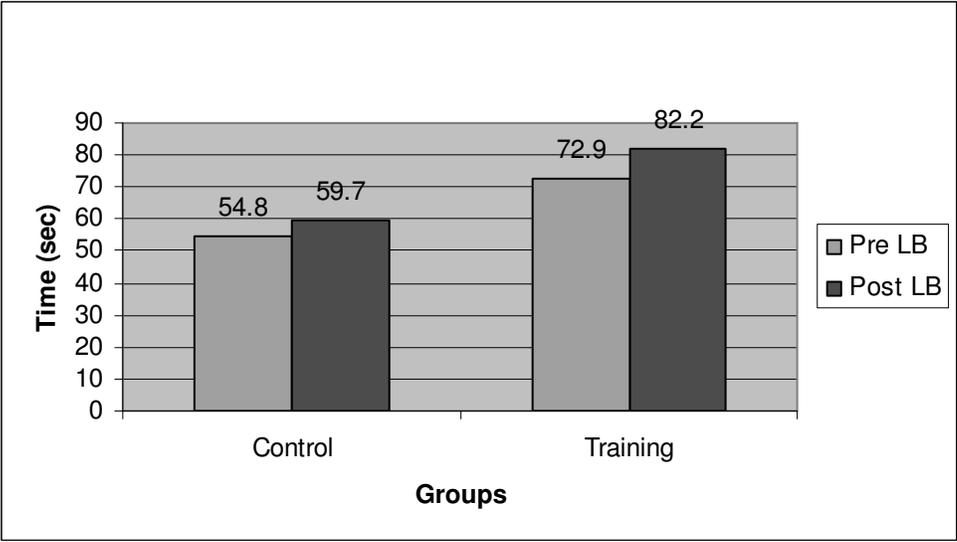


Figure 3. Left Side-Bridge Test Results

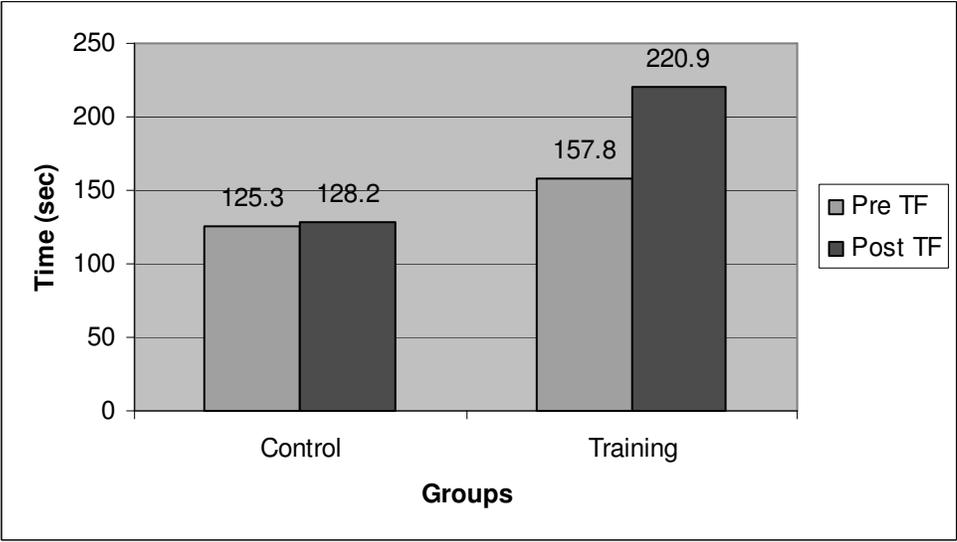


Figure 4. Trunk Flexion Test Results

## DISCUSSION

The purpose of this study was to examine the influence of the endurance training protocol of the trunk extensor and lateral flexor muscles on lumbar endurance capabilities as well as the association of the trunk endurance with LBP occurrence in gymnasts. Not surprisingly, we observed that subjects who performed exercises intended to increase trunk extensor endurance had significant increased in their hold times during the Biering-Sorenson test. We were however surprised that side-bridge hold times did not significantly increase in the training group in response to the sidelying double leg lift with lateral trunk flexion exercise. This result could be caused by two possible explanations. Either the training period (8 weeks) was inadequate for significant improvement or that the exercise did not sufficiently challenge the lateral flexor muscles as intended. In the aforementioned study by Durall and colleagues, significant improvements in side-bridge hold times were measured in response to a 10-weeks training period of side-bridge exercise. As the subjects progressed, manual force was applied to further challenge the muscles (4). As stated previously, the authors chose a different exercise for the lateral flexor muscles in the current study due to complaints by past study participants of upper extremity pain with the side-bridge exercise.

In a similar fashion, Harringe et al. studied the effects of 12 weeks of an abdominal “hallowing” exercise on LBP in a group of teamgym gymnasts (gymnasts competing in trampette (a form of trampoline), tumbling and floor program) Subjects performed abdominal hallowing in the prone position, four point kneeling position, and

standing on a balance board while ambulating arms up and down. After they progressed through the positions, trampette jumps specific to their sport were added to the regime. The training protocol was performed three to four times each week with every gymnastic training session. Of the thirty gymnasts participating in the intervention group, fifteen originally reported LBP at baseline evaluation. After eight weeks of segmental exercise training, eight of the LBP participants were pain free. The control group of gymnasts did not show any improvement in LBP incidence (7).

