

Spring 2015

The Relationship Between Core Stability Related Measures and Performance in Adolescent All-Star Cheerleaders

Rachel S. Leitz

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THE RELATIONSHIP BETWEEN CORE STABILITY RELATED MEASURES AND
PERFORMANCE IN ADOLESCENT ALL-STAR CHEERLEADERS

by

RACHEL LEITZ

(Under the Direction of Barry Munkasy)

ABSTRACT

Purpose: To determine if a relationship exists between core stability related measures (CSRM) and total cheer performance (TCP); including tumbling, jumping, and stunting. Secondly, to determine if TCP can be predicted by these CSRM.

Methods: Fifty female competitive cheerleading bases aged 10-18 from various all-star cheer programs in the southeastern region of the United States were included. Participants filled out a current health status questionnaire prior to participation. The CSRM included the timed sit-up test, trunk extensor endurance test, trunk flexion to extension range of motion, dominant limb single leg stance test, and normalized to height dominant limb single leg hop distance.

Performance measures included a standing back tuck, a running tumbling dismount, a toe-touch, and a base skill assessment. The CSRM were tested during one session and tumbling and jump performance was video recorded during a separate session. Pearson's product-moment correlations were used to examine the relationship between CSRM and TCP, multiple regressions were run to predict TCP, and independent t-tests were run to discriminate top performers from bottom performers.

Results: Significant correlations were present between TCP and gymnastics experience, normalized hop distance, and timed sit-up test. Backward regression analysis revealed a prediction equation for TCP including the normalized hop distance, dominant limb single leg

stance test, and timed sit-up test, with an adjusted R^2 of 0.47 ± 2.77 . Independent t-tests revealed significantly greater scores of top performers in timed sit-up test, dominant limb single leg hop distance, and normalized hop distance compared to bottom scoring performers.

Conclusions: Three CSRM can predict about half of performance in adolescent competitive cheerleaders. Future research should aim to extend methods utilized in this study to various sports.

INDEX WORDS:Core stability, Competitive cheerleading, All-star cheerleading, Athletic performance, Tumbling, Toe-touch, Base

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by

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B.S., University of Florida, 2013

M.S., Georgia Southern University 2015

A Thesis Submitted to the Graduate Faculty of Georgia Southern University

Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

STATESBORO, GEORGIA

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Electronic Version Approved:
May 2015

ACKNOWLEDGMENTS

I would like to acknowledge my committee for the time and effort put forth into this study. In addition, I would like to acknowledge Dr. Krissy Kendall for her guidance and support throughout the creation of this study. Lastly, I would like to acknowledge Mary Beth Winningham for her dedication and patience throughout the data collection process.

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CHAPTER 1

INTRODUCTION

Core stability is defined as the ability to control the position and motion of the trunk over the pelvis, allowing optimum production, transfer, and control of force and motion to the terminal segments during integrated kinetic chain activities.¹ While stabilizing muscles are responsible for absorbing and distributing force in the body and posture holding, mobility muscles are responsible for force, power, and rapid movement.² In sport performance, the core can be described as all of the anatomy from the knees up to the sternum, particularly the low back, hips, and abdominal region.² Core stability has been broken down into five contributing components including strength, endurance, flexibility, motor control, and function.³ Selecting one parameter to test each component has been suggested as a means to measure core stability. Reliable tests include the timed sit-up test (SU), the trunk extensor endurance test (EE), trunk flexion to extension range of motion (TFE), dominant limb single leg stance test (DLS), and dominant limb single leg hop distance (DLH). Previous literature has attempted to identify correlations between DLH and height, but found no significant results.^{4,5} However, when discussing athlete functionality and return to play guidelines post-injury, it has been suggested females should be able to jump at least 70% of their height to be cleared for full participation.^{6,7} Fitness professionals generally accept the concept that peak performance is directly related to core stability and therefore incorporate core stability into their training paradigms.⁸ However, a true understanding of the core's role in athletic performance requires sport-specific testing.^{1,9,10} In competitive cheerleading, sport-specific activities include tumbling, jumping, and stunting.

In 2009, there were an estimated 3.73 million cheerleaders in the United States participating in school, recreational, collegiate, and all-star cheerleading, with 68% of

participants between the ages of 7 and 17.¹¹ A report from 2012 claims participation is increasing approximately 18% per year in the US.¹² Performance in competitive cheer requires a high degree of strength, endurance, flexibility, agility, and balance; athletes must be able to not only generate forces at a high rate through the body, but also withstand eccentric loading of the body.^{13,14} All-star cheerleading requires a tryout in which team selections are made through an evaluation process primarily based on tumbling skills, with teams available for all skill levels and age groups. All-star teams do not cheer at sporting events; they travel to competitions across the US and compete against all-star teams of similar skill level. Comparable to gymnastics, cheerleading tumbling and jumping skills require repetitive trunk extension, flexion, and twisting movements, constantly challenging the muscles of core stability. Throughout the literature, core stability has been suggested as a means to improve overall athletic performance.¹⁵⁻²¹ With participation in competitive cheerleading costing families between \$2,500 and \$10,000 per year, and reported injury rates being approximately 1-2.8 per 1,000 athletic exposures, improved performance and decreased injury rate are of utmost importance.^{12,22}

Tumbling and jumping skills of competitive cheerleading require participants to efficiently generate and transfer forces through the body in performance of acrobatic-like maneuvers. Successful extremity movement, especially that of coordinated athletic movements like landing gymnastics flips, depends on efficient force transmission, utilizing proximal stability for distal mobility through a feedforward mechanism of muscle activation.^{1,2,23,24} Improvements attributed to core stability have been found in Tuck Jump Assessment scores, overall stamina in gymnastics routines, vertical jump height, and single leg hop distance.¹⁵⁻¹⁷ In addition, neuromuscular training interventions incorporating core stability training found significant improvements in athletic performance and movement biomechanics in young female athletes,

including vertical jump, squat, single-leg hop distance, bench press, speed, and dynamic balance.^{17,20} From these results, it can be assumed that tumbling and jumping skills of competitive cheerleading require sufficient core stability. The final component of TCP, stunting, requires bases to lift the flyer from the ground to an extended overhead position, similar to a snatch lift in weightlifting. This type of lift requires an efficient transfer of forces through the trunk, again incorporating feedforward muscle activation.²⁵

In regards to injury, tumbling and stunts are the leading causes of injury in cheerleading.¹² Female athletes typically display a more erect position upon landing than their male counterparts, affecting the absorption of forces through the body and potentially increasing their risk of sprain/strain injuries.¹² Reports indicate high school cheerleaders experience about 3.8 injuries over their career, while collegiate cheerleaders experience 3.5.¹² In various other sports, core stability interventions involving neuromuscular training have been shown to reduce the risk of knee injuries.^{26,27} In addition, core training led to alterations in kinetics at the hip joint and kinematics at the knee joint during a drop vertical jump that are warranted in injury prevention programs.²⁶ Finally, proprioceptive balance training, a component of core stability, significantly reduced self-reported athletic injuries over six months.²⁸ With increased performance being a common goal amongst athletes, it can be assumed that a decrease in injuries and/or pain in cheerleaders may lead to just that.

Cheerleading performance requires strength, endurance, power, flexibility, balance, agility, and high levels of coordination and technical skill. It appears evident that a relationship should exist between core stability and performance in competitive cheer. Feedforward muscle activation beginning with the core has been found in the landings of various gymnastics flips and in weightlifting techniques comparable to cheer basing.^{24,25} Muscles of core stability are

responsible for absorbing and distributing force in the body, which can be up to 13 times body weight upon landing of tumbling skills.²⁹ Increased vertical jump heights have been shown in relation to core strength, which may also contribute to successful performance of jumps and standing tumbling in cheerleading.³⁰ In addition, a stable core may also reduce the incidence of various injuries in female cheerleaders. Therefore, the purpose of this study will be to identify a relationship between core stability related measures (CSRM) and total cheer performance (TCP); including tumbling, jumping, and stunting. A secondary purpose will be to determine if TCP can be predicted by these measures. Our hypotheses were twofold: (1) significant relationships exist between CSRM and TCP; and (2) the variance in TCP is significantly explained by 5 CSRM.

