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Effects of lumbopelvic stabilization program in young, non-elite, community-based gymnasts

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EFFECTS OF LUMBOPELVIC STABILIZATION PROGRAM IN YOUNG, NON-ELITE, COMMUNITY-BASED GYMNASTS

An Abstract of a Thesis

Submitted

in Partial Fulfillment

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ABSTRACT

Context: Gymnasts are seen practicing and competing even though they are reporting high levels of low back pain that can hinder their career if not resolved. Therefore, it may be beneficial for gymnasts to train key muscles in the lumbopelvic region to decrease those symptoms and prevent future injury. This study assesses the effects of lumbopelvic stabilization training in young, non-elite, community-based gymnasts. Objective: Measure the effectiveness of core stability training on lumbar muscle endurance, lumbo-pelvic stabilization, abdominal strength and balance in adolescent female gymnasts and examine the effect of these interventions on the occurrence of low back pain. Design: Clinical prospective with 13 female gymnasts from a local gymnastics club. Methods: Participants were randomly allocated to either a lumbo-pelvic intervention group or yoga group in which they performed specific exercises for a total of 6 weeks. Four pre- and post-measurements tests were conducted on the participants before and after the 6-week intervention. Main Outcome Results: Biering-Sorensen Test, Lumbo-pelvic Control Test, Side Bridge Test, and Star Excursion Balance Test; low back pain log books. Results: Relationship between pre- and post-scores for the Biering-Sorensen Test revealed statistically greater results for the lumbopelvic group compared to the yoga group (p = .033. An ANCOVA showed statistically significant group differences (p = .043). Relationship between pre- and post-scores for the Lumbopelvic Control Test was statistical significance (p = .040) but the difference scores from pre- to post were not. Relationship between the right and left Side Bridge was statistical significance (p = .015; p = .001), respectively, and scores from pre to post were statistically greater for the yoga group (p = .039). ANCOVA results showed statistically significant group differences (p = .036). Results from a MANOVA revealed a statistically significant finding for group difference at post-test on the left side (p = .052). Out of the six fully completed log books, the yoga group showed less occurrence of low back pain compared to the lumbopelvic group. Conclusion: Those in the lumbo-pelvic group showed greater improvements from pre- to post-test scores in comparison to the yoga group for the development of muscle lumbar endurance and may be a better option for this aspect than yoga. Results from the left Side Bridge Test showed the yoga group influenced the development of lateral core stabilizer endurance more so than the lumbo-pelvic exercises. Overall, there were improvements in both groups for the Side Bridge Test, indicating both positively influence lateral stability. Results for the Lumbopelvic Control test suggests that the yoga and lumbo-pelvic interventions are equally effective for front-on stability. Log books revealed that some of the participants remained pain-free while some had both an increase and/or decrease throughout. The importance of core stability is viewed as being pivotal for efficient biomechanical function to maximize force generation and minimize joint loads in all types of activities associated with gymnastics. This study sets the basis for further research on the incidence of low back pain in young gymnasts and the effects of lumbo-pelvic stabilization exercises as a preventative matter.

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DEDICATION

I would like to dedicate this thesis to my family: my parents, Joann and Al Pomije, and my siblings: Krystal Riha and Justin Pomije. Your love and support throughout this journey to further my education has made this possible and for that I am truly grateful.

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INTRODUCTION

Low back pain is a commonly occurring health issue for millions of Americans with a life-time prevalence rate of 70-80% in the general adult population (Biering-Sorensen, 1983; Harringe, Renstrom, & Werner, 2007) and in the adolescent population it ranges between 24-57% (Burton, Clarke, McClune, & Tillotson, 1996; Harreby et al., 1999; Homer & Mackintosh, 1992). For the sporting population, which includes organized sports, low back pain is commonly encountered in gymnastics, football, golf, running, soccer, volleyball, and tennis (NCAA, 1999; NCAA, 1998). As low back pain is multifactorial, there is no consensus on a specific cause despite such high rates of prevalence (Pool-Gouzwaard, Vleeming, Stoeckart, Snijders, & Mens, 1998). However, lumbar instability has been frequently reported as a cause (O'Sullivan, 2000). With sports such as gymnastics, stability in the lumbo-pelvic region is a key component for participants to perform optimally.

Gymnastics has grown significantly in participation over the past twenty-five years with approximately 20 million young women being involved in the 1990's in the United States; with at least 2 million participating in competitive gymnastics (Tofler, Styler, Micheli, & Herman, 1996). In 2010 there were approximately 5 million participating in competitive gymnastics with 76% being female and of this 80% were under the age of 18 (Gymnastique, 2010).

In gymnastics, the body endures high amounts of repetitive twisting, rotating, and bending (Kolba, 2005). The sport involves a high level of skill as well as strength and flexibility, yet many sustain injury with the lower spine being a common site for acute and chronic overuse cases (Mulhearn & George, 1999). Injuries reported in gymnasts include anterior apophyseal ring avulsion, spondylolysis, spondylolisthesis, disc herniation, bone marrow edema (Bennett, Nassar, & Delano, 2006), endplate damages, fractures, disc degeneration, muscle strains, ligament sprains, and non-specific low back pain (Caine, Cochrane, & Caine, 1989; Harringe, Renstrom, & Werner, 2007; Harringe, Lindbald, & Werner, 2004; Homer & Macintosh,1992; Katz & Scerpella, 2003; Sward, Hellstrom, Jacobsson, & Peterson, 1990; Sward, Hellstrom, Jacobsson, Nyman, & Peterson, 1991).

The likelihood for a gymnast to acquire low back pain and injury is relatively high in comparison with other sports with annual incidences between 30-90% as well as frequently recurring incidence of 72% (Caine et al., 1989). Injury rates per 1000 exposures of female gymnasts range from 3.7 to 22.7 (Caine et al., 1989; Sands, Shultz, & Neumann, 1993; Weiker, 1985). Women's collegiate gymnastics has the highest percentage low back injury rate of all the NCAA sanctioned and monitored sports (NCAA, 2004).

A potential factor in the etiology of low back injury and pain is weakness in the lumbar spine musculature around the lumbar region (Pareniapour, Nordin, Kahanovitz, & Frankel, 1988). Controlling the spine is complex because it relies on well-coordinated muscles (Panjabi, 2006) specifically the transverse abdominis and abdominal obliques (Richardson, Topperburg, & Jull, 1990). These two muscle groups have obtained special attention due to their importance for controlling movement and stability of the spine (Richardson et al., 1990). In the general athletic population, reduced trunk extensor muscle endurance is found to be a risk factor for low back injury and resilient pain (Biering-Sorensen, 1984). Those with poor trunk muscle endurance, therefore, may have low muscle fatigue thresholds which could result in an increased loading of the passive low back structures such as bone, disc, and ligaments (Mayer, Gatchel, Betancur, & Bovasso, 1995; Wilder et al., 1996).

Reported risk factors for developing low back injury and pain in gymnasts include starting at a young age, training and competing during periods of growth (Kujala, Taimela, Oksanen, & Salminen, 1997), complexity of skills performed (Dixon & Fricker, 1993), and overall duration of training along with the exposures of biomechanical force (Daly, Bass, & Finch, 2001; Dixon & Fricker, 1993). One of the most crucial aspects of gymnastics which determines success is the landing component. It has been described as one of the mechanisms for low back pain in gymnasts as ground reaction forces are reported to be up to 13 times the individuals' body weight (Harringe, Nordgren, Arvidsson, & Werner, 2007). As there is no avoiding the landing component and amount of exposures to high intensity performance the gymnast is at increased risk for low back injury and subsequent pain.

One key aspect which may be effective in the prevention or reduction of low back injury and pain is optimal stability in the lumbo-pelvic region. Bouisset (1991) proposed that stabilization of the pelvis and trunk is necessary for all movements of the extremities. Its stability is dependent on a combination of global, superficial muscles around the abdominal and lumbar region and local stability in the intrinsic muscles of the abdominal wall (Marshall & Murphy, 2005). For gymnasts, core stability training is vital due to inherent components such as spinning and rotation (Kolba, 2005) as these require complex interactions between skeletal, ligamentous, and muscular components (McGill, Grenier, Kavcic, & Cholewicki, 2003).

Proper maintenance of balance and postural equilibrium is vital in sport (Riemann & Guskiewicz, 2000) so the focus of training should include muscular stabilization of abdominal, paraspinal, and gluteal muscles in order to provide better stability and control (Nadler et al., 2002). Therefore, it is not simply one element that needs to be trained, but numerous components including balance, proprioception, strength, and stability of the whole lumbo-pelvic region.

Several studies have measured the relationship of core stability and low back pain and exercise interventions that could be incorporated into training in order to reduce or prevent the likelihood of low back injury and pain. For example, Bassett and Leach (2011) implemented an 8-week training program split into two phases to improve core stability in female junior-level elite gymnasts between the ages of 9-13 years old. The first phase included exercises such as the pelvic tilts, transverse abdominis activation, crunches, heeltaps while lying supine and touching the heels side to side, and supermans where you lie prone and lift both arms and legs about an inch from the ground. The second phase was designated to dynamic exercises which included bicycle cross crunches along with standard crunches, superman, squat thrusts, and kneeling ball roll with exercise ball. They used the Bunkie test, which involves progressive loading of the legs to assess function of all the core muscles by using five testing positions, for their pre-and post-test measures. Results showed that those in the exercise group had increased lumbar stability and endurance as measured by the supine plank position.

Mills, Taunton, and Mills (2005) measured the effect of a 10-week training regimen on lumbo-pelvic stability and athletic performance with training of the transverse abdominis, lumbar multifidus, and the pelvic floor musculature on female collegiate-level basketball and volleyball players. Although improvement in athletic performance wasn't noticeably significant, increases in stability, agility, vertical jump, and static balance was reported significant in the intervention group. Durall et al. (2009) implemented a 10-week preseason trunk muscle training component on collegiate-level women gymnasts. They found significant improvements in all four trunk muscle endurance tests and reported no new episodes of low back pain. These studies have shown that various methods of core training can have an effect on the core musculature and therefore may positively impact low back injury and pain.

Other interventions have been used in attempt to alleviate or reduce low back injury and pain, including yoga. A study conducted by Tilbrook et al. (2011) took 313 adults with chronic low back pain with half placed into a gradual progressive yoga program over a 3-month period. Those who performed yoga had better back function at 3, 6, and 12 months compared to the other half who just performed 'usual care'. Similar findings were seen in a study by Sherman et al. (2011) who incorporated a yoga group intervention comparison to stretching intervention and a self-care book intervention. After 12 weeks of these interventions, the yoga group had greater reduced pain and at 26 weeks continued to have reduced pain but similar to those in the conventional stretching group.