Intervention programs in other sports and activities for trunk endurance have shown beneficial effect as well. A core endurance program was also implemented by Tse et al. in the training of a college-age rowing team. The twenty-five members of the core training group performed endurance exercises two days each week for a duration of eight weeks. The core training protocol progressed through the following exercises. A warm-up of spinal mobility exercises and stretching was included, followed by lessons in transverse abdominis activation, and training progressed into postural/ stability exercises. Finally, at four weeks of training, subjects were asked to perform static and dynamic exercises as well as controlled mobility tasks. This training was then continued for 4 more weeks. Trunk endurance was examined using flexion, extension, and lateral flexion tests, as well as functional performance measures. Contrary to the present study, the results found significant improvement in lateral flexion endurance, yet no significant improvements in trunk extensor endurance (22).

There were some limitations to this study. Although study subjects were asked not to perform additional exercise for their trunk muscles, it is possible that activities outside the study (e.g. running) may have influenced the results. Additionally, a control

group of competitive gymnasts would have been a beneficial asset to the research. Unfortunately, there were a relatively small number of gymnasts in competition at the institution. Therefore, researchers included all gymnast subjects in the experimental group to receive the training. Without a control group of gymnasts it is difficult to make inferences on the strength of the association between changes in trunk endurance and incidences of LBP. However, the trend of reduced occurrences of LBP observed in our previous analysis continued, albeit with three exceptions- one new episode of LBP and two recurrences of LBP.

### **Practical Application**

The results of this study suggest that trunk extension and flexor endurance can be improved with the implementation of a pre-season trunk endurance training regime in collegiate gymnasts. Incidences of LBP in the training group of gymnasts were minor in comparison to past seasons. The training program may have contributed to fewer incidences of LBP, but this remains to be proven conclusively. We can conclude at least that the training protocol implemented did not appear to harm gymnasts or hinder their performance during practice or competition. The training protocol used in this study was easily added to the normal pre-season training regime of the competitive gymnastic team. The training was completed in less than ten minutes and did not require any equipment or partner work. Therefore, all subjects could complete the exercises at one time. In conjunction with past research, it seems the implementation of simple trunk endurance training is beneficial to the gymnasts' low back health and athletic performance.