CHAPTER 2

METHODS

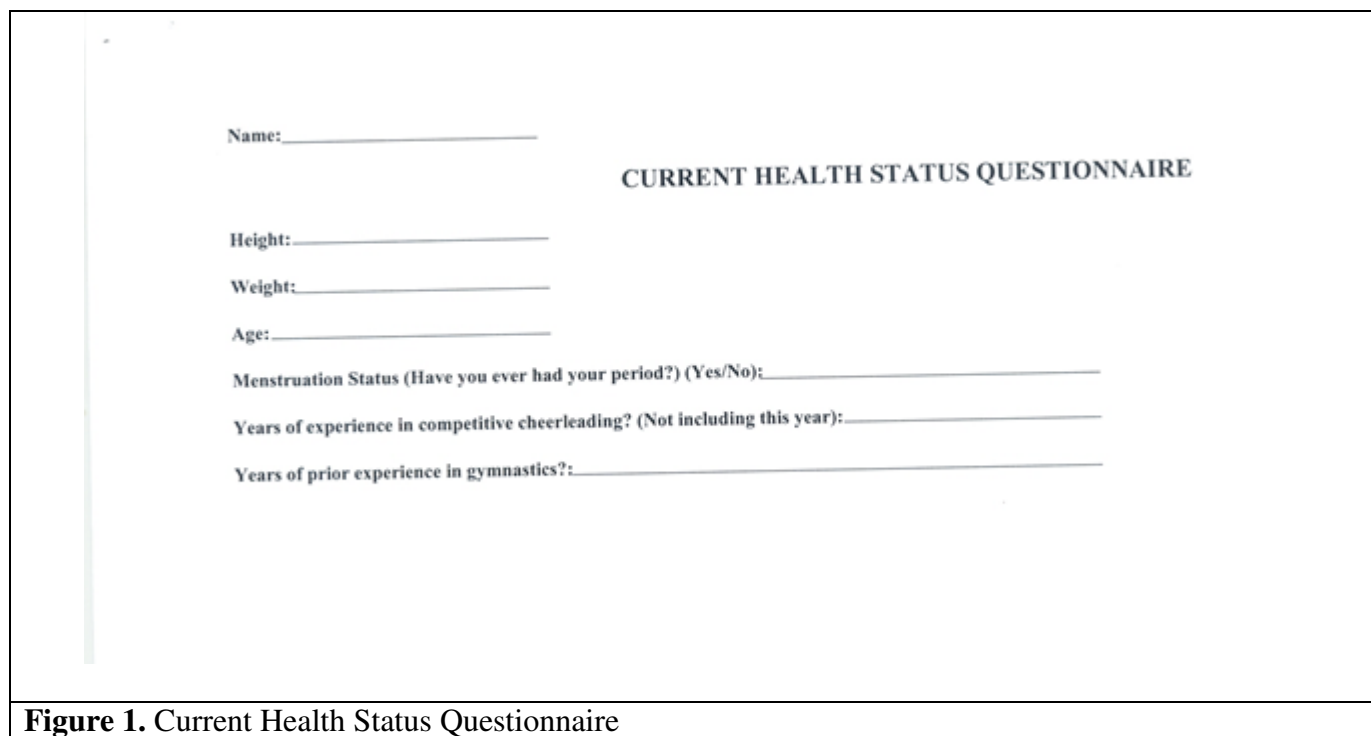
Participants

A total of 53 female competitive cheerleading bases aged 10 to 18 from various all-star cheer programs in the southeastern region of the US were recruited for this study. Two participants failed to complete both testing sessions and 1 failed to complete all CSRM, leaving a total of 50 participants for final analysis. The inclusion criterion for this study was females participating in competitive cheerleading for the 2014-2015 competition season. The exclusion criteria for this study were those individuals currently suffering from any orthopedic injury or ailment affecting performance, with the exception of low back pain (LBP), and those whose stunting position is exclusively a flyer. All facilities involved provided a signed letter of cooperation (Appendix F) and all participants provided signed parental informed consent as well as signed minor assent (Appendix G) prior to participation as approved by the University's Institutional Review Board.

Instrumentation

All testing was performed on the standard all-star practice floor consisting of a 14 m long by 2 m wide carpet-bonded foam mat on top of plywood connected to 10.16 cm springs. A stopwatch, Rosscraft anthropometric measuring tape, and folded tumbling mat were used in measuring various CSRM. The Voice Counting to 100 iPhone app was used as the automated metronome in the base skill assessment. A Befour PS-6600 ST digital scale (Saukville, WI), inspected on 10/28/2014, was used to weigh each participant. A dumbbell weighing 1/3 of each participant's weight rounded to the nearest 1-lb was used in the base skill assessment. Velcro ankle weights were attached to the handle of the dumbbell to make precise adjustments for the

desired weight. A current health status questionnaire (Figure 1) and the Micheli Functional Scale (MFS) (Figure 2) were distributed to all participants.³¹ Lastly, two Canon Vixia HFM31 video cameras (Melville, NY) secured to individual Proline Professional Aluminum tripods were used. Camera 1 was positioned 13 m away, directly in front of the participant (Figure 3) and zoomed in to view jump height and landing characteristics of both tumbling and jump. Camera 2 was positioned at a 90° angle to the participant, 1 m away (Figure 3), and zoomed in to view landing characteristics of both tumbling and the jump. Dartfish 7 (Alpharetta, GA) was used in the analysis and scoring of all video recordings.



Name: _____

CURRENT HEALTH STATUS QUESTIONNAIRE

Height: _____

Weight: _____

Age: _____

Menstruation Status (Have you ever had your period?) (Yes/No): _____

Years of experience in competitive cheerleading? (Not including this year): _____

Years of prior experience in gymnastics?: _____

Figure 1. Current Health Status Questionnaire

Name: _____

MICHELI FUNCTIONAL SCALE

Instructions: This survey asks for your assessment of back-pain and functional impairment. For each of the following questions, please mark the ONE appropriate response.

(A) Symptoms:

1. To what degree does pain affect your sports activity?

- No pain
 Pain is not affecting sports activity
 Pain has a slight or minimal effect on sports activity
 Pain has a moderate effect on sports activity
 Pain has a severe effect on sports activity
 Unable to participate in sports activity due to pain

(B) Activities of daily living:

1. To what degree is your pain associated with back extension (bending backwards) and/or upright activities?

- Able to run full speed and extend without limitations
 Able to run but extension causes some pain
 Running and extension cause pain
 Unable to extend at all
 Unable to run or extend

2. To what degree is your pain associated with sitting and/or flexion (bending forward) activities?

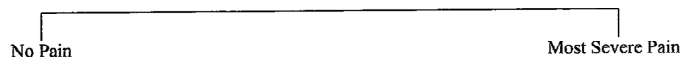
- Able to sit and flex at Lumbar Spine (lower back) without limitations
 Able to sit, but feel some pain with flexion activities
 Sitting and flexion activities cause pain
 Unable to sit or do loaded flexion activities

3. To what degree is your pain associated with jumping?

- Able to jump without pain
 Jumping causes some pain
 Jumping causes severe pain
 Unable to jump due to pain

(C) Visual Analogue Scale for Pain Assessment:

1. If the left extremity of the line indicates no pain, and the right end indicates such severe pain that you are unable to work or go to school, rate the intensity of your pain by marking an *X* on the part of the line which most corresponds to your experience.

**Figure 2. Micheli Functional Scale³¹**

In section B, question 2 has been modified to add the statement "lower back" next to "Lumbar Spine" for clarification purposes.

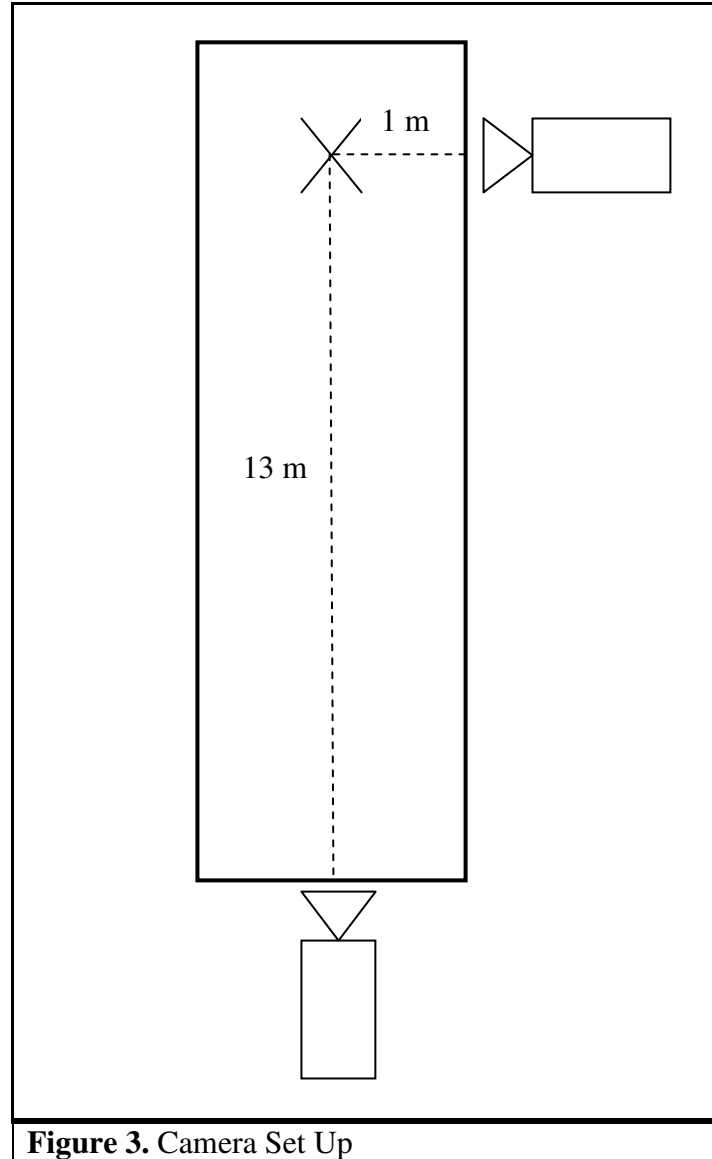


Figure 3. Camera Set Up

Procedures

Upon arrival to practice, each potential participant was explained the research protocol. Each participating teams corresponding coach distributed a parental informed consent and minor assent forms (Appendix G) to be signed. Participation in this study was completely voluntary. Data collection took place across 2 predetermined days for 2 teams, and on the same day for 1 team due to time constraints. For the participants on the latter team, session 2 was performed first followed by session 1, with 8 to 10 min rest between sessions. For testing session 1, after collection of signed consent and assent forms (Appendix G), participants were given a current health status questionnaire (Figure 1) and the MFS for LBP (Figure 2). Participants filled in their name, height, age, menstruation status, years of experience in competitive cheerleading, and years of experience in gymnastics. The MFS is comprised of 5 items, including 3 activity related questions, a symptom question, and a visual analogue scale to determine degree of pain.³¹ The overall score is based on a scale of 0 to 100 and assesses symptoms of back pain and level of difficulty relative to LBP associated with various sporting activities.³¹ Participants were then weighed in their normal practice attire and shoes, their weight was recorded, and the weight of each individual's dumbbell to be lifted was calculated and recorded. Participants then completed their normal pre-practice warm-up followed by all CSRM and the base skill assessment in groups of 4, as specified in the data analysis section. A sample video was shown to participants prior to each individual test and each test was described extensively (Appendix C). Two participants were tested simultaneously, while the other 2 assisted as their partners. Partners switched places at the completion of each test. Testing session 2 involved the video recording of cheerleading specific skills of each isolated individual. Participants performed their normal pre-practice warm-up followed by 3 toe-touches with a 30 s break between each attempt, 3 standing back tucks with

a 30 s break between each attempt, and 3 of their most elite running tumbling passes with dismounts with a 1 min break between each attempt. Video recordings were analyzed using Dartfish 7 and scored by the primary investigator.