The majority of studies have focused primarily on collegiate-level or elite adult and junior-level gymnasts and there exists a paucity of empirical evidence on the effectiveness of lumbo-pelvic stability on the adolescent level. Furthermore, those studies which have focused on junior-level participants have done so at the elite level. This is problematic as the majority of junior-level participants are not at the elite level and may not benefit from interventions. Therefore, the primary aim of this study was to examine the effect of two 6-week core stability interventions on lumbar endurance, lumbo-pelvic stabilization, abdominal strength and balance in non-elite level, young female gymnasts. A secondary aim was to examine the effectiveness of the 6-week core stability interventions on low back pain.

METHODS

This was a randomized control study which utilized a pre-measurements, intervention, and post-measurements design. The following will provide details of the participants, study design, measures, core stability interventions, data collection procedures, and data analysis of this study.

Research Participants

Participants were recruited from a local gymnastics academy in Cedar Falls, Iowa (Ruby Gymnastics Academy). A meeting with all the parents whose daughters may be interested in participating was scheduled and a thorough description of the study was presented. Interested parents were provided with a participant Health History Questionnaire, Parent Consent form, and Participant Consent form. Demographics on the Health History Questionnaire included age, height/weight, years of experience, previous/ current injuries, other sports and activities they are involved with, and history of low back injuries. The female gymnasts ranged from ages 9-17 years old (Table 1) who practice approximately 3-5 days per week at 4 hours per session. A total of 13 female gymnasts participated in this study and all participants had parental consent forms signed in order to participate. Participants were randomly allocated to a lumbo-pelvic stability intervention group (n=6) or yoga group (n=7). Those in the lumbo-pelvic stability group were guided on a 6-week lumbopelvic strengthening program while the yoga group was guided on a 6-week yoga intervention developed for an adolescent population.

Table 1. *Participant Demographics*

Participants	# Participants	Age (yrs) (±) S.D.	Height (cm) (±) S.D.	Weight (kg) (±) S.D.
Lumbo-pelvic Group	6	12±2.9	58.2 ±4.9	91.6 ±30.3
Yoga Group	7	11.2 ±1.3	56.8 ±1.6	79.8 ±13.0
Total	13	11.6 ± 2.4	57.5 ± 3.8	85.7 ± 24.1

Study Design

This study adopted a randomized controlled design with two 6-week core stability interventions. The participants were randomly allocated to be placed into the lumbo-pelvic stability intervention (n=6) group or a yoga intervention (n=7) group. The randomization consisted of marking folded cards of paper with either yoga or lumbopelvic ad placing them into a box and shuffling. After the participant completed their pre-measuremnt tests, a card was randomly pulled from the box by the primary investigator indicating which exercise intervention group they would be placed into.

Measures

The instruments for this study were designed to measure levels of muscle endurance, strength, balance, and lumbopelvic stability. This study utilized a self-administered daily log book with a low back pain scale that has been used in a previous, similar studies. The pre- and post- measurement instruments have been used in previous studies.

Demographics. For each participant age (years), height/weight (cm/kg), years of experience, and the number of training days and hours per week were obtained.

Pre- and Post-test Measures. A total of four pre- and post-assessment tests were used to measure muscle endurance, balance, and lumbopelvic stability. These tests included the Biering-Sorensen Test (Figure 11), Side-bridge (Figure 12), Star Excursion Balance Test (Figure 13), and the Lumbo-pelvic Control Test (Figure 14). The *Biering-Sorensen* Test assesses the endurance of the erector spinae muscles. Actions of these muscles include extending the vertebral column bilaterally and laterally flexing the vertebral column unilaterally which are components of a gymnasts' performance with backward (concentric) and forward (eccentric) bending motions. This test has been previously used by Durall et al. (2009) on collegiate female gymnasts and Leetun, Ireland, Wilson, Ballantyne, and Davis (2004) on male and female collegiate basketball and cross country athletes. The reliability and validity of this test was done on subjects with reporting current or previous nonspecific low back pain (NSLBP). Results showed those without NSLBP had longer holding times while those with NSLBP terminated the test due to fatigue or pain in the buttocks, posterior thighs, and low back (Latimer, Maher, Refshauge, & Colaco, 1999). *Lumbopelvic Control* Test assesses the rectus and transverse abdominis muscles. When activated, these muscles help maintain a neutral position of the pelvis in order to decrease the pressure being placed on the spine. This disperses the load from the spine to a larger region of muscles to help complete complex skills. The test was developed by the Cricket Australia National Physiotherapy Working Group that assesses youth, teenage, and adult cricket players (Sims et al., 2013). The *Side*

Bridge engages primarily the obliques and quadratus lumborum muscles. Together they help with rotation, forward flexion, back extension, thsst are all actions during flips, twist, or rotating movements. Durall et al. (2009) used this as a pre-measurement on female collegiate gymnasts. Balance is incorporated in most, if not all, components a gymnast is exposed to, therefore the *Star Excursion Balance Test* (SEBT) was determined to be included to measure dynamic balance. The SEBT has been used in numerous research (Plisky, Rauh, Kaminski, & Underwood, 2006; Filipa, Byrnes, Paterno, Myer, & Hewett, 2010; Gribble, Hertel, & Plisky, 2012).

All the pre- and post-measurement tests were conducted at the gymnastics academy under the supervision of the primary investigator. Each participant was tested individually to ensure confidentiality. Prior to the tests, the participant were instructed on spinal and extremity stretches.

Low Back Pain Survey. Participants were provided with a home low back pain survey for the duration of the study. At the end of each day participants were requested to respond to a primary question, (Figure 15) consisting of a single question and depending on their response were directed to answer two additional questions. The primary question was, "Do you have or have you had back pain today?" If so, the participant was instructed to make a mark on the exact location of pain on a diagram of the body and rate the intensity of pain with a category-ratio scale from 0-10; 0 being no pain and 10 being worst pain. Those who indicated 'yes' were then asked, "What generated the pain and what did they do to get relief?" This survey was used in a similar study by Harringe, Renstrom, and Werner (2007) on competitive female gymnasts between the ages 11-17. In the current study, participants filled them out two weeks prior to commenting their assigned intervention before the study, throughout the 6-week intervention period, and two weeks post study.

Exercise Interventions

All exercise training sessions were conducted and supervised by the primary investigator and supervising investigator at Ruby Gymnastics Academy in Cedar Falls, Iowa. Each training session took approximately 20 minutes and began after their team warmup. There was a total of two training sessions per week with exercises gradually progressed over the 6-week period (total of 12 sessions for each group). Participants were considered compliant if they attended at least 80% of the exercise sessions over the 6-week training period.

Lumbo-pelvic intervention. Five exercises from the Princeton University Pelvic Stabilization, Lateral Hip, and Gluteal Strengthening Program were used for the six-week intervention. These exercises included: double leg bridge; single leg bridge; side bend; side plank; and fire hydrants. Previous studies have incorporated various interventions to train and strengthen the core, however, this is the first study to specifically incorporate Princeton University Pelvic Stabilization, Lateral Hip, and Gluteal Strengthening Program. Similar exercises such as the side plank and bridging were incorporated into previous studies (Mills et al., 2005; Durall et al., 2009).

Yoga Intervention. Five yoga poses were used for the six-week intervention for the control group. Each of the poses are commonly used for this age group (Bregel, 2013).

These exercises included downward-facing dog, bridge, child's pose, happy baby, and rag doll.

Procedures for Collecting Data

Following IRB [16-0286] approval, the parent consent forms were distributed during a presentation with parents and potential participants. At this time, potential participants and parents were provided with an explanation of the study, Parent Consent forms, and a Health History Questionnaire which focused on the participants' history of low back and other musculoskeletal areas including both past and present. Participants were assured confidentiality and informed they may discontinue at any time without penalty. Following consent each participant was contacted to determine their eligibility. This was based off participation status as well as no current or past injuries that may harm the participant while doing the pre- and post- measurement tests and intervention exercises. Once this was determined, the demographics and anthropometric characteristics were obtained on each approved participant and they were scheduled for their four pre-test assessments on muscle endurance, balance, and lumbo-pelvic stability. The participants were provided with a daily log book (as described previously) and were instructed to make daily entries for two weeks prior to the commencement of the pre-test assessments.

Following baseline data collection, participants were randomized to the lumbo-pelvic training intervention (n=6) or yoga (n=7) intervention and notified which group they were allocated to on the first day of the intervention. Those in the lumbo-pelvic group were supervised on a pelvic stabilization, lateral hip, and gluteal strengthening program and maintained a daily log book of low back pain. Those in the yoga group were supervised on their routine and also maintained a daily log book of any symptoms of low back pain.

The exercises were performed under the direct supervision of the primary investigator and supervising investigator at the gymnastics academy twice a week for approximately 20 minutes prior to practice after each had participated in the team warmup. Prior to participants engaging in either intervention, the exercises were demonstrated by the investigators with repetitions and sets included. At weeks two and four, each participant was assessed on their progress of each of the specific intervention components. For example, a participants' ability to reach the intended level of repetitions and sets. At this time, the investigators determined whether the participant was able to progress, reduce their levels, or continued at the same amount of repetitions and sets. Upon completion of the six-week interventions, participants from both groups were scheduled to complete the post-measurement testing at the Academy.

Furthermore, participants submitted their daily log books that measured their low back pain. They were instructed to fill them out daily two weeks prior to the commencement of pre-assessments, during the 6-weeks of intervention, and two weeks' post study. Once the log books were completed, they were given to the primary investigator.

Data Analysis

The data from the pre- and post-measurement tests was entered into SPSS v23. Multiple independent sample t-tests were conducted to establish any differences between the groups for pre-test, post-tests, and pre- to post- gains with the Biering-Sorensen Test, Side Bridge, and Lumbopelvic Control. To further explore group effects, an ANCOVA was conducted for both the Biering-Sorensen Test and the Side Bridge in which the pre-test scores were used as covariates. A MANOVA was conducted for the Star Excursion Balance Test to compare groups at pre-test, post-test, and gains from the pre- to post-test on both right and left sides. In order to measure low back pain or change in low back pain, log book data was analyzed to assess the percentage of LBP occurrence for each group and group member. Of the 13 participants, 6 log books were fully completed and these were used in the analysis.