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APPENDIX A  
INFORMED CONSENT

## Informed Consent

Protocol Title:           Effect of Trunk Endurance Training on Low Back Endurance and Injury Rates in Collegiate Gymnasts

Principle Investigator: Leah Creager 920 Cameron Ave. #201 La Crosse, WI 54601  
(309) 678-5324

Faculty Advisor:        Brian Udermann  
(608) 785-8181

Emergency Contact:    Leah Creager  
(309) 678-5324

### Purpose and Procedure:

- The purpose of this study is to determine the effect of lumbar endurance training on lower back injury rates in collegiate gymnasts.
- My participation will involve pre and post lumbar endurance testing and lumbar endurance training three times each week for eight weeks.
- The total time involvement requirement is approximately thirty minutes each week for eight weeks.
- Testing will take place in Wittich Hall, UW-L.
- Training will take place in Wittich Hall, UW-L.
- Testing will be performed until fatigue determined by myself.

### Potential Risks

- I may experience muscle soreness, fatigue, muscle strain, or ligament sprain.
- The risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.

### Rights and Confidentiality

- My participation is voluntary.
- I can withdraw from the study at any time for any reason without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using grouped data only.
- All information will be kept confidential by use of number codes. My data will not be linked with personally identifiable information.

### Potential Benefits

- I and other athletes may experience improvement in flexibility, strength, and endurance for practice and performance during the 2008 gymnastics season.

Questions regarding study procedures may be directed to Leah Creager (309) 678-5324, the principle investigator, or the study faculty advisor, Brian Udermann, Department of Exercise and Sport Science, UW-L (608) 785-8181. Questions regarding the protection of human subjects may be directed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608) 785-8124 or [irb@uwlax.edu](mailto:irb@uwlax.edu).

Participant \_\_\_\_\_ Date \_\_\_\_\_

Researcher \_\_\_\_\_ Date \_\_\_\_\_

APPENDIX B  
TESTING RECORD

**Effect of Trunk Endurance Training on Low Back Endurance Capacity and Low Back Injury Rates in Collegiate Gymnasts  
2008 Testing Data**

**Demographic Information:**

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Phone: \_\_\_\_\_ Email: \_\_\_\_\_

Age: \_\_\_\_\_ Height (in): \_\_\_\_\_ (cm) \_\_\_\_\_ Weight(lbs): \_\_\_\_\_

History of back injuries: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Testing Data (sec):**                      Pre-test    Post-test

**Biering Sorenson:**                      \_\_\_\_\_    \_\_\_\_\_

**Side bridge (right):**                      \_\_\_\_\_    \_\_\_\_\_

**Side bridge (left):**                      \_\_\_\_\_    \_\_\_\_\_

**Trunk Flexion:**                      \_\_\_\_\_    \_\_\_\_\_

Mean Endurance Times (sec) and Ratios Normalized to the Extensor Endurance Test Score

Mean age 21 yrs (men: n=92; women: n=137)									
	Men			Women			All		
Task	Mean	SD	Ratio	Mean	SD	Ratio	Mean	SD	Ratio
Extension	161	61	1.0	185	60	1.0	173	62	1.0
Flexion	136	66	0.84	134	81	0.72	134	76	0.77
RSB	95	32	0.59	75	32	0.40	83	33	0.48
LSB	99	37	0.61	78	32	0.42	86	36	0.50
Flexion/extension ratio	0.84			0.72			0.77		
RSB/LSB ratio	0.96			0.96			0.96		
RSB/extension ratio	0.58			0.40			0.48		
LSB/extension ratio	0.61			0.42			0.50		

APPENDIX C  
TRAINING RECORD

**Effect of Trunk Endurance Training on Low Back Endurance Capacity and Low Back  
Injury Rates in Collegiate Gymnasts  
2008 Training Data**

Name: \_\_\_\_\_

**Week 1**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 2**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 3**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 4**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 5**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2\_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 6**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2\_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 7**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

**Week 8**

Day 1 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 2 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

Day 3 \_\_\_\_\_

Double leg lift w/ crunch (right) \_\_\_\_\_reps  
Double leg lift w/ crunch (left) \_\_\_\_\_reps  
Right arm, left leg lifts \_\_\_\_\_reps  
Left arm, right leg lifts \_\_\_\_\_reps