Data Analysis

This was a prospective cross-sectional study. The independent variables were CSRM according to its 5 components: (1) Core strength measured by SU; (2) Core endurance measured by EE; (3) Core flexibility measured by TFE as described by Norkin and White; (4) Motor control measured by DLS; and (5) Core function measured by DLH.³ These CSRM are incorporated into batteries of youth fitness tests used worldwide and were selected based upon previously reported reliability values and practicality. Various fitness agencies have noted these measures are safe, reliable, and valid for use in testing youth ranging from age 5 to 18.³²

Timed Sit-Up Test

This protocol was developed by the American Alliance of Health, Physical Education, Recreation, and Dance and found to have very high intra-rater reliability, with an intra-class correlation coefficient (ICC) of 0.92.³ It is a standard measurement in the American College of Sports Medicine's Health-Related Physical Fitness Assessment Manual.^{3,33} The participant performed as many full sit-ups as possible within 1 min, with the primary investigator providing verbal cues every 10 s consisting of a brief motivational statement. The test was initiated in the hook-lying position, with the knees flexed to 90°, arms across the chest with each hand on the opposite shoulder, and feet secured by each participant's partner. For a full sit-up to count, the participant had to have their scapulae touching the mat in the lying position and the elbows contacting the knees in sitting. Number of repetitions was recorded.

Trunk Extensor Endurance Test

This is an endurance test established by McGill et al, with EE displaying high intra-rater reliability, with an ICC of 0.79.³ The test was performed with the participant lying prone on a folded tumbling mat. Their pelvis, hips, and knees were secured by their partner. When instructed, the participant assumed a horizontal position with arms across their chest, hands on the opposite shoulder, and elbows pointing vertically down to the floor. This position was held for as long as possible, with the primary investigator giving verbal cues every 10 s alongside a brief motivational statement. The test was discontinued when the participant fell below the horizontal position, or when their elbows touched the floor beneath them. Time was recorded in seconds.

Trunk Flexion to Extension Range of Motion

These measurements yield high intra-rater reliability, with ICC's of 0.71 for flexion and 0.79 for extension.³ Measurements were taken by measuring the distance between cervical vertebrae 7 (C7) and sacral vertebrae 1 (S1) while standing in neutral position, as described by Norkin and White.³⁴ These landmarks were marked with a pen for consistency. After the anatomical landmarks were identified, the participant flexed forward as far as possible while stabilizing their pelvis. They were instructed to "hunch forward as far as you can, keeping your hips still." The length between C7 and S1 was re-measured and the difference between neutral and flexed was recorded as trunk flexion range of motion. The same protocol was used in evaluating trunk extension, with the participant extending back as far as possible and the distance re-measured. The difference between neutral and extended was recorded as trunk extension range of motion. Trunk flexion to extension range of motion was recorded as the difference

between trunk flexion distance and trunk extension distance in centimeters, rounded to the nearest ½ cm.

Dominant Limb Single Leg Stance Test

Waldhelm and Li performed this test using the Biodex Balance System SD. For convenience and accessibility purposes, this test was performed on the ground, which was found to have an inter-rater reliability ICC of 0.99 for eyes closed best of three trials.³⁵ The participant stood in their normal practice shoes on their dominant limb with the other limb raised, not touching the stance limb. To determine dominant limb, the participant was asked: “If you were to kick a ball, which foot would you kick it with?” The participant was instructed to cross their arms over the chest prior to lifting the limb. Tests were performed with their eyes closed and the best of 3 trials was recorded. Time started when the participant raised the foot off of the floor and time was discontinued when the participant either: (1) uncrossed the arms, (2) touched the floor with the raised foot, (3) moved the foot on the ground to maintain balance, (4) a maximum of 45 s passed, or (5) the participant opened their eyes. Time was recorded in seconds.

Dominant Limb Single Leg Hop Distance

This test was performed according to the protocol described by Reid et al, which were found to have very high intra-rater reliability with ICC's of 0.91 and 0.92 for right and left hop, respectively.³ Hop testing has been shown to be a valid measure of performance incorporating neuromuscular control.³⁶ The participant performed the test by hopping and landing on their dominant limb. The distance hopped was marked with tape and measured from toe to toe, with the participant required to maintain their landing for at least 2 s for a successful trial. Three hops were performed, with the longest hop recorded in centimeters. For statistical analysis, DLH was

normalized to each participant's height (DLH/H) to determine if significant correlations existed in our population.

Total Cheer Performance

The dependent variable for this study was TCP, including measures of standing back tuck, running tumbling dismount, the toe-touch, and a base skill assessment. Performance was scored based upon pre-established gymnastics and cheerleading scoring guidelines (Table 1, 2, 3). Standing back tuck was evaluated based on Table 4, running tumbling dismount was evaluated based on Table 5, and the toe-touch was evaluated based on Table 6. Toe-touch height was analyzed in Dartfish 7 using the reverse angles tool. The image was maximized in order to clearly see the anatomical reference points. The angle was measured from the most inferior aspect of the pelvis to the Achilles notch of each shoe. Each picture frame of each jump was observed in succession, with the highest vertical point of the anatomical landmarks being analyzed.

Table 1. 2014-2015 Varsity All-Star Scoring System ^a
Athlete Fall - .25
Hands down in tumbling or jumps
Knees down in tumbling or jumps
Blatant incomplete tumbling twist(s)
Multiple body parts touch the floor in tumbling or jumps
Drops to the floor during individual skills (tumbling, jumps, etc.)
^a Data adapted from nca.varsity.com/Competitions/Rules-And-Divisions

Table 2. International Federation of Gymnastics: Section 8.3 Table of General Faults and Penalties^a					
Landing Faults (all elements including dismounts)		Small Error	Medium Error	Large Error	Very Large Error
Legs apart on landing	Each time	X			
Movements to maintain balance:					
Extra arm swings		X			
Lack of balance	Each time	X	X		
Extra steps, slight hop	Each time	X			
Very large step or jump (more than shoulder width)	Each time		X		
Body posture fault	Each time	X	X		
Deep squat	Each time			X	
Brushing/touching apparatus/mats, but not falling against the apparatus	Each time		X		
Support on mat/apparatus with 1 or 2 hands	Each time				1.00
Fall on mat to knees or hips	Each time				1.00
Fall on or against apparatus	Each time				1.00
Failure to land feet first on landing from element	Each time				1.00

^aData adapted from the 2013-2016 code of points women's artistic gymnastics.

Table 3. NCA Scoring Guidelines: Jumps^a	
Score	Guideline
5-6	Below Level Jumps
6-7	Level jumps and jump combinations with average execution by the majority of the team
7-8	Level jumps and jump combinations with above average execution. Must include at least one back handspring combination by the majority of the team.
8-9	Level jumps and jump combinations with above average execution. Must include at least one jump-to-tuck combination by the majority of the team.
9-10	Hyperextended jumps and jump combinations with above average execution. Must include at least one jump-to-back handspring-to-tuck or layout variation by the majority of the team.

Abbreviations: NCA, National Cheerleaders Association.
^aData adapted from the 2013-2014 NCA College Scoring Guidelines.

Table 4. Standing Back Tuck	
Score	Guideline
4	Stick Landing- No error ^a
3	Small Error- Feet < shoulder width, small step/hop, ≤1 step
2	Medium Error- Hand down, feet > shoulder width, large step/hop, 2+ steps
1	Large Error- multiple body parts touch the mat (knees, etc.)
0	Cannot perform skill

^a Errors refer to landings and are defined based on Tables 1 and 2, modified by the authors to conform more to competitive cheerleading standards.