RESULTS

Relationship between pre- and post-scores for the Biering-Sorensen Test did not reach statistical significance (b = 0.44, p = .24). No group difference was observed at the pre-test (p = .63). While no group difference was observed for the absolute post-test scores (p = .15), the difference scores from pre to post were statistically greater for the lumbopelvic group (M_{Δ} = 22.0) compared to the yoga group (M_{Δ} = 9.8) with $t(11)$ = 2.04, p = .033 (using a directional test). Please refer to Table 2 and 3.

To further explore possible group effects, an ANCOVA model was run in which the pre-test scores were used as covariates. In alignment with the previous result, statistically significant group differences were observed (standardized coefficient for yoga group effect: β = –0.58, p = .043). To keep the number of parameter estimates reasonable, the age variable was treated as an interval measure instead of an ordinal measure, though comparable estimates were obtained when the larger parameter models were employed. Neither age nor pre-test were significant measures, and the experience difference was evident between levels 1 (1-2yrs experience) and 2 (3-5yrs experience) [(p = .047)] and levels 1 and 3 (6+ yrs experience) [(p = .037).]

Relationship between pre- and post-scores for the Lumbopelvic Control Test was statistical significance (b = 0.96, p = .040). Group differences were observed at the pre-test (M_1 = 1.5 & M_2 = 0.7) with $t(11)$ = 2.11, p = .029). No group difference was observed for the absolute post-test scores (p = .92), and the difference scores from pre- to post were not statistically different (p = .80). Please refer to Table 2 and 3.

Table 2**.** T-Test, Biering Sorenson Test (BST), Lumbopelvic Control Test (LCT), Side Bridge (SB)

Variable	**N**	**Mean**	**SD**	***p***
BST (pre-test)				
LP group	7	26.38	9.41	
Yoga	6	23.73	9.67	
				0.22
BST (post-test)				
LP group	7	36.19	7.81	
Yoga	6	45.77	13.95	
				0.98
Lumbo-pelvic C (pre-test)				
LP group	7	0.71	0.49	
Yoga	6	1.5	0.84	
				.029
Lumbo-pelvic C (post-test)				
LP group	7	1.86	1.07	
Yoga	6	3	1.26	
				0.92
Right Side Bridge (pre-test)				
LP group	7	30.19	14.93	
Yoga	6	33.22	9.65	
				0.68
Right Side Bridge (post-test)	7	41.9	18.87	
LP group	6	42.96	17.77	
Yoga				0.92
Left Side Bridge (pre-test)				
LP group	7	24.01	11.4	
Yoga	6	33.41	14.92	
				0.22
Left Side Bridge (post-test)				
LP group	7	46.83	11.63	
Yoga	6	46.61	22.28	
				.98

P = ≤.05

Relationship between pre- and post-scores for the right-side Side Bridge was statistical significance ($b = 0.93$, $p = .015$). No group difference was observed at the pre-test ($p = .68$). No group difference was observed for the absolute post-test scores ($p = .92$), and the difference scores from pre to post were not statistically different ($p = .80$). Thus, it appears both groups were comparable at pre- and post-test and comparable in their gains over time. Please refer to Table 2 and 3.

Relationship between pre- and post-scores for the left Side Bridge was statistical significance ($b = 0.99$, $p = .001$). No group difference was observed at the pre-test ($p = .22$). While no group difference was observed for the absolute post-test scores ($p = .98$), the difference scores from pre to post were statistically greater for yoga group ($M_\Delta = 22.8$) compared to lumbopelvic group ($M_\Delta = 13.2$) with $t(11) = -1.94$, $p = .039$ (using a directional test). Please refer to Table 2 and 3.

To further explore possible group effects, an ANCOVA model was run in which the pre-test scores were used as covariates. In alignment with the previous result, statistically significant group differences were observed (standardized coefficient for yoga group effect: $\beta = +0.34$, $p = .036$—using a directional test). This indicates that the yoga group showed higher scores on the left Side Bridge post-test scores after accounting for their pre-test scores.

To assess the Star Excursion Balance Test scores, a MANOVA was run comparing the groups at pre-test, post-test and gains from pre- to post-test on both right and left sides. The only statistically significant finding (at a significance level of 0.10) was a possible group difference at post-test on the left side (*p* = .052). However, with the small sample size, this finding should be treated with caution.

Table 3. Paired-sample t-tests for the pre- to post change and paired-sample *p*-value (p (Δ)) and the correlation (*r*) and *p*-value (p(r)). Biering Sorenson Test (BST), Lumbopelvic Control Test (LCT), Side Bridge (SB)

Variables	Group	N	Mean	SD	p (Δ)	*r*	*p (r)*
BST	Pre	13	25.15	9.22			
BST	Post	13	40.60	11.67			
BST	Δ	13	15.45	12.10	0.001	0.35	0.244
LCT	Pre	13	1.07	0.76			
LCT	Post	13	2.38	1.26			
LCT	Δ	13	1.30	1.03	0.001	0.58	0.040
SB (right)	Pre	13	31.58	12.36			
SB (right)	Post	13	42.38	17.60			
SB (right)	Δ	13	10.79	13.32	0.013	0.66	0.015
SB (left)	Pre	13	28.34	13.47			
SB (left)	Post	13	46.72	16.56			
SB (left)	Δ	13	18.37	9.87	0.000	0.80	0.001

$P = \leq .05$

Six fully completed logbooks were used in the analysis. Of the six logbooks, there were group differences in the occurrence of low back pain. The yoga group showed two participants with an absence of low back pain throughout the whole study while one showed an increase at weeks 3-6 and a decrease post study. For the lumbopelvic group, subject 2 showed a decline of low back pain throughout the study while subject 3 showed a slight increase and subject 1 had a decline in the beginning but inclined to the same percentage at the end. Please refer to Figure 1 and Figure 2.

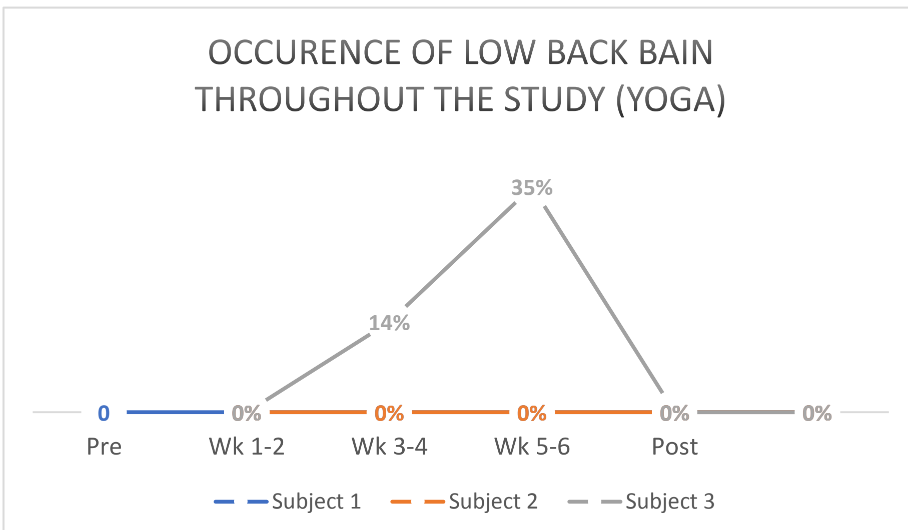

Figure 1. Occurrence of Low Back Pain throughout the Study for the Yoga Group

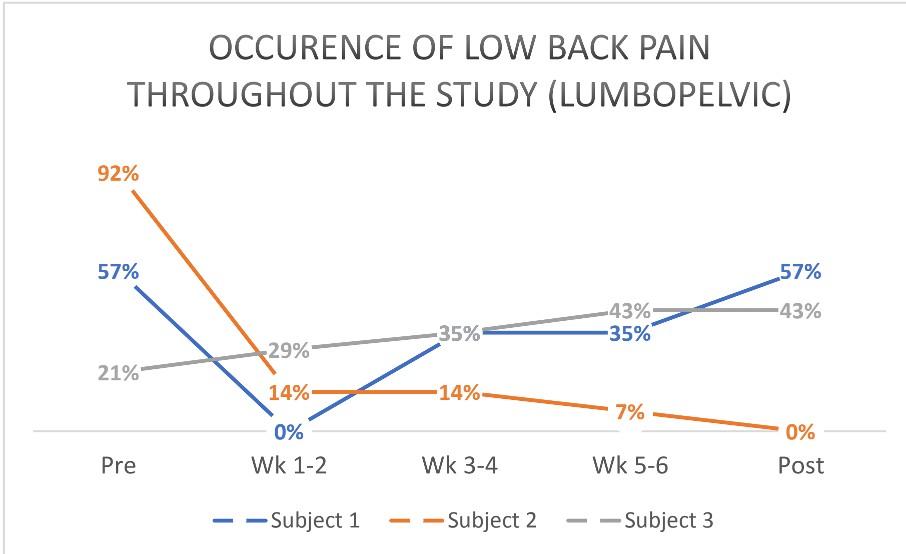

Figure 2. Occurrence of Low Back Pain throughout the Study for the Lumbo-pelvic Group

DISCUSSION

The primary aim of this study was to measure the effectiveness of core stability training on lumbar muscle endurance, lumbo-pelvic stabilization, abdominal strength and balance in young non-elite-level female gymnasts.

It was hypothesized that lumbar endurance would be significantly increased in the lumbo-pelvic group. The Biering-Sorensen Test and Side Bridge were two measures used to determine participant lumbar endurance. The results for the Biering-Sorensen Test did not show statistically significant group change after the 6-week intervention with improvements seen in 12 of the 13 participants. However, those in the lumbo-pelvic group showed greater improvements from pre- to post-test scores in comparison to the yoga group with an average increase of 22 seconds compared to 17 seconds, respectively. Furthermore, the lumbo-pelvic group showed a statistically greater change over time as there was no group difference at pre-test, indicating the groups were equally split on age and level of experience. Although there was no statistically significant difference, the lumbo-pelvic stability training may be a better option than yoga training in this age group for the development in muscle endurance of the erector spinae muscles.