APPENDIX D  
REVIEW OF LITERATURE

## **Effect of Trunk Endurance Training on Low Back Endurance & Injury in Collegiate Gymnasts Review of Literature**

**Leah Creager**

Low back pain is a prevalent ailment that affects a wide variety of ages in everyday life. Victims of this disorder can appear in all shapes, sizes, occupations, and fitness levels. Low back pain (LBP) may be attributed to excessive movement and strain requirements of the back, therefore, it is evident the condition is also an important issue in the world sports and athletics (14). Numerous studies and observations support LBP has particularly plagued the gymnastics field, low back injury can account for 10-15% of all athletic injury (30). According to Krause, low back pain rates can be as high as 75% in female gymnasts (14). An 8 month survey was administered by Cupisti, et al. to 70 competitive rhythmic gymnasts and 72 age-matched (13-17 yr.) control subjects. Injuries were recorded by all subjects in weekly injury booklets found 49 significant injuries within the gymnasts and 34 within the control group. The injury rates reported 1.08 athletic injuries per 1000 hours of training. Second only to ankle and foot, back injuries comprised 22.2% of these ailments. Surprisingly, gymnasts are known for training while injured (3, 25). They only missed an average of 4.1 training day while the control group missed 18.9 average days of activity (3). Similarly, Sands et al. conducted a 5 year study recording injuries affecting a National Collegiate Athletic Association Division I team. Records were kept by means of computer dot sheets by gymnasts before each training session. Body part effected, event injury occurred, date, and duration of injury were all collected. Data showed gymnasts training 71% time with injury. New injuries were found in 9% of training time and increased during competition preparation and performance (25). Increasingly, a study consisting of forty-two traditional gymnasts

performed by Harringe et al. observed 40 male and female Swedish gymnasts having 42 injuries within 27 individuals during a single season. There was no gender difference as the incidence rate was shown to be 2.2 in every 1000 hours of gymnastics, 28.5% resulting from the back (11). National Collegiate Athletic Association (NCAA) released the results of an injury surveillance system of gymnastic seasons 1988-1989 through 2003-2004 seasons. During the 16 year study, the number of involved schools dropped from 112 schools with 1,550 participants in 1988 to 86 teams involving 1,380 athletes in 2003. While the overall injury rate during competition decreased annually, the injury rate over practice hours remained constant. The percentages of trunk and back injuries amid competition and practice were 9.5% and 19.1% respectively; both figures placed trunk injuries third in prevalence (20). However, Parks et al performed a comparison of LBP and LBI between 63 competitive and 15 non-competitive gymnasts. There was no significant difference found between the two groups for incident rate of LBP or LBI (21). Although the incidence of LBP and LBI greatly affect the career of gymnasts, consideration should be given to the effect during gymnasts' life after gymnastics. Hudash et al conducted a study that followed 26 gymnasts for four years during their gymnastics career. 106 total injuries were recorded; 60 (57%) were acute onset caused by a specific event or fall and 46 (43%) were gradual overuse injuries. Hence, 22 of the 26 gymnasts were contacted 3 years later to find that 45% of the recorded injuries were still bothering the former athletes, especially the low back injuries. 27% of subjects felt their activity level was still limited although they were able to remain active (13).

While the prevalence of LBP and LBI in the gymnastic world is obvious, the cause is seen to be multifaceted and complex. Understanding of many disorders is