Table 5. Running Tumbling Dismount	
Score	Guideline
4	Full Twist- small error ^a
3	Layout- small error Full Twist- medium/large error
2	Back Tuck- small error Layout- medium/large error
1	Back Handspring- small/medium error Back Tuck- medium/large error
0	Cannot perform back handspring

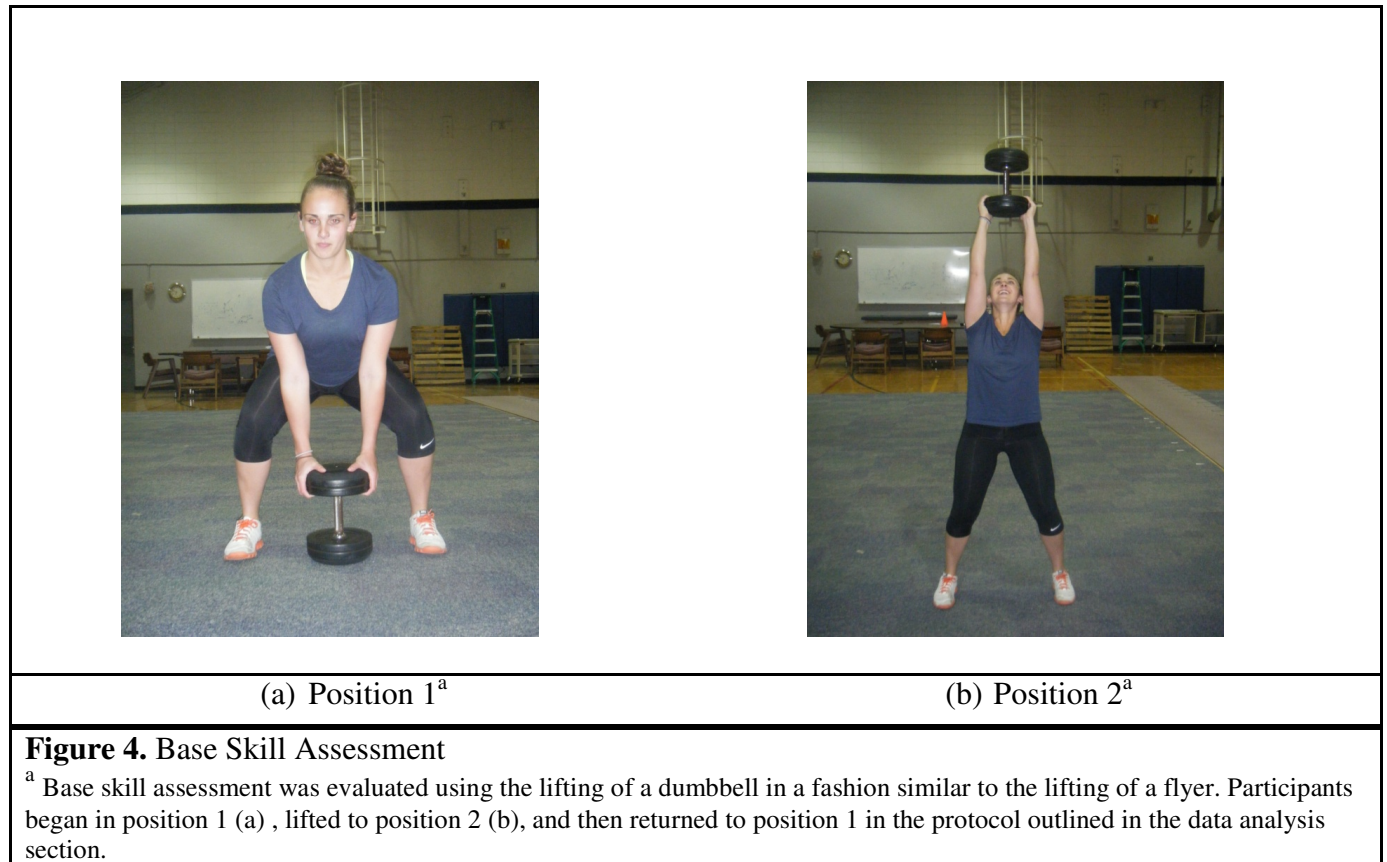
^a Errors refer to landings and are defined based on Tables 1 and 2, modified by the authors to conform more to competitive cheerleading standards.

Table 6. Toe-Touch	
Score	Guideline
4	Hyper Extended ^a - small error
3	Level ^b - small error Hyper Extended- medium/large error
2	Below Level ^c - small error Level- medium/large error
1	Below Level- medium/large error
0	Cannot perform skill
^a Hyper extended (> 195.0°) ^b Level (175.0° to 195.0°) ^c Below level (< 175.0°) Angles refer to the reverse angle of both legs at highest vertical height of jump. Scores are based off of Table 3.	

The base skill assessment was created by the primary investigators to simulate the action of a base as closely as possible and was evaluated by the primary author based on Table 7. To the primary investigator's knowledge, this measurement has not yet been validated or previously used in other studies. Participants performed this test using a dumbbell weighing 1/3 of their body weight. This weight was determined due to 2 contributing factors; (1) this allows a standard of measurement in order to make comparisons amongst participants, and (2) three bases typically hold 1 flyer in the air. Simulating a cheerleading stunt, the test started with the dumbbell on the ground on end and the participant in a squat position, legs slightly wider than shoulder width (Figure 4a). Participants assumed the start position and grasped the dumbbell on the top end. When cued, participants lifted and inverted the dumbbell from ground position to an overhead position (Figure 4b), keeping the dumbbell close to the body. This technique requires forces created in the lower extremities to be transferred into the hands as the dumbbell is propelled overhead. An automated metronome set to 85 beats per minute cycled through 9 cycles of 8 counts, verbally counting 1 through 8. Participants assumed the overhead position, with elbows completely extended and the shoulders level with the ears, on each 1 count, began to lower the

dumbbell to the starting position on each 6 count, tapped the dumbbell on the mat, and resumed an overhead position on the following 1 count. The test was discontinued when form was broken, the participant was unable to keep the cadence, or the maximum time was reached. Each participant demonstrated 2 practice lifts prior to performance of the test: first with a 20-lb dumbbell to practice cadence, next they performed 1 lift with the actual weight, critiqued by the investigator, with a spotter, to ensure that they could safely accommodate the weight. During testing, a spotter was in position to assist with the weight if needed to decrease injury risk due to an unbalanced repetition. Performance skills being assessed were activities similar to what participants engage in on a regular basis at practice as well as in competition.

Table 7. Base Skill Assessment	
Score	Guideline
4	8-9 reps
3	5-7 reps
2	3-4 reps
1	1-2 reps
0	0 reps



The TCP score consisted of the summed values from the evaluation of standing back tuck, running tumbling dismount, toe-touch, and the base skill assessment. Therefore, TCP was scored based on a scale of 0 to 16.

Statistical Analysis

Pearson's product-moment correlations were used to examine the relationship between CSRM and TCP. Multiple backwards regressions were run to predict TCP. Independent t-tests were run to discriminate the top performers (TCP > 10; N=20) from the bottom performers (TCP < 7; N=19). Groups were formed based on the top 40% and bottom 40% of TCP scores. SPSS version 19.0 (Armonk, NY) was used to test for significance ($P \leq .05$). Intra- and inter-rater reliability was determined for video analysis, and test-retest reliability was determined for all CSRM, TCP, and MFS.

CHAPTER 3

RESULTS

The final sample was composed of 50 healthy female all-star cheerleaders from 3 facilities in the southeastern region of the US. Descriptive statistics are presented in Table 8. Pearson Correlation Coefficients and significance levels are presented in Table 9. We found DLH to be significantly correlated to height ($P < .001$), therefore, DLH/H was used in all analyses. Results reveal 3 independent variables to be significantly related to TCP: gymnastics experience, DLH/H, and SU.

Table 8. Descriptive Statistics (N=50)	
Variable	Mean \pm SD
Age, y	14.3 \pm 1.7
Height, cm	161.2 \pm 7.8
Weight, kg	55.7 \pm 7.1
Gymnastics Experience, y	2.2 \pm 3.2
Cheer Experience, y	3.8 \pm 2.5
SU, #	36 \pm 6
EE, s	86.9 \pm 45.0
TFE, cm	12.2 \pm 4.2
DLS, s	12.4 \pm 10.5
DLH/H, cm	1.09 \pm 0.12
MFS, %	29.4 \pm 18.5
TCP, #	9 \pm 4
Abbreviations: DLH/H, normalized hop distance; DLS, dominant limb single leg stance time; EE, trunk extensor endurance test; MFS, Micheli Functional Scale; SU, timed sit-up test; TCP, total cheer performance; TFE, trunk flexion to extension range of motion.	

Table 9. Pearson Correlation Coefficients and Significance Levels between demographics, CSRMs, LBP as measured by MFS score, and TCP		
Variable	Pearson Correlation	P Value
Height	0.130	.184
Weight	0.060	.341
Gymnastics Experience	0.290	.020
Cheer Experience	0.164	.128
SU	0.574	> .001
EE	-0.069	.318
TFE	0.032	.412
DLS	0.224	.059
DLH/H	0.558	> .001
MFS	-0.060	.340
Abbreviations: CSRMs, core stability related measures; DLH/H, normalized hop distance; DLS, dominant limb single leg stance time; EE, trunk extensor endurance test; MFS, Micheli Functional Scale; SU, timed sit-up test; TFE, trunk flexion to extension range of motion. Bold values represent significance.		

Backward regression analysis was performed to predict TCP and yielded a prediction equation as follows:

$$\text{TCP} = 14.067(\text{DLH/H}) + 0.074(\text{DLS}) + 0.227(\text{SU}) - 15.572$$

Results produced an adjusted R^2 value of 0.470 with a standard error (SE) of 2.77. The detailed data for TCP are presented in Table 10. Figure 5 represents the scatterplot of individual data showing the correlation between the actual TCP and regression predicted TCP.

Table 10. Backward Regression Model of TCP in Relation to 3 CSRM			
CSRM	Regression Coefficient	Standardized Regression	P Value
SU	0.227	0.381	.002
DLS	0.074	0.204	.061
DLH/H	14.067	0.426	.001

Abbreviations: CSRM, core stability related measures; DLH/H, normalized hop distance; DLS, dominant limb single leg stance time; SU, timed sit-up test.