A possible reason for the greater improvement in lumbo-pelvic group is the inclusion of the Sidebend, also known as the Side Bridge, and Side Plank. This maneuver can activate muscles of the posterior abdominal wall and back such as the lumbar erector spinae, a key endurance muscle (McGill, Juker, & Kropf, 1996; McGill, 1998). Similar to the results in the current study, Durall et al. (2009) incorporated the Side Bridge to influence muscle endurance on collegiate-level gymnasts. In their study, the results reported statistically significantly higher endurance improvements. However, their intervention was over a 10-week time period and the age of the participants were older. This is an important distinction as the response to muscle endurance gains may be similar to those of strength as longer duration periods of training provide more time to make gains (Kraemer & Fleck, 2007; Kraemer et al., 2002). Additionally, the use of collegiate-age participants, as compared to the current study's participants' younger age range, may also be a factor. For example, although muscle endurance is targeted in the current study it is known that maximal muscle force is lower in the younger population than in adults, even when size-normalized to body mass (De Ste Croix, Armstrong, & Welsman, 1999; Lambertz, Mora, Grosset, & Perot, 2003) or to muscle cross-sectional area (Grosset, Mora, Lambertz, & Perot, 2008; Halin, Germain, Bercier, Kapitaniak, & Butteli, 2003; Kanehisa, Ikegawa, Tsunoda, & Fukanaga, 1995a, 1995b; Lambertz et al., 2003; Seger & Thorstensson, 2000; Wood, Dixon, Grant, & Armstrong, 2006).

The relationship between muscle endurance and low back pain has been documented. Nicolaisen and Jorgensen (1985) found those who had never experienced low back pain are able to hold isometric endurance of the trunk extensor muscles, measured with the Biering-Sorensen Test, longer than those who had previously experienced low back pain. Similar findings from Hultman, Nordin, Saraste, and Ohlsen (1993) found that those with chronic low back pain averaged shorter endurance hold times in comparison to those who had never experienced low back pain. This is noteworthy, as a few of the participants in the current study had endured low back pain prior to the intervention, during the intervention, and/or even after the intervention.

Therefore, if a participant was experiencing or had experienced low back pain the gains may have been negligible, at best. Previous research has suggested that variations in trunk extensor endurance times between non-low back pain individuals and low back pain individuals may be due to differences in muscle fiber type proportions. Postural muscles consist primarily of fatigue-resistant, Type I fibers, but this may not apply to the erector spinae as it is composed of 60% Type I fibers, and 40% Type II, or fast-twitch fibers (Thorstensson & Carlson, 1987). This would make it have less endurance capabilities. It has also been suggested that individuals who have low back pain have higher proportions of Type II fibers, and therefore have less endurance capacity (Roy, De Luca, & Casavant,1989; Tsuboi, Satou, Egawa, Izumi, & Miyazaki, 1994). Future studies needs to further measure the relationship between lumbar endurance, low back pain and age.

For lumbo-pelvic stability, it was hypothesized that the lumbo-pelvic and yoga groups would both show increases but only the lumbo-pelvic group would be significant. To assess for stability, the Side Bridge, Lumbo-pelvic Control and Star Excursion Balance tests were utilized. The Side Bridge is ideal as it tests an aggregate of trunk and abdominal muscles as they work synchronously (McGill et al., 2003) such as the obliques and quadratus lumborum that are key for stabilizing. Leetun et al. (2004) found the collegiate female basketball and cross-country athletes demonstrated significantly reduced Side Bridge capacity along with hip abduction and external rotation suggesting that hip and trunk weakness reduces the ability of females to stabilize the trunk. In the current study, testing of the right side partially supported the hypothesis with results demonstrating no group differences at post-test or pre- to post differences indicating both groups were comparable at pre- and post-test and comparable in gains over time.

Results from the Side Bridge Test to assess the left side showed the yoga group having statistically greater scores from pre- to post suggesting those exercises influenced the development of lateral core stabilizer endurance more so than the lumbo-pelvic exercises. This result was not hypothesized and future research should assess how certain yoga possess, for example a prone bridge that was incorporated into the yoga group, may influence endurance of the lateral stabilizers.

Interestingly, the results showing side dominance may be an area for future research. The exercise interventions were bilateral in structure and for the most part, gymnastics is not considered a one-side dominant sport, but gymnasts have a dominant, or favorite, "side or direction" to perform a skill and an attempt to train, or exercise, on the non-dominant side may have influenced the results. Additionally, since this side is less dominant in most individuals (Hepper, Shahidullah, & White, 1991), there may have been more room for improvement in comparison to the right side. Moreover, the length of time of the intervention may have contributed as well. For example, in Durall et al.'s (2009) study, which used the Side Bridge test for assessing endurance levels following a 10-week exercise intervention, results showed significant, but equal, differences in the right and left Side Bridge. The reason for the dissimilarities between the Durall et al. (2009) study and the current study may be attributed to the intervention duration time (6-weeks versus 10 weeks) allowing more time for improvement if there were initial side-to-side variations.

Overall, there were improvements in the yoga and lumbo-pelvic group in the Side Bridge Test, indicating both interventions positively influence lateral stability. In this study, the yoga group (n=7) showed improvements over time averaging 13 seconds on the right side and 23 seconds on the left side. For those in the lumbo-pelvic group (n=6) there were improvements on the right side for a majority of the participants, however, all showed improvements on the left side.

Stability in the lumbo-pelvic region was further assessed using the Lumbopelvic Control test. The results indicated a statistically significance difference between pre- and post-scores for both training groups. This suggests that the yoga and lumbo-pelvic interventions are equally effective for front-on stability as opposed to lateral stability noted above. The results did show a group difference at the pre-test thus they were not equal at the start and this can be attributed to the smaller sample size and age range span. The lumbo-pelvic group had two of the older participants and three of the youngest but the yoga group was balanced in age. Experience was similar in both groups.

For both the lumbo-pelvic and yoga groups, all participants increased by at least one level. However, it should be noted this is on a 5 points scale; therefore, this must be interpreted with caution, as a possible ceiling effect, in which the participants in the yoga group may have shown more increase if they had started lower and comparable to the lumbo-pelvic group. That is, having started higher, they had less room to “grow” before hitting the ceiling effect. Optimal muscle recruitment patterns are essential to attain and maintain stability (Perrott, Pizzari, Opar, & Cook, 2012). Without these patterns, a lack of improvement during the Lumbopelvic Control test may have occurred. Endurance training has been seen to increase stabilization effectively by specific recruitment of muscles in the lumbo-pelvic region (Carpes, Reinehr, & Mota, 2008).

For additional testing of stability and balance with the Star Excursion Test the results indicated a slight, but not significant, group difference on the left side. However, the sample size needs to be considered when reviewing these results. The possible reasons for this dissimilarity could be comparable to that of the left Side Bridge increases. Hand and foot dominance was not obtained from the participants but it can be assumed that the majority are right foot dominant (Dargent-Paré, De Agostini, Mesbah, & Dellatolas, 1992) therefore there was more room for improvement on the left side. Some participants in the current study did show some improvements but his was minor. In a study by Filipa et al. (2010) soccer players, as assessed with the Star Excursion Balance Test, had significant improvements after a neuromuscular training program. However, that intervention differed from the current study by including two 45-minute lower extremity and core stability training sessions over an 8-week period.

It was hypothesized that there would be no occurrences, or development of low back pain in both groups and those with low back pain would see a reduction in its occurrence. This was based on the assumption that the interventions were low impact and focused on areas that, if deficient, would affect the development or further development of low back pain. Unfortunately, only six logbooks were entirely completed over the required time and therefore caution needs to be taken when reviewing the results. Three logbooks were analyzed for each group with mixed results. Some of the participants remained pain-free while some had both an increase and/or decrease throughout.

Although a similar study had reported better results (Harringe, Nordgren, et al., 2007) the control of the spine is complex and it is only possible to diagnose a small proportion of low back sufferers on a patho-anatomical basis (Albert et al., 2008). Therefore, the cause of some of the participants' low back pain is undefined and this is problematic when incorporating an intervention aimed on one aspect of a multifactorial problem.

There were several limitations to this study and most notably a lack of control group and an insufficient number of participants to determine whether these results can be reliably interpretable. Another limitation was the incompletion of several logbooks. Of the 13 participants, only six were fully completed and assumed filled out truthfully. The 'ceiling effect' in the Lumbopelvic Control test is also a limitation. This demonstrated that the results may not have shown statistical significance because there wasn't much room for improvement. The duration of the intervention is a limitation in that many similar core-focused studies have been over longer periods and each individual session being longer, as well. Finally, the age range of the participants were too broad as it compared nine-year-olds to older teens. A majority of similar studies have an older population with many being at the elite-level. However, as other studies have used either collegiate or professional-level participants the need for research on a younger and more vulnerable population, especially in gymnasts, is further warranted. Thus, the novelty of this current research project.

Although the current study presented several limitations, there were several strengths considering the challenges and difficulties that come with conducting in-situ clinical research. For example, this prospective study included working with active youth participants with low back pain and the requirement for parental permission and careful monitoring of all the gymnasts. Furthermore, to enhance participation and provide convenience for parents and participants all data collection was completed in an off-campus environment over a 10-week period. These challenges impacted the number of participants and the ability to have a control group which is required in true experimental design. It can argued that formulating this study as a case study or series may have been a better option due to the limitations and noted challenges. However, the aim and intent was to develop a research endeavor that is acceptable, maintains scientific examination and analysis, and adds to the limited body of research in this population and this was accomplished

The current study provided a basis for further research, but there are still aspects lacking evidentiary support for the younger gymnast population and its correlation to low back pain injuries. Future research should utilize the younger gymnast population to compare how their bodies react to certain interventions in contrast to the older collegiate population. Most literature used collegiate or more elite level of gymnasts even though there are reported low back issues starting as early as 9 or 10 years old which was found in the current study. Also, it needs to be further investigated on what can be done to keep the younger physically active gymnasts safer and possibly injury free while participating. This study incorporated exercises that are commonly used to strengthen the core, but further research should develop a specific protocol geared towards young gymnasts whose bodies are still in the developmental stages. The occurrence of low back pain was very dependent on how the participant felt was low back pain when filling out the logbooks. This subjective method may be the best way to gather information on the occurrence of low back pain, but further research may benefit by indicating the etiology of the pain. In other words, showing whether it was a lack of strength or endurance of the lumbo-pelvic region verses a mechanical or technical issue while performing their sport or other activities they are involved in.

In conclusion, the importance of core stability is viewed as being pivotal for efficient biomechanical function to maximize force generation and minimize joint loads in all types of activities associated with gymnastics. The current study looked at a prevention regimen to influence core muscle endurance, stability and affect low back pain. The results revealed much of the data to be statistically insufficient which was due to the small sample size, but improvements were seen from pre- and post-test in most if not all tests for each participant. The limited amount of completed logbooks needs to be consider when viewing the results of low back pain in the participants. Some fluctuated with low back pain throughout the study while others remained pain free. This shows the need for further research with larger sample sizes and a population who has or is experiencing low back pain in order to find a solution to decrease stress on the spine for young gymnasts. Therefore, the basis for further research should be on the incidence of low back pain in young gymnasts and the effects of lumbo-pelvic stabilization exercises as a preventative matter.