needed in order to prevent and treat the onset of LBP or LBI. The specific anatomy of LBP can surface in a broad spectrum of severity. The pain felt by the individual may be caused by a simple strain to numerous low back structures (14). Of the gymnast subjects in the study by Harringe et al. 6 of the 26 injured experienced injury to the lumbar back in the form of muscle and ligament strains (10). Intervertebral disc injury, herniated vertebral disk, vertebral growth plate injury and finally Scheuermann's disease may also be the root of LBP in athletes and gymnasts. Very often, even evaluation by a physician may not explain the exact cause; such LBP is then considered "nonspecific" back pain or "mechanical" back pain. One of the most common specific conditions to cause lower back pain in gymnasts is spondylolysis (14). This term can be defined as a defect or fracture of a part of the vertebrae near where one vertebra connects to another (32). Spondylolysis has been found in up to 50% of athletes experiencing LBP (27). The ailment is usually a result of repetitive combined hyperextension and rotation of the trunk. Spondylolysis may worsen into spondylolisthesis if not identified and treated. Determination of spondylolisthesis is noted by one vertebra slipping forward over the other. Facet syndrome may also be caused by vigorous extension and twisting of the torso. The facet joints are the points at which each vertebrae glides on the other; pain occurs as these synovial joints are irritated. Finally, scoliosis, a lateral curvature of the spine, may also affect few gymnasts (14).

The extensive use of flexibility, extension, and range of motion are evident in gymnastic performance, therefore the mechanical contributions to LBP by the sport are investigated. Five commonly executed gymnastic skills were performed by 4 competitive athletes in order to measure the impact and extension during a study done by Hall. Front

walkover, back walkover, front handspring, back handspring, and the handspring vault were measured while using Wielke's method. The protocol measured lumbar curvatures from film during normal relaxed standing posture as well as all five skills. Vertical and lateral ground forces were observed by use of a force platform at the end of each skill. Results found the handspring vault to produce the most vertical and lateral impact forces, while the back walkover and back handspring required the most lumbar hyperextension. The combination of lumbar hyperextension and impact to hands or feet were very close in time during the front walkover, back walkover, and back handspring (8).

Mechanical forces such as the previously mentioned may come into effect during adolescent growth spurts. This combination of intense training during growth may cause an increased risk of LBP and LBI (19, 27). Sward states disc degeneration is more frequently found in young elite athletes such as wrestlers and gymnasts. This diagnosis is defined as a disc height reduced on radiographs and decreased disc signal during magnetic resonance imaging (MRI) (27). Controversial, Terti et al found only 3 of 35 gymnasts to have disc degeneration associated with conditions of Scheuermann's disease and spondylolysis. Therefore, they concluded that despite the extreme range of motion and load impact of gymnastics, incurable damage to intervertebral discs is rare in young gymnasts during growth periods (28).

Another possible cause of LBP is thought to be muscle imbalance between levels or bilaterally. The spinal curvature and trunk muscular tone of rhythmic gymnasts were investigated by Kums et al. during three consecutive years of international competition. Subject pool consisted of 32 competitive rhythmic gymnasts as well as 48 un-trained control females. Measures of lumbar lordosis and thoracic kyphosis were quantified by

pantography over three trials and a mean score was recorded. The angles of both curves were found to be lower in gymnasts than in the controls. Trunk flexors of the gymnasts were also found to be under toned combined with a more rigid vertebral column caused a muscular imbalance between trunk flexors and trunk extensors that was not present in the control measures. Relative, 50% of the gymnast group suffered from LBP (15).

The idea that muscle activation and recruitment patterns affecting the magnitude and direction of loading on the intervertebral joints, muscle activation imbalance was the area of interest for another study. Reeves was able to conduct a larger scale experiment using 242 varsity athletes of various sports to measure EMG activity of lumbar and thoracic erector spinae muscles during isometric extension of the trunk. Activation was compared between athletes with a history of LBP and those with no history of LBP. There was no significant difference between groups in the imbalance between muscle pairs on sides, however the history of LBP group had a greater imbalance in the activation of muscles between levels of thoracic and lumbar. Yet, the activation of level muscles was similar between those with no LBP and those that encountered a first time incident; this suggests to researchers that the imbalance does not necessarily cause LBP. No significant differences were found between groups with one injury and those with multiple or short and long duration injuries; leading to the idea that imbalance is not an impairment to athletes (23). The final possible contributor to be discussed will be the simple muscle fatigue. Udermann found the patients with ongoing or intermittent LBP have been tested to have decreased endurance of trunk muscles. According to Udermann, fatigue reduces the protection of the spine and musculature and therefore leaves the lumbar region more susceptible to injury (30).