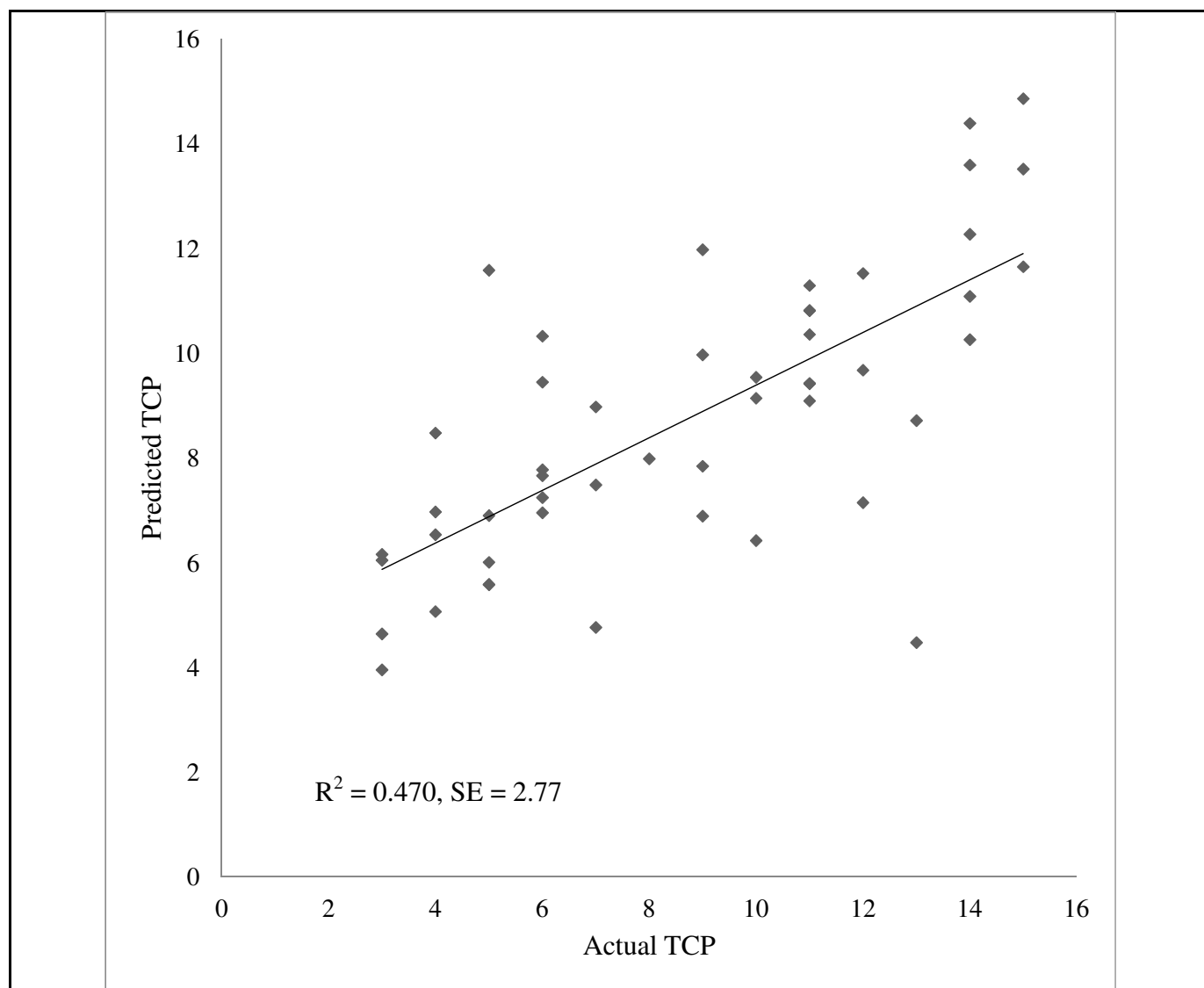


Figure 5. Scatterplot of the Actual TCP vs. the Regression Predicted TCP. Solid line represents the linear regression fit across all participants.

Independent t-tests found 2 variables capable of discriminating between the top (Group A) and bottom (Group B) performers, including SU and DLH/H. Table 11 presents the mean \pm standard deviation (SD) and significance levels for all independent variables.

Table 11. Results of Independent t-test		
Independent Variable	Mean \pm SD	P Value
SU: Group A	39 \pm 7	.001
Group B	33 \pm 4	
EE: Group A	86.9 \pm 48.0	.641
Group B	93.9 \pm 46.1	
TFE: Group A	12.2 \pm 5.2	.795
Group B	12.6 \pm 3.7	
DLS: Group A	15.5 \pm 12.9	.280
Group B	11.5 \pm 9.7	
DLH/H: Group A	1.15 \pm 0.10	> .001
Group B	1.01 \pm 0.12	
MFS: Group A	29.5 \pm 20.0	.632
Group B	32.3 \pm 15.5	
Abbreviations: DLH/H, normalized hop distance; DLS, dominant limb single leg stance time; EE, trunk extensor endurance test; MFS, Micheli Functional Scale; SU, timed sit-up test; TFE, trunk flexion to extension range of motion. Bold numbers represent significance.		

Inter-rater and intra-rater reliability were both determined to be 0.99 in the scoring of TCP. The TCP components analyzed for reliability included the video recordings of standing back tuck, running tumbling dismount, and toe-touch.

Test-retest reliability was found to be acceptable for EE (0.757), DLH/H (0.805), and MFS (0.813). Test-retest reliability for overall TCP was found to be acceptable (0.979) and all individual components of TCP had acceptable values as well. All test-retest reliability values are presented in Table 12. Table 13 presents test-retest reliability values for individual components of TCP.

Table 12. Test-Retest Reliability	
Variable	Reliability
SU	0.511
EE	0.757
TFE	0.654
DLS	0.616
DLH/H	0.805
MFS	0.813
TCP	0.979
Abbreviations: DLH/H, normalized hop distance; DLS, dominant limb single leg stance time; EE, trunk extensor endurance test; MFS, Micheli Functional Scale; SU, timed sit-up test; TCP, total cheer performance; TFE, trunk flexion to extension range of motion.	

Table 13. TCP Test-Retest Reliability	
Variable	Reliability
Standing Back Tuck	0.936
Running Tumbling Dismount	0.897
Toe-Touch	0.933
Base Skill Assessment	0.886
Abbreviations: TCP, total cheer performance.	

CHAPTER 4

DISCUSSION

The purpose of this study was to determine if a relationship exists between CSRM and TCP; including tumbling, jumping, and stunting. We hypothesized that significant relationships would exist between CSRM and TCP. Significant correlations were found between TCP and gymnastics experience ($P = .02$), DLH/H ($P < .001$), and SU ($P < .001$). A secondary purpose was to determine if TCP can be predicted by these CSRM. We hypothesized that the variance in TCP will be significantly explained by the 5 CSRM. Backward regression analysis yielded a prediction equation including 3 out of the 5 CSRM, including DLH/H, DLS, and SU. With this equation, we are able to significantly explain 47% of the variance in TCP with a SE of 2.77.

To the best of our knowledge, this is the first study to examine the relationship between CSRM and competitive cheer performance. Numerous studies have been conducted involving the 5 CSRM and normative values have been suggested.^{35,37-40} According to the American Alliance for Health, Physical Education, Recreation and Dance, our participants fall between the 50th and 55th percentile for SU for their age group (mean 14.3 y).³⁷ Participants classified as the top 20 performers placed in the 65th percentile. McGill reported a mean EE of 185 ± 60 s in healthy females, although the mean age of their population was 21.³⁸ Participants in our study had a mean EE of 86.9 ± 45.0 s. The large variation in EE times between our population and those reported by McGill could be explained by the presence of LBP in our population. Participants reported a mean MFS score of $29.4 \pm 18.5\%$. McGill reported a mean EE of 90 ± 49 s in a population with a history of disabling back troubles, a value that more closely agrees with our population.³⁸ Another explanation for this variation could be the age differences between our population and that reported by McGill, as our population had a mean age 7 years younger than

that of McGill. Norkin and White present a normal TFE of 11.00 ± 2.55 cm for females aged 15 to 24.³⁹ Our results are in agreement with Norkin and White, with a mean TFE of 12.2 ± 4.2 cm. Springer et al reported a mean DLS time of 13.1 s with a SE of 12.3.³⁵ Our results are in agreement with Springer et al, having a mean time of 12.4 ± 10.5 s. Lastly, Myers et al proposed normative values for the DLH in female high school athletes to be 129 ± 18 cm.⁴⁰ Our participants hopped a mean of 175.4 ± 22.7 cm. This variation could be explained by the testing surface utilized in our study. While Myers performed this test on a hard surface, our participants performed the hop on their normal practice floor consisting of carpet bonded foam mat on top of 10.16 cm springs secured to plywood. A second possible explanation could be the differences in sporting activities (basketball and soccer vs. competitive cheer). Although the literature has failed to find a correlation between DLH and height, we did find a significant correlation and therefore suggest normalizing DLH to height in this population.^{4,5} We did not find discussion in the literature on the normalization of any other variable utilized in this study.

Previous literature on female cheerleaders has focused solely on physiologic profile of the fitness status of participants in the collegiate setting.^{13,14} With participation in competitive cheerleading on the rise and the high costs associated with participation, it may be of interest to coaches and participants alike to have a fitness test that could predict TCP. Backward regression analysis yielded a prediction equation that included 3 testing variables: DLH/H, DLS, and SU. These variables may be used in talent identification and in formulating strength and conditioning programs for specific participants. With this equation, we were able to account for 47% of the variability in TCP with a SE of 2.77. These results suggest that 95% of the time, a participant's predicted score will fall within ± 5.54 points of their actual score. This is an acceptable range considering our prediction equation only accounts for CSRM. Other factors that could contribute

to TCP that were not accounted for in this study include psychological factors, social factors, and/or specific strength of body parts (e.g. upper trapezius, latissimus dorsi, gastrocnemius, etc.). In addition, independent t-tests revealed 2 values that allow us to significantly discriminate top performers from bottom performers. Participants in the top performance group performed a mean of 6 more SU than those in the bottom performance group. In addition, top performers had a DLH/H 0.14 greater than the bottom performers, which is approximately 24 cm. These CSRM utilize musculature specific to the explosive, acrobatic-like maneuvers performed in cheerleading. With these values, it may be possible to discriminate those who will perform at a higher level from those who may not when selecting participants for specific teams.