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APPENDIX A

EXTENDED RATIONALE AND PURPOSE

Statement of the Problem

The primary aim of this study was to measure the effectiveness of core stability training on lumbar muscle endurance, lumbo-pelvic stabilization, abdominal strength and balance in adolescent female gymnasts. A secondary aim was to examine the effect of these interventions on the occurrence of low back pain in those with reported mild low back pain, and those with no low back pain. In this study, participants were randomly allocated to a 6-week lumbo-pelvic stabilization exercise intervention or yoga intervention.

Research Questions and Hypotheses

1. What is the effect of an exercise intervention (lumbo-pelvic or stretching/yoga) on lumbar endurance measured by the Biering- Sorensen's Test and Side-bridge test?

   Hypothesis 1A: Lumbar endurance will be significantly increased in the lumbo-pelvic group

   Hypothesis 1B: Lumbar endurance will not be significantly increased in the yoga group
2. What is the effect of an exercise intervention (lumbo-pelvic or stretching/yoga) on lumbo-pelvic stability measured by the Lumbo-pelvic control test?

   Hypothesis 2A: Lumbo-pelvic stability will be significantly increased in the lumbo-pelvic group

   Hypothesis 2B: Lumbo-pelvic stability will be increased in the yoga group

3. What is the effect of an exercise intervention (lumbo-pelvic or stretching/yoga) on balance measured by the Star Excursion Balance test?

   Hypothesis 3A: There will be improvements, but not significant, differences in balance in the lumbo-pelvic group

   Hypothesis 3B: There will be improvements, but not significant, difference in balance in the yoga group

4. Does an exercise intervention prevent the occurrence on low back pain in an adolescent gymnast population?

   Hypothesis 4A: There will be no occurences of low back pain in the lumbo-pelvic group

   Hypothesis 4B: There will be no occurences of low back pain in the yoga group

5. Does an exercise intervention reduce the occurrence of low back pain in an adolescent gymnast population?

   Hypothesis 5A: There will be a reduction in the occurrence of low back pain in the lumbo-pelvic group

   Hypothesis 5B: There will be a reduction in the occurrence of low back pain in the yoga group

Significance of the Study

Studies have shown that many gymnasts practice and compete even though they are reporting high levels of low back pain (Harringe, Renstrom, & Werner, 2007; Kolt & Kirkby, 1999; Sands, Schultz, & Newmann, 1993). This is significant as it may affect the gymnasts' ability to train which consequently hinders their career (Caine, Cochrane, & Caine, 1989; Kolt & Kirkby, 1999). Therefore, it is beneficial for gymnasts to train key muscles in the lumbopelvic region which may decrease the occurrence of low back injury and pain and with a secondary benefit of improved performance. It was hypothesized that both intervention group will show improvements in the four pre- and post-measurement test, however, the lumbopelvic group will report a decrease in their symptoms while those without low back pain will remain symptom free.

This study fills a void in the paucity of empirical evidence on young female, non-elite gymnasts with these interventions. It is beneficial for gymnasts and coaches to be knowledgeable about the results of this study. Furthermore, gymnastic coaches may seek to incorporate these interventions into their training routines.

Delimitations

Parameters designated for the present study include:

1. Youth, non-elite gymnasts participating in a local academy
2. Female participants between the ages of 9-17
3. Smaller sample size
4. Shorter intervention period

Limitations

The following were limiting factors in this study:

1. Participants will indicate low back symptoms daily and honestly
2. Participants will perform exercises properly

3. Participants will give full effort to each exercise and test assessment
4. Lack of a control group

Assumptions

The following assumptions underlie this study:

1. Participants entered low back symptoms daily and honestly
2. Participants performed exercises properly
3. Participants gave full effort to each exercise and test assessment

Definition of Terms

Lumbo-pelvic stability: The ability to attain and then maintain optimal body segment alignment of the spine, pelvis, and the thigh in both a static position and during dynamic activity (Perrott, Pizzari, Opar, & Cook, 2012).

Lumbo-pelvic Control Test: A series of tests that increase in difficulty in order to grade the level of lumbo-pelvic control. (Cricket Australia Sport Science Sport Medicine, 2013)

Star Excursion Balance Test: A functional screening tool that's used to assess lower extremity dynamic stability, monitor rehabilitation progress, assess deficits following injury, and identify those at higher risk for a lower extremity injury (Filipa, Byrnes, Paterno, Myer, & Hewett, 2010).

Biering- Sorensen Test: This test is used to evaluate the relationship between isometric endurance of the trunk extensor muscles with non-specific low back pain. It measures how long one can hold the unsupported upper body horizontally while the lower body is strapped down to a table (Biering-Sorensen, 1984; Luoto, Heliovaara, Hurri, & Altaranta, 1995; Nicolaisen & Jorgensen, 1985).

Side-Bridge Test:

A test where the body is placed in a side lying position then raised up while balancing on forearm and feet. Time until failure in this position measures control and endurance of the lateral core stabilizing muscles. (Durall et al., 2009; Leetun, Ireland, Wilson, Ballantyne, & Davis, 2004)

Home-based weekly low back pain log book:

Participants will keep daily track of low back pain symptoms by answering questions and writing answers down. (Harrange, Noorgren, Arvidsson, & Werner, 2007)

List of exercises:

Lumbo-pelvic Stabilization Intervention

Double-Leg Bridge (Figure 1): Supine with knees bent and heels close to glutes and then engage abdominals while raising and lowering hips slowly with control.

Single-Leg Bridge (Figure 2): Same as double leg, but only one leg is fixed to the ground.

Sidebend (Figure 3): Lie on side with knees bent and over each other while the body is propped up with the elbow and forearm before lifting pelvis off the floor while reaching the other arm up by the ear.

Plank (Figure 4): Same positioning as sidebend except knees are straight and feet are over each other before lifting pelvis off the floor.

Fire Hydrants (Figure 5): On all fours with hands over shoulders and knees over hips while lifting leg out and maintaining a 90-degree angle of hip flexion and knee flexion.

Yoga Intervention

Happy Baby (Figure 6): Bend forward with a slight bend in the knee and hands tuck under outside of feet while the head and arms release to gently sway from side to side

Child's Pose (Figure 7): Start on all fours and the sit back on the heels while resting head on the ground

Rag Doll (Figure 8): Lie on back and pull knees towards the belly while grabbing on to the outside of the feet

Downward-facing Dog (Figure 9): Start on hands and knees and then tuck toes and lift bottom high so the body creates a triangle

Bridge (Figure 10): Lie on back and bend both knees with feet flat on the ground and then bring heels as close to bottom before lifting hips up

APPENDIX B

EXTENDED LITERATURE REVIEW

Injuries with a Focus on Lower Back

Injuries in the sport of gymnastics occur in a variety of areas and it's suggested that female gymnasts don't pass through their years of training and competition without a variety of injuries (Tofler, Styler, Micheli, & Herman, 1996). They include injuries to the spine and trunk region, lower extremity such as knee and ankles, and the upper extremity including shoulder and wrists. An epidemiologic study on young female gymnasts revealed that the low back was the most commonly injured area followed by ankle, knee, and wrist (Caine et al., 2003). At the collegiate level, women's gymnastics has climbed its way to the top as the highest percentage of injuries rates of all National Collegiate Athletic Association sanctioned and monitored sports (NCAA, 2004). For adolescent gymnasts, the injury rate per 1000 hours of exposure range from 0.5-4.1 and when athletic exposures are used gymnastics rates in of top three highest incidence rates for girls at an 8.5 per 1000 hours of exposure (Caine, Caine, & Maffulli, 2006).

The lower back is a common area of injury in the sport. Injuries to this region include anterior apophyseal ring avulsion, spondylolysis, spondylolisthesis, disc herniation, and bone marrow edema (Bennett, Nassar, & Delano, 2006), endplate damages, fractures, disc degeneration, muscle strains, ligament sprains, and non-specific injuries to the low back (Harringe, Renstrom, & Werner, 2007; Harringe, Lindbald, & Werner, 2004; Homer & Macintosh,1992; Katz & Scerpella, 2003; Sward, Hellstrom, Jacobsson, Nyman, & Peterson, 1991; Sward, Hellstrom, Jacobsson, & Peterson, 1990; Caine, Cochrane, & Caine, 1989). On cause is the amount of force the trunk endures with repeated flexion during landing from various heights, as this creates biomechanical forces sufficient enough to cause vertebral endplate injuries (Bruggemann, 1999; Sward, 1992; Sward et al., 1991). Additional risks and causes are outlines in the next section.

Injury rates per 1000 hours of exposure for female gymnasts range from 3.7 to 22.7 (Caine et al., 1989; Sands et al., 1993; Weiker, 1985) with lower back spine injuries accounting for 12% of these injuries (Sands et al., 1993). Re-injury rates are reported to be at 2 injuries per 1000 athletic exposures (NCAA report, 1994) with the majority being overuse that suggests there is a common re-occurrence of chronic injuries (Caine et al., 2003).

An epidemiologic study by Kolt and Kirkby (1999) reported 86% of gymnasts had developed low back pain at some point over an 18-month time frame. The reported annual incidences range between 30-90% (Caine et al., 1989; Daly, Bass, & Finch, 2001; Harringe, Nordgren, et al., 2007; Homer & Macintosh, 1992; Ohlen, Wredmark, & Spangfort, 1989, Tsai & Wredmark, 1993) with a recurrence rate of 72% (Caine et al., 1989). In the adolescent gymnastics population, reported incidence of low back pain range between 24- 57% (Burton, Clarke, McClune, & Tillotson, 1996; Harreby et al., 1999; Homer & Macintosh, 1992; Hutchinson, 1999; Kujala, Taimela, Erkintalo, Salminen, & Kaprio, 1996) and this prevalence increases with age in adolescents (Burton et al.,1996).

With these epidemiological studies indicating performance inhibiting back injuries, it reveals it is a common occurrence in women’s gymnastics (Bennett et al., 2006), thus the need for interventions addressing weaknesses. Gymnasts are at a significant risk of sustaining a lower back injury which may impair their ability to train (Caine et al., 1989; Kolt & Kirby, 1999). Due to the high demands of competitive gymnastics, the return of a gymnast at 95% normal strength, coordination, and flexibility isn't enough and could result in retirement in the sport (Singer, 1984).