Clinical tests to measure the strength and endurance of trunk and lumbar muscles have been a useful tool for administrators for many years. There are many tests in practice that use a range of equipment. Udermann et al performed a study to determine the reliability and variability of both static and dynamic tests on both a dynamometer and a roman chair. The study consisted of 8 subjects (5 men and 3 women) performing an isometric lumbar-extension strength test followed by four lumbar muscle endurance tests; dynamic on dynamometer, static on dynamometer, dynamic on roman chair, and static on roman chair. The initial isometric lumbar –extension strength test was a 7-angle test on the dynamometer, used to establish maximal lumbar-extension peak-torque value. Endurance tests on the dynamometer were loaded with 40% of peak torque, while the roman chair endurance tests were simply using body weight as load. Dynamic tests were measured by number of repetitions completed to failure, as the static tests were simply holding the desired angle until fatigue. The results concluded the test reliability for all four endurance tests were between 0.91 and 0.96 interclass correlation, high and satisfactory (31). Hagar and Udermann et al continued research in reliability of dynamometers in 2006 with testing of the Back-Up dynamometer. This study included 16 subjects performing 2 trials static and 2 dynamic trials with 50% of their body weight serving as load. Again, one day of rest was given between tests. Additionally, the interclass correlations of the static and dynamic tests were 0.92 and 0.93 respectively, both satisfactory (7).

Arab et al. tested the sensitivity and specificity of 5 clinical tests in practice at 4 hospital orthopaedic and physical therapy departments and out-patient rehabilitation clinics. The study involved 200 participants divided into 4 categories; 50 men with LBP,

50 men without LBP, 50 women with LBP, and 50 women without LBP. The clinical tests on trial were the Biering-Sorenson test, prone double leg raise, supine double leg raise, prone isometric chest raise, and supine isometric chest raise. While all five tests were found to have satisfactory sensitivity and specificity in low back pain, the prone double leg raise achieved the highest sensitivity, specificity, and predictive value.

Discussion of results and previous literature included confusion of the validity of the commonly used Sorenson test. Arab stated previous literature found conflicting ideas of the tests ability to measure endurance of the paraspinal muscles opposed to the hip extensor muscles (gluteus maximus and hamstring). In this particular study, the Biering-Sorenson test, while still satisfactory, scored the worst for overall intraclass correlation of LBP. The prone double leg raise would be clinically useful in predicting LBP in patients (1). However, Latimer et al. found the Biering-Sorenson protocol to have what they thought to be reliable measures and the ability to discriminate between subjects with and without LBP. The intraclass correlation coefficient were found to be; subjects with current nonspecific LBP ICC 0.88, previous nonspecific LBP ICC 0.77, and no symptoms of LBP ICC 0.83 (16). The Sorenson test received more support from the study performed by Simmonds et al as they tried numerous clinical tests for validity. All tests including Sorenson were found to have excellent intertester reliability with ICC >0.95 (26). Finally, da Silva et al compared 3 back test protocols by recording electromyography bilaterally from four homologous back muscles while 31 subjects completed static trunk extension effort. There were 18 healthy subjects involved as well as 13 subjects that experience chronic LBP. Fatigue of the muscles was measured by the slopes of linear regression of electromyography and found no significant difference

between the two subject groups for any of the three tests including the Biering-Sorenson. However, it was observed that the Sorenson test produced more fatigue to the back muscles than the semi-crouched lifting test also tested (14).