As with any study of human performance, there were multiple assumptions and limitations associated with this study. We assumed TCP accurately measured performance in competitive cheerleading. We incorporated many of the athletic aspects of performance and scored based upon pre-established guidelines when possible. Secondly, we assumed all participants were honest on their health status questionnaire and MFS. Participants were encouraged to report honestly and ensured that any information reported would not affect their testing scores. Individual scores were not presented to any coaches, and performance did not affect their status within the team. Lastly, we assumed all participants gave maximum effort in testing. Throughout both testing sessions, verbal encouragement was given at frequent time intervals and coaches of each team were present to provide further support when they deemed necessary. We were limited to adolescent all-star competitive cheerleaders, which decreases the potential applicability to other populations. For purposes of this study, we were solely interested in the adolescent population since the majority (68%) of all cheerleading participants (school, recreational, collegiate, and all-star) in the US fall within this age range.¹¹ Secondly, we utilized

performance variables that have not been previously tested for validity. When scoring tumbling and jumping skills, we referenced pre-established scoring guidelines for gymnastics and competitive cheerleading used by judges. In creation of the base skill assessment, we mimicked the action of lifting of a flyer from the ground to an extended overhead position with scaled weight for each individual. Next, we were limited to those whose stunting position was a base and excluded those whose position was exclusively a flyer. In performance of stunts, bases and flyers are required to utilize musculature specific to the demands placed upon them. For consistency in TCP scoring, we exclusively studied bases. Additionally, there was a lack of blinding in the investigation team; however, each participant was assigned a letter and number code to de-identify them during analysis. The investigators had no prior contact with participants and results of this study did not affect their status on the team. Secondly, each participant's MFS questionnaire was not scored until after all data collection and performance scoring had taken place in order to reduce potential scoring bias. Lastly, one team performed both testing sessions within 1 day and completed testing session 2 prior to testing session 1. The investigators allowed sufficient rest time (8 to 10 min) between testing sessions and we do not believe this influenced their performance. According to the National Strength and Conditioning Association, complete recovery after brief, explosive activities can occur within 8 min.⁴¹

Reliability values of the CSRM ranged from 0.511 to 0.979. Variables with below acceptable reliability included SU, TFE, and DLS, presenting a further limitation. Re-testing took place nearly 3 months post original testing and post competition season, which could explain the low reliability of these measures. A larger population may provide higher reliability across all performance variables. Future studies should attempt to establish higher test-retest

reliability through performance of re-testing within an acceptable time frame to prevent changes in ability or learning between the test administrations.

This study represents a starting point in predicting athletic performance through the use of CSRM. Future research should be conducted in order to extend the methods utilized in this study to other sports in an attempt to aid in predicting athletic performance. In this study, regression analysis revealed variables specific to musculature required for performance of cheerleading activities. Future studies should attempt to generalize this concept to other sports through the use of sport-specific variables. In regards to cheerleading specifically, future research should be conducted in order to validate performance variables utilized in this study, to include flyers, and on various populations, including, but not limited to, the collegiate level and male participants. Lastly, research should be continued in larger populations and to cross validate the prediction equation. The literature on cheerleading is sparse, and with participation steadily increasing from year to year, future research is necessary in order to further understand the physical demands placed on this population.

CHAPTER 5

CONCLUSIONS

The current study showed that specific CSRM can account for nearly half of performance in athletics. Specifically, that TCP, including standing tumbling, running tumbling, toe-touch, and base skill assessment, can be significantly predicted by the SU, DLS, and DLH/H. Furthermore, 2 variables were able to significantly discriminate top performers from bottom performers. These variables included SU and DLH/H. Therefore, it may be valuable for competitive cheer coaches and participants to utilize these measures in fitness testing prior to team selections, in talent identification, in post-season testing, and for specific training purposes. With the population of cheerleaders steadily on the rise, further research should be done to support these results as well as to extend these results to various populations.

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APPENDIX A

LIMITATIONS, DELIMITATIONS, ASSUMPTIONS, HYPOTHESES

Limitations

1. We were limited to adolescent all-star competitive cheerleaders in the southeast region of the US.
2. We used performance variables that have not been tested for validity.
3. We only investigated bases and excluded those whose stunting position was exclusively a flyer.
4. There was a lack of blinding in the investigation team.
5. One team performed both testing sessions in 1 day, with testing session 2 performed prior to testing session 1, due to time constraints placed on the investigators by the coach.

Delimitations

1. We were delimited to adolescent all-star competitive cheerleaders from multiple facilities.

Assumptions

1. We assumed the TCP score accurately measured performance in competitive cheerleading.
2. We assumed all participants were honest on their health status questionnaire.
3. We assumed all participants were honest on the MFS.
4. We assumed all participants gave maximum effort in testing.

Hypotheses

1. Significant relationships will exist between CSRM and TCP.
2. The variance in TCP will be significantly explained by the 5 CSRM.

APPENDIX B
EXTENDED STUDY

Methods

Data Analysis

The sixth independent variable of this study was MFS score (Figure 2).

Statistical Analysis

Pearson's product-moment correlations were used to examine the relationship between CSRМ, TCP, and LBP. Multiple regressions were run to predict LBP.

Results

Pearson Correlations were run to determine significance between demographics, CSRМ, TCP, and LBP as measured by MFS score. Results are presented in Table 13.

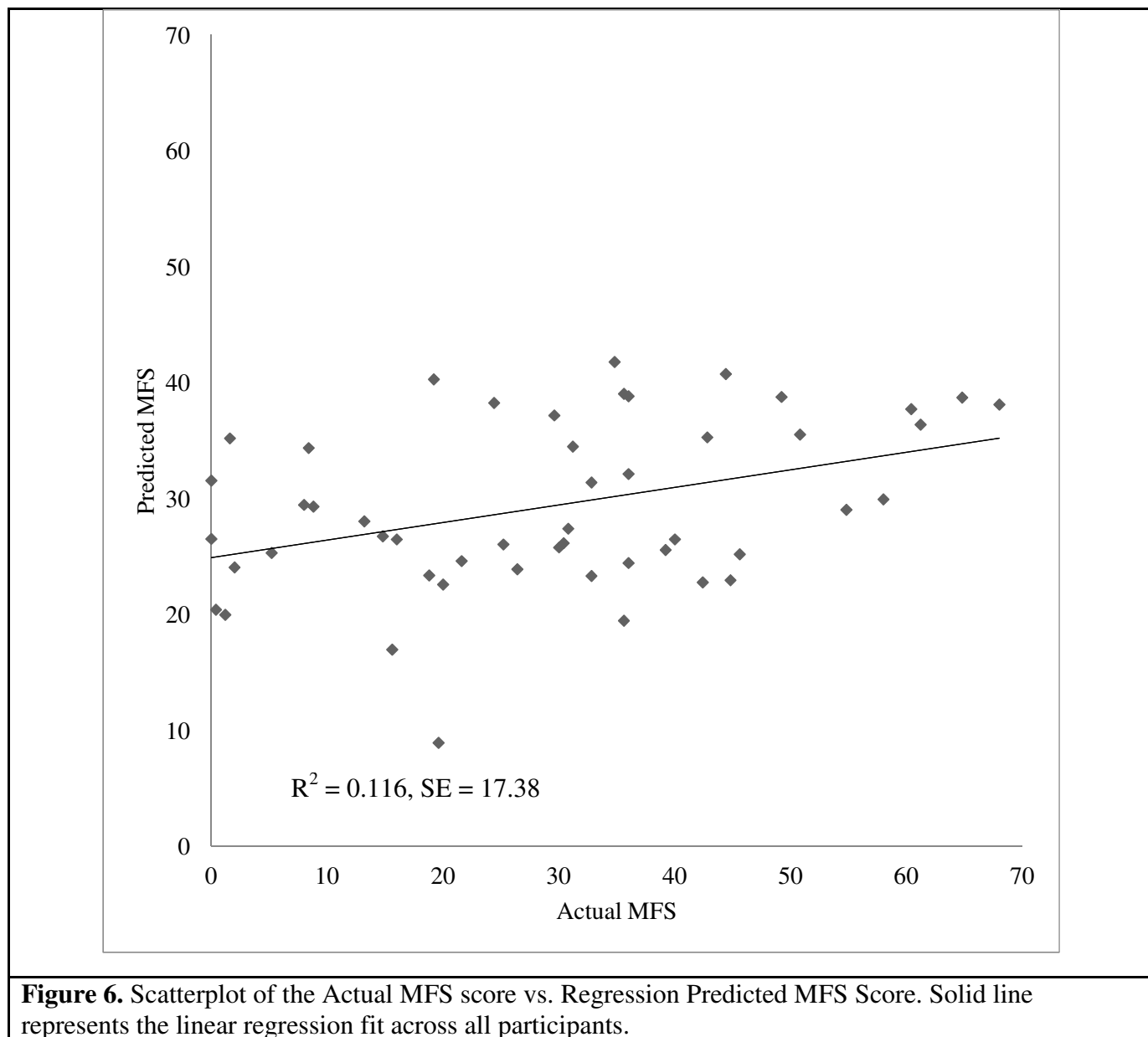
Table 14. Pearson Correlation Coefficients and Significance Levels between demographics, CSRМ, TCP, and LBP as measured by MFS score		
Variable	Pearson Correlation	P Value
Height	0.005	.487
Weight	0.283	.023
Gymnastics Experience	0.003	.492
Cheer Experience	0.220	.063
SU	-0.168	.122
EE	-0.220	.062
TFE	-0.181	.104
DLS	-0.216	.066
DLH/H	0.259	.034
TCP	-0.060	.340
Abbreviations: CSRМ, core stability related measures; DLH/H, normalized hop distance; DLS, dominant limb single leg stance time; EE, trunk extensor endurance test; SU, timed sit-up test; TCP, total cheer performance; TFE, trunk flexion to extension range of motion. Bold values represent significance.		