Risk Factors/ Causes for LBP in Gymnasts with a Focus on Adolescents

In the general population, the etiology of low back pain is hard to verify and a definite diagnosis cannot be made in a majority of cases. This is due to symptoms and pathologic changes not being closely related (Deyo, 2002; Jarvik & Deyo, 2002). Furthermore, the risk of developing low back pain is multifactorial (Kerr et al., 2001; Stevenson, Weber, Smith, Dumas, & Albert, 2001) and history of previous low back pain is the highest indicator for future low back pain (Kerr et al., 2001, Bigos et al., 1992; Bigos et al., 1991; Mannion, Dolan, & Adams, 1996). The multifactorial cause may be attributed to nature of training, inherent skeletal abnormalities, poor posture, inability of the lumbar spine musculature to control movement and protect against injury, or complex interactions of these factors (Mulhearn & George, 1999). Additional factors include poor muscles endurance, altered muscle firing rates, muscular imbalance, inflexibility of lower extremities, and leg length discrepancies (Nadler, Wu, Galaski, & Feinberg, 1998).

Reduction of function in the musculature around a joint can lead to instability and this includes the spine as well (Gracovetsky, Farfan, & Helleur, 1985). Weakness in the musculature around the lumbar spine and hip region is a potential factor in the etiology of back injuries and resultant pain (Parnianpour, Nordin, Kahanovitz, & Frankel, 1988).

Function of the hip is a primary contributor to both trunk and spine stability and function therefore reduction in its function may play a role in the development and response to low back injury and pain (Gombatto, Collins, Sahrmann, Engsberg, & Dillen, 2006; Nadler et al., 2001; Leinonen, Kankaanpaa, Airaksinen, & Hanninen, 2000; Kankaanpaa, Taimela, Laaksonen, Hannien, & Airaksinen, 1998).

Impaired motor control has also been shown to be a predisposing risk factor for a low back injury (Cholewicki & McGill, 1996; Panjabi, 1992). Those with low back pain demonstrate a significant reduction in the number of trunk muscles that respond to quick force release (Cholewicki et al., 2002; Radebold, Cholewicki, Panjabi, & Patel, 2000) which gymnasts need in order to produce and complete a tumbling pass.

For gymnasts, reported physical risk factors include starting guided training at a young age (Gymastique, 2010), training and competing during periods of growth (Kujala, Taimela, Oksanen, & Salminen, 1997), excessive force exposure relating to overall duration of training (Daly et al., 2001; Dixon & Fricker, 1993), and complexity of skills (Kruse & Lemmen, 2009; Wojtys, Ashton-Miller, Huston, & Moga, 2000; Hall, 1986). Specifically, for young athletes in general, long duration has been suggested to predispose them to low back pain (Kujala, Salminen, Taimela, Oksanen, & Jaakkola, 1992).

A reduction in the trunk extensor muscle endurance may lead to low fatigue threshold and an increased loading of passive low-back structures that results in non-specific low back pain (Seidel, Beyer, & Brauer, 1987). McGill, Grenier, Kavcic, and

Cholewicki (2003) suggested that the value of trunk muscle endurance is greater than the ability of these muscles to generate force in the prevention of low back pain. Therefore, it is imperative that gymnasts have optimal muscle endurance in order to prevent injuries and symptoms from the repetitive motions placed on the lower spine region.

The landing component is also an important aspect to consider in the development of low back injury due to the amount of force generated to the spine and pelvic region. It was reported (Harringe, Nordgren, et al., 2007) that a gymnast is able to produce ground reaction forces up to 13 times their body weight. Additionally, they routinely positioned in extreme lumbar positions, such as extension when absorbing this force (Daly et al., 2001). For a gymnast, optimal landing is required for success with the lower spine impacting that success.

Importance of Lumbopelvic Stabilization in Gymnastics

When considering lumbo-pelvic stability in gymnastics, it is important to first note what movements are involved. Twisting, rotating, jumping, and bending of the body facilitates the gymnast to perform a tumbling pass or to complete a landing. These components demand the attention to the muscles that are involved and their importance when the athlete is in motion.

There are many muscles throughout the whole body that help produce movements for gymnasts with a focus placed on the core of the body, also known as the lumbopelvic region. If there are deficits in neuromuscular control of the body's core musculature, uncontrolled trunk displacement may occur. (Hewett, Myer, & Ford, 2005; Hewett, Zazulak, Myer, & Ford, 2005). The musculoskeletal core is comprised of abdominal structures, spine, hips, pelvis, and the lower limbs (Kibler, Press, & Sciascia, 2006). The key muslces of the core include tranverse abdominus, multifidus, quadratus lumborum, internal and external obliques, rectus abdominis, erector spinae, and the diaphragm. These muscles support the spine during movements but provide little movement themselves. It is up to the core musculature to lessen the forces on the spine and to stabilize the kinetic chain during functional movements (Bassett & Leach, 2011).

The spine is described as a series of spinal segments and its stability is described as each segments ability to resist translation or rotation in the sagittal, frontal, and coronal plane (Panjabi, Kuniyohsi, Duranceau, & Oxland, 1989). Because the movements that gymnasts engage in place the body in these three planes, the need for sufficient strength and stability in the hip and trunk muscles becomes quite important (Leetun et al., 2004). The spine structures can give support and stability if active and passive tissues work together, but the stability might not be guaranteed if only passive structures are considered (Wagner et al., 2005). Trunk muscle activation before the movement of the lower extremities help to stiffen the spine in order to provide a foundation for functional movements (Hodges & Richardson, 1997).

Stability can be defined as the body's ability to control the trunk in response to internal and external disturbances and acts as a foundation for trunk dynamic control which allows for production, transfer, and control of force and motion to distal body segments and expected or unexpected perturbations (Kibler et al., 2006). Stabilization of the pelvis and trunk is necessary for all movements of the extremities (Bouisset, 1991) and the lumbo-pelvic muscles control those movements by creating a stable foundation (Wilson, Dougherty, Ireland, & Davis, 2005). Its stability is dependent on a combination of global, superficial muscles around the abdominal and lumbar region along with local stability intrinsic muscles of the abdominal wall (Marshall & Murphy, 2005).

Gymnasts are some of the strongest and most flexible competitors which is seen in their ability to control body movements in a variety of positions (Claessens, Lefevre, Beunen, & Malina, 1999). Therefore, the importance of core stability training increases due to the components of spin and rotation involved (Kolba, 2005) and these gross motor activities need complex interactions between skeletal, ligamentous, and muscular components in order to make that possible (McGill et al., 2003). If the frequency of lumbopelvic motion is increased, it may also increase stress in that region especially if the motion is always in the same direction which is often the case for a gymnast (Adams, Bogduk, Burton, & Dolan, 2002).

Interventions Used in Stabilization Training

In the present study, the effect of a lumbopelvic stabilization program in young gymnasts on a series of lumbopelvic stabilization strength measures and its relationship with low back pain were examined. This section will review previous studies using a variety of strategies on strengthening the lumbopelvic region. A few of these studies have utilized the pre- and post-test measurements that were used in the present study including the Biering Sorensen Test, Side Bridge Test, Star Excursion Balance Test, and a low back pain log book.

Mills, Taunton, and Mills (2005) measured the effect on lumbo-pelvic stability (LPS) and athletic performance after a 10-week training program on thirty female collegiate basketball and volleyball players. They measured LPS with pressure biofeedback on agility, leg power, and static balance that were used as indicators of athletic performance. The subjects were split into a training group, pseudo-treatment group, and control group. The training group focused on activating the transverse abdominis, lumbar multifidi, and pelvic floor musculature while the pseudo-treatment group were instructed on recruiting global mobility muscles through trunk flexion, rotation, and lateral bending maneuvers. Both the training and pseudo-treatment group showed significant improvements in stability and static balance with the treatment group showing significant improvements in the post-test agility times and vertical jump. This study was important as it showed the effectiveness of lumbo-pelvic stability on not only dynamic movements like agility and vertical jumps, but also stability and static balance which are components for a gymnast.

To measure the effects of an eight-week training program, Bassett and Leach (2011) assessed female junior elite level gymnasts between the ages of 9-13 years old. The training group completed 4 weeks of static stability training and then progressed to dynamic stability training for the remaining 4 weeks. For the static training, the participants performed transverse abdominis activation, pelvic tilts, abdominal crunches, heel taps, and supermans. The dynamic stability training included bicycle crunches, abdominal crunches and supermans on an exercise ball, squat thrust while kneeling on ball in a push up position, and kneeling ball roll with hands on ball that ended in push up position. While performing these exercises, they were also instructed on how to palpate their transverse abdominis to assess for proper muscle activation. They measured core stability using the Bunkie Test which provides progressive loading of the legs in five testing positions holding them for a target time (TT) of 20 seconds. The results showed that the training group could hold their position to TT on more occasions and hold positions significantly longer than the control group after core stability was implemented.

Durall et al. (2009) measured the effect of preseason trunk muscle training on low back pain occurrence in women's collegiate gymnastics. For the study, 15 varsity women's gymnasts and 15 collegiate non-athletes were tested pre, post 5 weeks, and post 10 weeks with 4 static holds: Biering-Sorensen trunk extensor test, trunk flexor test, and right and left lateral side bridges test. The training group was guided with a 15-minute trunk muscle training intervention twice per week for 10 weeks. They showed significant improvements in all 4 trunk endurance tests and there were no reported new episodes of low back pain.

Leetun et al. (2004) also incorporated the Side Bridge and Biering-Sorensen Test for their study that didn't use an intervention, but instead monitored the athletes during the season. For their study, they used 139 athletes both male and female from basketball and cross-country teams. The results indicated that athletes who had an injury during the course of the season demonstrated lower core stability. Interestingly, females demonstrated significantly reduced Side Bridge times as well as hip abduction and external rotation isometric strength suggesting that hip and trunk weakness reduces the ability of females to stabilize the hip and trunk. This is pertinent as the current study with use only a female group.

Filipa et al. (2010) assessed 20 participants on two soccer team with no prior history of lower extremity injuries. They implemented a core stability intervention to measure its effect on balance using the Star Excursion Balance Test. This core stability intervention included a 5-minute warmup agility ladder followed by 45-minutes of strength training and core stability and ending with a 5-minute cooldown. Dynamic trunk control defines core stability so the aim of this intervention was to improve the athlete's ability to control the center of mass during dynamic activity. At baseline, both groups had similar scores but after the intervention training group's score significantly improved. The results showed that the effect of the intervention improved posterolateral and posteromedial reach.