Due to the variety and prevalence of LBP and LBI injury found in the gymnastic field, intervention using training modification is needed for improvement. Numerous studies have followed this idea in other sports. For example, Tse et al implemented a core endurance intervention program for a college- age rowing team. The intervention involved 45 subjects with approximately 1 year of rowing experience. All subjects were actively participating in 3-5 rowing sessions each week prior to the study. Twenty-five of the subjects became the training group while 20 did not receive any additional training. Testing for the study would include not only trunk muscle endurance test including; extensor, flexor, and both side bridge tests, but also physical performance tests such as; vertical jump, standing broad jump, shuttle run, 40 meter sprint, and medicine ball throw. The core training implementation included two 30-40 minute sessions each week for 8 weeks. The core training began with simply learning how to activate the transverse abdominis and multifidus muscles, then static and dynamic exercises were introduced, finally, controlled mobility exercises were taught and performed. The results exhibited significant improvement in lateral flexion endurance; however, trunk extensor endurance did not increase in the core training group involved in the study (29). Udermann, Reineke, et al implemented a study in order to evaluate the effect of 10 weeks of training of a BackUp lumbar extension dynamometer (BLED) on lumbar strength and endurance. Twenty-four individuals were split into a control and treatment groups, each with 6 males and 6 females. The treatment group received

training on the BLED two times each week for ten weeks. The training was performed for one set of 20 repetitions at 40% mean torque value determined during a 7-angle isometric test. Progression was made in 5% increments as the subjects were bale to complete 20 repetitions. Each repetition involved a 6 second concentric and 6 second eccentric phase. The control group tested significantly stronger than the treatment group at the beginning of the study. Strength improvement was much greater at every angle for the treatment group than the control group. The lumbar resistance training resulted in a 134.8% increase in lumbar extension endurance. This study was the first to provide improvement on a BLED, a machine much less expensive than other dynamometers used in clinics and previous studies. Improvement difference could have been partially caused by the extensive weight difference and pre-study strength difference between the control and training groups (31). Harringe, Nordgren, et al. found evidence that specific segmental exercise was beneficial to patients with LBP. They developed a study to find if this exercise protocol would also decrease intensity of LBP and incidence of injury in adolescent teamgym gymnasts (one that participates in trampoline, tumbling, and floor exercise). Forty-two gymnasts between the ages of 11-16 years both with and without LBP completed LBP questionnaires daily for 12 weeks. Baseline data was collected for 4 weeks, and found 24 gymnasts (47%) reported LBP. The intervention group of 30 athletes was trained using specific segmental exercises, at completion questioning (post 8 weeks training) 8 of the 15 that previously reported LBP were pain free. The control group did not show any difference from baseline pain to completion. The researchers concluded that specific segmental muscle exercises may prevent or reduce LBP in adolescent teamgym participants (10).

Several pre-season training protocols have been observed to include little to no trunk extension training while focusing more attention to trunk flexor training. Durall implemented a trunk extension protocol to supplement the training program for a competitive collegiate (NCAA Division III) women's gymnastic team in order to observe the effect on the rate of LBP in the athletes. The study included a training group of fifteen gymnasts and a control group of fifteen collegiate non-athlete females. Both groups were tested prior to training, mid-point of five weeks, and after ten weeks training using four well-supported tests for endurance of the trunk flexors, extensors, and right/left oblique. The training group underwent two sessions of a simple trunk extension and oblique exercises each week. The training group showed significant endurance improvements in all four tests from pre-testing to mid-testing as well as mid-testing to final testing. Particularly, the training group achieved 32% mean improvement in trunk extension after ten weeks of training. The control group only exhibited insignificant improvement in the trunk flexion test. The results of the study also found a reduction in incidences of LBP from 3 to 4 each season to 1 recurrent incident during the intervention season. There were no new episodes of LBP reported by athletes, coaches, or athletic trainers during the season following the conditioning. Although the study produced positive results, there were also limitations to the conclusion. The trunk flexor test was subject to variability due to tester discretion and verbal cueing. Only a small number of gymnasts were available and therefore, the control group was comprised on non-athlete collegiate females. Finally as with many studies, there was little control over the actions and exercise habit of the subjects. The effect of the trunk extensor training on endurance and decrease in LBP could be the results or numerous variables. Therefore, Durall et al.

intended to repeat the study with progressive changes in order to greater support the results (6).

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