A second backward regression analysis was performed to predict LBP and yielded a prediction equation as follows:

$$\text{MFS} = 60.996(\text{DLH}/\text{H}) - 0.909(\text{SU}) - 4.289$$

Results produced an adjusted R Square value of 0.116 with a SE of 17.38. The detailed data for MFS score are presented in Table 14. Figure 6 represents the scatterplot of individual data showing the correlation between actual MFS score and the regression predicted MFS score.

Table 15. Backward Regression Model of MFS Score in Relation to 2 CSRM			
CSRM	Regression Coefficient	Standardized Regression Coefficient	P Value
SU	-0.909	-0.315	.036
DLH/H	60.996	0.381	.012
Abbreviations: CSRM, core stability related measures; DLH/H, normalized hop distance; SU, timed sit-up test.			



Discussion

We hypothesized that significant relationships would exist between CSRM, TCP, and LBP as measured by the MFS. Significant correlations were found between MFS score and weight ($P = .023$), as well as DLH/H ($P = .034$). Secondly, we hypothesized that the variance in MFS score will be significantly explained by the CSRM and TCP. Backward regression analysis

yielded a prediction equation including 2 CSRM; SU and DLH/H. With this equation, we are able to significantly explain 11.6% of the variance in MFS score with a SE of 17.38.

Previous research has shown the MFS to be a valid clinical tool in evaluating LBP in the adolescent population. Although MFS has demonstrated validity in differentiating LBP patients from controls, normative values have not yet been established.

Our results displayed statistical significance, but clinical meaningfulness comes into question. Results suggest that 95% of the time, a participant's predicted MFS score will fall within ± 34.76 points of their actual score. This wide range of scores, although statistically significant, is not meaningful from a clinical perspective.

We assumed that all participants were honest while completing the MFS. Participants were encouraged to answer honestly and ensured that their responses would be kept confidential and would not affect their performance scores.

APPENDIX C

CSRM TESTING INSTRUCTIONS

Timed Sit-Up Test:

“Your partner will be holding your feet down and counting the number of repetitions you do. Start lying down with your knees bent and arms across your chest, hands on the opposite shoulder. When I say ‘go,’ you will perform as many sit-ups as you can within 1 minute. For each rep to count, you have to touch your elbows to your knees, then go back down to having your shoulder blades flat on the mat. I will tell you every 10 seconds. Any questions?”

Trunk Extension Endurance Test:

“You’re going to lay down on your stomach off the edge of the mat, with your hips right at the edge. Your partner is going to sit across your lower body to hold you down. When I say ‘go,’ you will lift your upper body up to a horizontal position, keeping your arms across your chest, hands on the opposite shoulder and elbows pointing straight down to the floor. Hold this position as long as you can! I will let you know every 10 seconds. Any questions?”

Trunk Flexion to Extension Range of Motion:

“For this test you will need to be in just a sports bra. If you are uncomfortable with being in front of everyone, we can go into the bathroom, if you are OK with that. I will be marking dots on

certain points of your back for measurements. First, I want you to stand normally with your feet shoulder width apart, hands relaxed at you side. Now I want you to hunch forward as far as possible, keeping your hips still and neutral. Now I want you to extend back as far as possible while looking at a point on the wall directly in front of you. Keep looking at that spot and extend back as far as you can and hold that position.”

Dominant Limb Single Leg Stance Test:

“If you were to kick a ball, what foot would you kick it with? That’s the foot you’re going to be balancing on for this test. When I say ‘go,’ you will lift your other foot off the ground, bending it behind you to 90 degrees, so NOT in a liberty position. Your hands will be across your chest, hands on the opposite shoulder, and you will close your eyes. Balance in this position for as long as you can. Time will stop if you touch your foot down, move the foot you are standing on to maintain balance, use the leg you are standing on as support to maintain balance, if your arms come off your chest, or if you open your eyes. We will do 3 attempts at balancing. Any questions?”

Dominant Limb Single Leg Hop Distance:

“For this test, you will be hopping on the same leg that you balanced on. You will start with your toe behind the piece of tape, with your toe right up on the edge. You will then take off and land

on the same leg, hopping as far as you can forward. You must maintain the landing for at least 2 seconds for the hop to count. Your partner will be in a position to put their finger right in front of your toe when you land. You will then go and get the piece of tape with your initials on it and come back and place the tape right behind your partner's finger. Your partner will then have her turn at jumping, repeating the same thing you just did. We will perform 3 hops each, alternating partners between each hop. If your next jump is farther than the previous one, you will move your piece of tape up to the new spot. If you do not jump as far as your previous hop, leave your piece of tape where it is. Any questions?"

APPENDIX D
REVIEW OF THE LITERATURE
CORE STABILITY AND ATHLETIC PERFORMANCE

Core stability can be defined as the ability to control the position and motion of the trunk over the pelvis, allowing optimum production, transfer, and control of force and motion to the terminal segments during integrated kinetic chain activities.¹ This concept has been researched extensively throughout the fields of strength and conditioning, performance enhancement, rehabilitation, and injury prevention.¹⁻⁴⁰ Variations exist in regards to components of core stability and strength and to whether or not core training actually has an effect on athletic performance. To date, no study has attempted to identify a relationship between core stability and performance in female competitive cheerleaders. The following text will provide a review of the literature involving an overview of the core, the concept of feedforward, core endurance versus core strength, associated neural adaptations in relation to athletic performance, relationships found between core stability and athletic performance, results of core stability interventions in relation to athletic performance, and core stability as it relates to injury reduction. To conclude, performance variables in competitive cheerleading will be reviewed and comparisons will be made between these variables and previously studied core based performance measures.

In an attempt to understand the components of the core, we must first present a definition of the core and core stability. Multiple definitions of core stability have been presented, including: the ability of the lumbo-pelvic hip complex to return to equilibrium following a perturbation without buckling of the vertebral column,² and being able to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of

force and motion to the terminal segment in integrated kinetic chain activities.¹ An additional commonly used term, lumbo-pelvic stability, can be defined as the “dynamic process of controlling static position in the functional context, but allowing the trunk to move with control in other situations.”² When sport performance is a main focus, the core, or lumbo-pelvic hip complex, can be described as all of the anatomy from the knees up to the sternum, particularly the low back, hips, and abdominal region.³ The stability of the core involves the spine, hips, shoulder girdles, and pelvis functioning together through the use of three subsystems: the passive (ligamentous); the active (musculotendinous); and the neural control.⁴ Core stability can be broken down into five components including strength, endurance, flexibility, motor control, and function.² Four mechanisms presented as necessary for achieving core stability can be directly related to these components; including: coordinated muscle cocontraction (function), rapid activation of the primary spinal stabilizer muscles (motor control), sufficient strength of choice muscles (strength), and requisite endurance (endurance).⁵ For purposes of this review, core stability will be defined as the ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities¹ crucial to athletic performance.

In order to examine the effects that core stability may have on performance, we must have reliable assessment measures. When addressing the assessment of core stability, 35 different tests have been identified and classified into the five components of strength, endurance, flexibility, motor control, and function.² Strength tests include maximal isometric strength for trunk flexion and extension, bilateral hip extension, hip abduction, and hip external rotation, and the sit-up test.² With the exception of the right hip abduction test (ICC = 0.45), all tests of strength show moderate to very high intra-rater reliability (IRR) with intra-class

correlation coefficients(ICC) ranging from 0.61 to 0.92, the sit-up test contributing the highest ICC.² Endurance tests include the trunk flexor test, trunk extensor test, and bilateral side bridge tests.² These tests also show moderate to very high IRR, with ICC's ranging from 0.66 to 0.96, the left side bridge showing the highest ICC and trunk flexion showing the lowest.² Flexibility tests include the sit-and-reach, trunk flexion and extension, bilateral trunk rotation, bilateral hip extension, bilateral hip internal rotation, and bilateral hip external rotation, which show moderate to very high IRR with ICC's ranging from 0.62 to 0.98, sit-and-reach providing the highest ICC and right hip external rotation providing the lowest.² Motor control measurements include passive reposition tests for each hip and a single limb balance assessment both with eyes open and closed. These show moderate to high IRR, with ICC's ranging from 0.52 to 0.90, with right leg balance assessment with eyes closed contributing the highest ICC and left hip reposition providing the lowest.² Functional tests including the squat test, bilateral hop distance, and bilateral hop timed tests show a large range of IRR, with ICC's from 0.42 to 0.92, with left hop distance exhibiting the highest ICC and left hop timed test showing the lowest.² Through the use of reliable assessment measures, areas of potential weakness can be identified. By identifying these weaknesses, researchers can eventually formulate connections to decreased performance in various athletic activities and create training protocols to assist in sport performance as well as injury prevention.