Harringe, Norgren, et al. (2007) examined 55 elite gymnasts between the ages of 11-16 years old. In the study, each participant would respond to a survey that consisted of questions about their low back pain. After a 4-week baseline time period, the control group met over an 8-week period with a physiotherapist to ask questions regarding injury and seek advice. The training group was instructed on how to perform specific segmental muscle control exercises and performed them 3-4 times per week. Results from baseline testing showed 47% of the gymnasts having low back pain. After completing the 8-week training program, the intervention group reported 8 out of 15 gymnasts who previously had low back pain became pain free and only one sustaining low back pain. These results showed the significance of incorporating core muscle control exercises for gymnasts who have low back pain as well as preventing the occurrence of low back pain.

Mulhearn and George (1999) investigated whether postural abdominal muscle endurance is reduced in elite gymnasts compared to a control group. This study took 10 female and 12 male gymnasts along with a control group who didn't participate in gymnastics or similar sports. A plumbline was used to assess posture and 4 exercise tests were used to assess the ability to contract the postural abdominals isometrically. These exercise tests involved hollowing the abdominals and maintaining a static hold for 30 seconds. Results showed that gymnasts reported lower endurance times compared to the control and those with a history of back pain had a reduction in performance.

The studies reviewed provide a foundation for future research to answer questions pertaining to the gymnastic population and its correlation with low back pain. Since there is no empirical evidence on young female gymnasts, it exposes the need for further research. The literature creates a basis for the present study to disclose information on both a young gymnastic population and the effects of incorporating lumbopelvic stability exercises to eliminate or prevent the occurrence of low back pain.

APPENDIX C

EXTENDED METHODS

Appendix C1. Parental Consent.

UNIVERSITY OF NORTHERN IOWA
HUMAN PARTICIPANTS REVIEW

PARENTAL PERMISSION

Invitation to Participate: Your child has been invited to participate in a research project conducted through the University of Northern Iowa. The University requires that you give your signed agreement to allow your child to participate in this project. The following information is provided to help you make an informed decision whether or not to allow your child to participate.

Nature and Purpose: As low back commonly occurs in gymnasts due to a variety of reasons such as low back instability, altered flexibility, balance deficits, one primary cause, especially in youth, is a lack of low back muscle (lumbo-pelvic) stability. In other words, weakness in the core region which consists of the abdominal and lower back musculature. Therefore, the purpose of our study is to measure the effect of two 6-week core stability interventions on back muscle endurance, abdominal strength, and balance in adolescent gymnasts. A secondary purpose is to examine how these interventions makes their back feel (stronger, tired, less sore, etc.).

Explanation of Procedures: The following describes all the procedures included in this study for the gymnast.

- All gymnasts who are permitted to participate and agree to participate will be placed into either a lumbo-pelvic stability group or a Yoga group.
- Those in the **lumbo-pelvic group** will be guided on a six-week program 2 times per week (10-15 minutes in duration).
- Those in the **Yoga group** will be guided on a six-week program 2 times per week (10-15 minutes in duration).
- What we need to measure just one time at the beginning for **all gymnasts**:
  - Age, height/weight, years of experience, and the number of training days and hours per week.
- What we need to measure before and after the 6-week sessions for all gymnasts (***Please refer to handout for details on each test***):
  - Muscle endurance strength in the lower back using a 2-minute horizontal holding test.
  - A 2-minute core (lumbo-pelvic) muscle control tests which assesses the abdominal muscles
  - The side-bridge test which assesses the side abdominal muscles and lower back muscles. This test takes about 3-minutes.
  - A standing balance text which takes about 3-minutes.

- Daily low back logbook:
    - Every night **your child** at home will fill out a small survey consisting of two questions:
        1. Do you have or have you had back pain over the past few days?
        2. If so, they will make a mark on the exact location on a pain map as well as rate the intensity of pain.
- What your child will do if they are selected to be in the **Yoga group**:
    - There will be five age-appropriate Yoga poses. They consist of: Happy Baby, Child's Pose, Rag Doll, and Bridge. ***Please refer to handout for details on each exercise***.
- What your child will do if they are selected to be in the **lumbo-pelvic group**:
    - There will be five routines developed from the Princeton University Pelvic Stabilization protocol. They consist of: double leg-bridge, single leg bridge, side bend, side plank, and fire hydrants. ***Please refer to handout for details on each exercise***.
- When the study is complete, we will share our conclusions for each group without identifying your child.
- If one of the interventions is more effective, we will offer it to all the gymnasts in the other group. This will be in the form of a hand out. We will give the coach one as well.

Discomfort and Risks: While the risk is low for injury, the pre- and post-measurements procedures may cause your child some minimal discomfort, namely muscle soreness. We will instruct them and you on proper care, including stretching, icing, and heating procedures. If agreeable to you, we would like to follow up with a phone call the same day and the following day to monitor their post-testing progress. Furthermore, the intervention may cause some minor soreness in areas where its emphasized on, for example the hip region. As the student researcher will be on hand during all intervention sessions she will be able to instruct your child on appropriate care.

Benefits: Your child's participation may be of no direct benefit to them, however, they may benefit from gains in core stability and thus reduce the likelihood of developing lower back injury and pain in the future.

Confidentiality: We respect you and your child's rights of confidentiality in this project. The results of this study will not reveal any individual gymnasts name or the Academy in future publications. The results from the study will only be in summarized findings with no identifying information published in an academic journal or presented at a scholarly conference.

Right to Refuse or Withdraw: Your child's participation is completely voluntary. She is free to withdraw from participation at any time or to choose not to participate at all, and by doing so, your child will not be penalized by the coach or anyone else.

Questions: If you have questions about the study you may contact or desire information in the future regarding your child's participation or the study generally, you can contact Dr. Mark Hecimovich at the Division of Athletic Training, University of Northern Iowa at 319-273-6477, or on 319-230-4819, or Miranda Pomije the Master's Student investigator at 952-594-1104. You can also contact the office of the Human Participants Coordinator, University of Northern Iowa, at 319-273-6148, for answers to questions about rights of research participants and the participant review process."

Agreement:

> **I am fully aware of the nature and extent of my child's participation in this project as stated above and the possible risks arising from it. I hereby agree to allow my son/daughter to participate in this project. I have received a copy of this form.**

___________________________________ _____________________
(Signature of parent/legal guardian) (Date)

____
(Printed name of parent/legal guardian)

Phone number(s) and best time call: ____

____
(Printed name of child participant)

___________________________________ _____________________
(Signature of investigator) (Date)

___________________________________ _____________________
(Signature of instructor/advisor) (Date)

Appendix C2. Participant Consent.

University of Northern Iowa
Human Participants Review

Informed Assent

Impact of core stability training on lumbo-pelvic and core strength and stability, balance and low back pain in youth gymnasts

Name of Principal Investigators

Miranda Pomije and Dr. Mark Hecimovich

Hello gymnast!

Gymnastics is a great sport which has some of the best athletes in the world. Of course you know this already.

Sometimes with the sport low back pain can develop. If this happens it may affect the way you perform. So we decided to look at two types of commonly used solutions used in other sports. One is a routine which helps strengthen your stomach and leg muscles and is called **lumbo-pelvic routines**. The other is **Yoga** which also strengthens the same area but uses different movements. Both are easy to perform, especially for gymnasts

With our study we are going to place you in either the **lumbo-pelvic** routine group or the **Yoga** routine group. Then, over the next 6 weeks we will guide you on these routines 2 times per week for 6 weeks before practice.

Two other small things we would really like you to do for us is have us check you on some simple strength and balance procedures before and after the 6 weeks. The other is every night before bed just fill answer two simple questions about any possible pain you may have experienced during that day only. It will take 2 minutes, tops.

The details of all the procedures included in this study for you are:

- If you are permitted to participate and agree to participate we will place you into either a lumbo-pelvic routine group or a Yoga routine group.
- Those in the **lumbo-pelvic group** will be guided on a six-week program 2 times per week (10-15 minutes in duration).
- Those in the **Yoga group** will be guided on a six-week program 2 times per week (10-15 minutes in duration).
- What we need to measure just one time at the beginning:
    - Your age, height/weight, years of experience, and the number of training days and hours per week.
- What we need to measure before and after the 6-week sessions (***please take a look at the handout we gave your parents*****).**
    - Muscle endurance strength in the lower back using a 2-minute horizontal holding test.
    - A 2-minute core (lumbo-pelvic) muscle control tests which assesses the abdominal muscles
    - The side-bridge test which assesses the side abdominal muscles and lower back muscles. This test takes about 3-minutes.
    - A standing balance text which takes about 3-minutes.
- Daily low back logbook:
    - Every at home just fill out a small survey consisting of two questions:
        3. Do you have or have you had back pain over the past few days?
        4. If so, they will make a mark on the exact location on a pain map as well as rate the intensity of pain.
- What you will do if selected to be in the **Yoga group**:
    - Happy Baby, Child's Pose, Rag Doll, and Bridge. (***Please refer to handout we gave your parents*****).**
- What you will do if selected to be in the **lumbo-pelvic group**:
    - double leg-bridge, single leg bridge, side bend, side plank, and fire hydrants. (***Please refer to handout for details on each exercise*****)**.

Discomfort and Risks: While the risk is low for injury, the pre- and post-measurements procedures may cause some minimal muscle soreness. If this happens we will assist you on proper care, including stretching, icing, and heating procedures.

The routines may also cause some minor soreness but Miranda will be on hand during all sessions and will be able to instruct you on appropriate care.

Right to Refuse or Withdraw: Your participation is completely voluntary. This means that you are free to withdraw from participation at any time or to choose not to participate at all, and by doing so will not be penalized by the coach or anyone else.

If you have any questions please ask your parents, Miranda or Dr. Hecimovich. We are all happy to assist.

I, __________________, have been told that one of my parents/guardians has given his/her permission for me to participate in a project about gymnastics and helpful routines to reduce low back pain.

I understand that my participation is voluntary. I have been told that I can stop participating in this project at any time. If I choose to stop or decide that I don't want to participate in this project at all, nothing bad will happen to me.

______________________   ___________

Name   Date

Appendix C3. Health History Questionnaire.

Health History Questionnaire

Participant (gymnast) name: ______________________ Age: ______________

Today's date: ________________

The number of years participating in gymnastics.

1 to 2 years **3 to 5 years** **6+ years**

Are they currently participating in training sessions and competition? **YES** **NO**

If no, is it due to any injury?

Does your child currently have or have they ever had a previous injury to the spine, hip, knee, foot, and ankle?

YES **NO**

If so, were they evaluated and treated? What was the injury?

What is their ability to participate in competition/games and practices since the injury?

Other sports or physical activities they currently or during the off-season are involved with

Have they ever been diagnosed with any of the following?

Sprains, strains, hematoma (swelling), contusions (bruise). **YES** **NO**

Spinal disc problems **YES** **NO**

Spondylolysis, including complete spine fracture, spine stress fracture, and pars stress reaction.

YES **NO**

Spondylolisthesis **YES** **NO**

Non-specific lower back, sacro-iliac, knee or hip pain **YES** **NO**

Scoliosis **YES** **NO**

If so, please provide details below or on back.

Appendix C4. Low Back Pain Logbook

Weekly Log Book

Your name: ______________________

Todays' date: _____________________

Do you have or have you had back pain today?

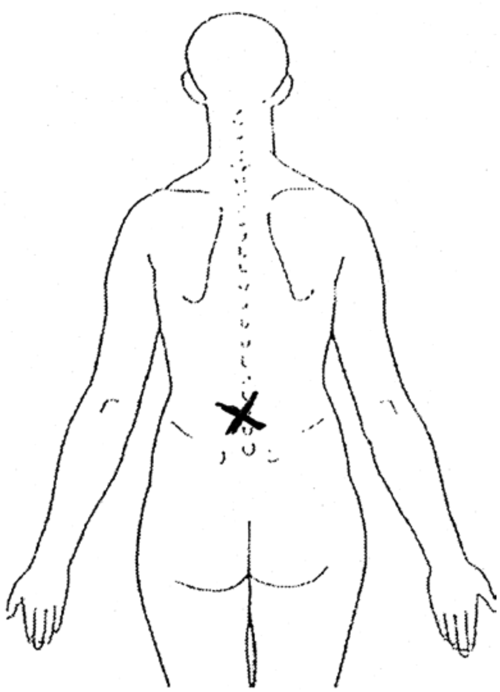
Yes No

If so, please make a mark on the exact location on a pain map below and please rate the intensity of pain.

Pain intensity scale

0	1	2	3	4	5	6	7	8	9	1 0

No pain Mild pain Moderate pain Worst possible pain



APPENDIX D

ADDITIONAL MATERIAL

Appendix D1. Recruitment Script.

Script for Parent, Gymnast Presentation

1. Welcome statement and Introductions:

Appreciation for attending and introduction of PI and FA.

2. Overview of injuries in the sport and purpose of study:

It is estimated that the prevalence of low back pain in gymnastics is between 30 and 85% and this is seen across all age groups. Reductions in core strength has been cited as one of the primary causes. It is vital that interventions which may help reduce the occurrence of lower back pain be incorporated at all levels, but more importantly at the younger age group. Therefore, the primary aim of this study is to measure the effect of a 6-week lumbo-pelvic stability intervention, either with Yoga or a lumbo-pelvic stability protocol, on lumbar muscle endurance, abdominal strength and balance (all key components in lumbo-pelvic stabilization) in adolescent gymnasts. A secondary aim is to examine the effect of these interventions on low back pain.

3. What are the pre- and post-tests and the exercise interventions

What is the effect of a lumbo-pelvic stability intervention on lumbar endurance measured by the Biering-Sørensen's test? What is the effect of an exercise intervention on lumbo-pelvic stability measured by the Lumbo-pelvic control test? What is the effect of an exercise intervention on balance measured by the Star Excursion Balance test? Does an exercise intervention prevent or reduce the occurrence of low back pain in an adolescent gymnast population?

4. Confidentiality

We respect you and your child's rights of confidentiality in this project. The results of this study will not reveal any individual gymnasts name or the Academy in future publications. The results from the study will only be in summarized findings with no identifying information published in an academic journal or presented at a scholarly conference.

Right to Refuse or Withdraw: Your child's participation is completely voluntary. He or she is free to withdraw from participation at any time or to choose not to participate at all, and by doing so, your child will not be penalized by the coach or anyone else.

The results from this study will be disseminated to the team of gymnasts, with no individual results provided. Furthermore, it is anticipated this project will be submitted to a peer-review journal for publication.

5. Dealing with aches and pains

While the risk is low for injury, the pre- and post-measurements procedures may cause your child some minimal discomfort, namely muscle soreness. We will instruct them and you (parent/guardian) on proper care, including stretching, icing, and heating procedures. We will follow up with a phone call the same day and the following day to monitor their progress.

Furthermore, the intervention may also cause some minor soreness in areas where the exercise focusses on, for example the gluteal region. Miranda will be on hand during the exercise sessions and will instruct them on appropriate care.

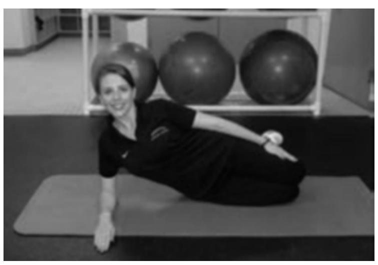
If your child indicates that they are suffering any back pain, Miranda, who is a registered, certified Athletic Trainer and/or me, also a registered, certified athletic trainer, will offer an evaluation to determine if the discomfort is musculature in nature or originating near the structures at the spine. If you and your child accept the offer for the evaluation, they will be guided appropriately to either continue the study or withdraw and seek medical attention if it appears the pain is originating at the spine.

Appendix D2. Pictures of Intervention Exercises.

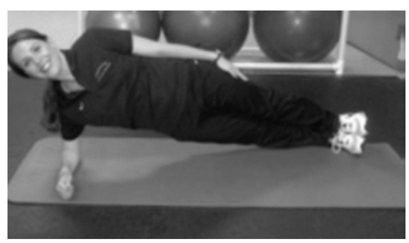
Double-leg bridge

Single-leg Bridge

Sidebend

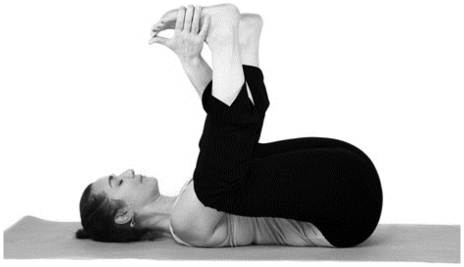


Side Plank

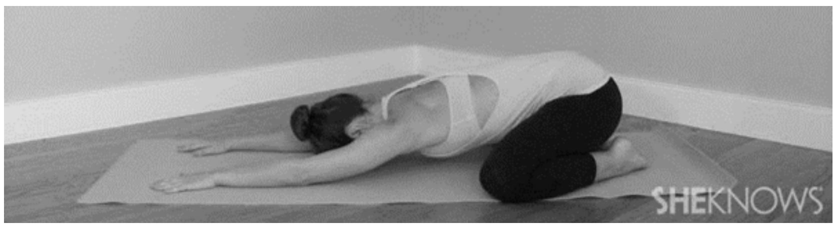


Fire Hydrants

Happy Baby



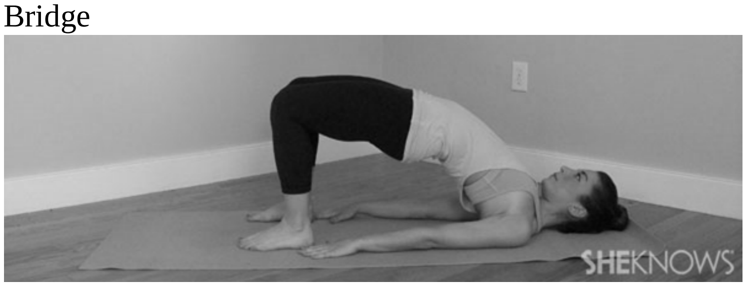
Child’s Pose



Rag Doll

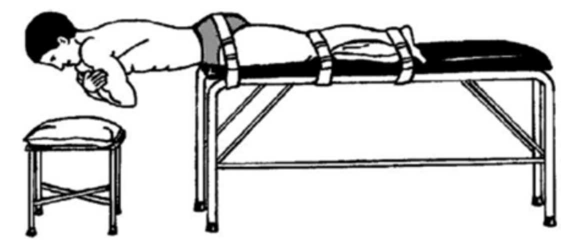
Downward-facing Dog

Bridge



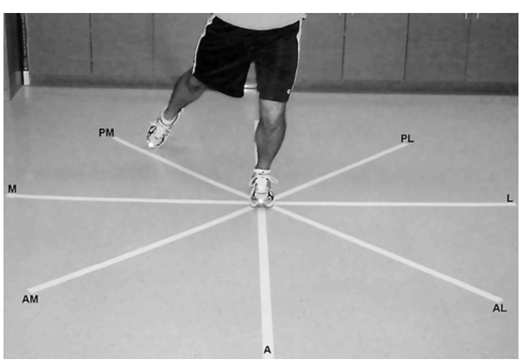
Appendix D3. Pictures of Pre- and Post-Measurement Tests.

Biering-Sorensen



Side Bridge

Star Excursion Balance Test



Lumbo-pelvic Control Test

The athlete performs a series of test, in order of increasing difficulty, designed to grade their level of lumbo-pelvic control. The starting position when the athlete is supine with both lower limbs extended. One leg is then flexed to a position where the medial malleolus of the ankle approximates the medial knee joint line of the opposite leg (hip approx. 45° flexion, knee approx. 90° flexion). The extended limb is then flexed to a matching position. The examiner places one hand palm down underneath the athlete's lumbar lordosis between skin and floor. The thumb side of the hand should be approximately level with the lumbosacral junction. This starting position will be constant throughout the series of grading tests. The athlete progresses through the series of tests outlined below, until the point where lumbo-pelvic control is lost. The test is stopped when the examiner feels a sufficient loss of pressure against the dorsum of his/her hand as a results of increased lumbar lordosis, indicating a loss of lumbo-pelvic control.

Grade 1: Double leg-left. Lift one foot 5 cm off ground, ten other foot to the same position and hold 5 sec.
Grade 2: From grade 1 position, slowly and alternately extend one leg to fully extended position, with foot approximately 5cm off the ground and return to Grade 1 position.
Grade 3: Double-leg lower x1, and return to starting position
Grade 4: Double-leg lower x2-4 reps
Grade 5: Double-leg lower x5+ reps. Note number of reps obtained.
RECORD: The level the athlete can obtain before losing lumbo-pelvic control. The athlete is allowed 2 trials to obtain each level before the test is stopped.
EQUIPMENT: Mat
TIME: 2 minutes

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