On the positive side, multiple benefits of adopting a core stability program have been presented, including correcting postural imbalances, aiding in the corrective treatment of trunk injuries, preventing/reducing injuries and low back pain (LBP), and enhancing performance.^{5,41} In fact, successful movement of the extremities is reliant upon the stability of the trunk in a concept referred to as proximal stability for distal mobility.⁵ The body is comprised of stabilizing

muscles that are responsible for absorbing and distributing force in the body as well as posture holding, in addition to muscles of mobility, which are responsible for force, power, and rapid movement.³ In activities where postural demand is increased, a delay in limb movement occurs due to an increase in time necessary to prepare the body for resultant forces.³ Looking back at its definition, core stability is accomplished through stabilization of the trunk, allowing optimal control, production, and transfer of forces and motion down the kinetic chain to the limbs.⁶ This concept is further supported by Hodges and Richardson's findings of a feed forward mechanism of muscle activation in which core muscles are activated prior to the primary movers in lower limb movements.⁷ When a muscle other than that of the primary mover is activated prior to or shortly after activation of the primary mover of the segment, the muscle activity is referred to as feed forward since "it cannot be initiated by feedback from the limb movement."⁷ Activity of the transverse abdominis may occur prior to activation of the primary movers by 42 to 100 ms.⁷ Therefore, it can be concluded that the transverse abdominis is involved in preparing the body for perturbations produced by movement, proving this mechanism of feed forward.⁷ Additionally, rapid unilateral left and right arm raising demonstrated bilateral asymmetrical responses of the transverse abdominis, internal obliques, and biceps femoris.⁸ The side contralateral to the movement arm showed an increase in amplitude during feed forward prior to the ipsilateral side, indicating that core muscle activity was specific to the direction of the disturbance to posture.⁸ This feed forward mechanism supports the need to have a strong core when performing gross movements related to sport, especially in performance of complex skills where all limbs should move rhythmically like in gymnastics and competitive cheerleading tumbling and stunting.

Diving deeper into the definition of core stability, Kibler, Press, and Sciascia describe the muscles of the core not only as those that stabilize, but that also help to transfer and generate energy from large to small body parts during sporting activity, providing further support of the concept of proximal stability for distal mobility.¹ The muscles responsible for intra-abdominal pressure are contracted prior to the initiation of large upper limb segment movement.¹ By doing so, a solid base for motion and muscle activation is created for the limbs.¹ Muscles involved in this process include the transverse abdominis, rectus abdominis, internal and external obliques, and the diaphragm.¹ Pre-programmed physiological muscle activations cause several biomechanical effects that mandate efficient function both locally and distally.¹ These muscle activations create anticipatory postural adjustments, in-turn creating the proximal stability by activating and positioning the body to withstand the perturbations to balance which are created by movements of the limbs.¹ Kibler compares this process to the cracking of a whip: the larger muscles of the core create a rigid cylinder and a large moment of inertia against perturbations while the central core acts as the motor of force development, which allow small motions around the core to effect large changes in motion of the distal limbs.¹ This concept is important to keep in mind when assessing the role of core stability in athletic performance, as well as for core stability programs. Exercises should focus not only on stability of the core, but also in relation of the core to its role in limb function and, inevitably, in athletic activities.¹

Moving forward into comparing core endurance versus core strength, core strength can be defined as the ability of the muscles to produce force through intra-abdominal pressure and contractile forces.³ In order for strength benefits to occur, more than 60% maximal voluntary contraction is required, with low repetition exercises.³ When developing a core strength program, multiple components must be incorporated to ensure that all core musculature is being

challenged at different intensities, including: exercises in an unstable environment; dynamic and isometric exercises; and flexibility of the hip flexors, hip extensors, low back, and abdominal muscles.³ Similar to any other performance-based strengthening program, any core strength program must be specific to performance goals in order to produce improvements.³ In competitive cheerleading, athletes must be able to generate forces at a high rate through the body in activities such as tumbling and jumping.⁴² In addition, landing of a tumbling skill can be directly related to the take-off height, with lower take-offs causing larger landing errors.⁴³ Neuromuscular training interventions including core stability training demonstrate statistically and clinically significant improvements in athletic performance and movement biomechanics in female athletes, including vertical jump and squat, compared to both pre-test values and controls.¹² These specific movements are significant in tumbling and jumping activities. In addition, this training program leads to hypertrophy of the muscles in addition to neural adaptations that benefit performance.³ When muscular endurance is discussed, it has been suggested that endurance is more important than strength in regards to overall stability and that it should therefore be trained prior to strength through the use of low load, longer duration exercises.^{3,44} Core endurance training has been advocated to increase active pelvic and spinal stability and to increase fatigue threshold, which may translate into performance.⁹ Looking at healthy male and female recreational athletes, a relationship between functional movement, core stability, and performance exists.⁶ Through the use of the McGill protocol for measuring core muscle endurance, which includes trunk flexor, extensor, and right and left lateral muscle tests, along with the functional movement screen developed by Cook, significant correlations between core tests and performance tests emerged.⁶ Specifically, that trunk flexor, right lateral trunk musculature, and right shoulder mobility accounted for 86% of the variability in total

performance.⁶ From this, it can be concluded that the use of a functional program involving both low and high load training should impact sport performance by improving both core stability and core strength.³ In gymnasts, 10 weeks of core training allowed significant improvements in McGill endurance test times, including a 32% mean increase in trunk extensor endurance, with subjects reporting greater overall stamina during longer routines attributed to the aforementioned core training.⁹ Further supporting the notion that the core can be directly related to performance, six weeks of core stability training in recreationally active individuals resulted in improvements in lower trunk endurance performance, a direct link to improvement in sport performance as well as prevention of low back pain.¹⁰ Additionally, when comparing resistance-trained men, participants with a high strength level in one repetition maximum(1RM) shoulder press under unstable conditions demonstrated higher scores on trunk flexion muscular endurance and on trunk flexion to extension ratio compared to those with high strength levels under stable conditions only.¹¹ This indicates that increased core endurance contributes directly to increased performance in upper-limb strength activities. Contrary to these findings, core endurance improvements as shown by the McGill protocol produced no significant changes in the rowing ergometer test as performed by college-age rowers, and 8 weeks of core endurance training in gymnasts only produced increases of core endurance times up to 20 s intervals.^{12,13} While improving core strength and endurance have shown increased performance in many instances, these components only comprise two out of the five variables necessary for core stability.

A third component of core stability, motor control, has the ability to contribute great performance improvements, if trained correctly. Correct training of the core promotes neural adaptations including improved synchronization of motor units, more efficient neural recruitment patterns, a lowering of neural inhibitory reflexes, and faster nervous system activation.³ Since

fast motor units in muscles are recruited during optimal performance of quick movements, and slow motor units are recruited in postural sway, training of both the fast and slow motor units in a muscle is important for optimum motor control in order to enhance core strength and stability.³ The effects of neuromuscular training in adolescent female athletes have been positive in regards to balance tests, prevention of lower-extremity injuries, and athletic performance.^{14,15} Not only is the implementation of a neuromuscular training program focused on core stability exercises promoted for prevention of lower extremity injuries, it has been theorized to increase performance in power activities in adolescent female athletes who traditionally display lower baseline levels of power and strength compared to their male counterparts.¹⁵ In fact, 6 weeks of training resulted in improved measures of vertical jump, squat, single-leg hop distance, bench press, and speed in adolescent female athletes compared to both their pre-trained values and values of untrained controls.¹⁵ Most notable of these results is an increase in double-leg vertical jump from 39.9 ± 0.9 cm to 43.2 ± 1.1 cm.¹⁵ In addition, 8 weeks of a neuromuscular training program focused on core stability and lower extremity strength showed significant improvements in performance of the Star Excursion Balance Test (SEBT), suggesting that training improves motor control as it relates to balance.¹⁴ Composite scores improved from a mean \pm SD of $96.4\% \pm 11.7\%$ to $104.6\% \pm 6.1\%$ of right leg length and from $96.9\% \pm 10.1\%$ to $103.4\% \pm 8.0\%$ of left leg length on the star excursion balance test in the experimental group with a large effect size, despite the training not replicating this test.¹⁴ Improvements were likely less related to lower extremity strength, and more to improved neuromuscular control and balance since they were seen in the posteromedial and posterolateral directions, as suggested by previous research.¹⁴ Previously, research showed an increase in SEBT scores in the anteromedial reach direction from $84.9\% \pm 7.6\%$ of stance limb to $89.0\% \pm 6.6\%$, in the medial reach direction from $85.1\% \pm 8.9\%$

to $91.1\% \pm 7.7\%$, and in the posteromedial reach direction from $85.5\% \pm 9.6\%$ to $92.5\% \pm 6.9\%$ following a 6 week core stability training protocol in young, healthy adults.¹⁶ Because the training protocol was specifically focused on core stability, any improvements in performance scores can be directly related to core stability. More recent research has also shown significant improvements in medial and anteromedial reach directions on the SEBT in adolescents following a 6 week core stability training program, further supporting the importance of core stability in neuromuscular tasks.¹⁷ When looking at postural stability, defined as the “ability to control the center of mass in relationship to the base of support,”⁴⁵ a core stability program using Pilates produced significant effects on the path length of center of pressure as well as lower extremity muscle strength.¹⁸ This combined evidence suggests that performance can be increased through neuromuscular training programs that focus on core strength and stability.

After discussing how single components of core stability may affect overall performance, the next step is to determine how core stability as a whole effects athletic performance. A search of the literature presents conflicting evidence of the effect of core stability on athletic performance.^{3,6,12,13,19-31,46} Fitness professionals generally accept the highly debated concept that peak performance is directly related to core stability and therefore incorporate core stability into their training paradigms.¹⁹ Peak performance not only consists of flawless technique leading to higher jumping, faster running, etc.,³ but also includes ideal functional movement, or “the ability to produce and maintain a balance between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency.”⁶ Since the ability to train the muscles to produce increases in core stability is dependent upon the training being specific and functional, athletes should train with exercises mimicking movements specific to their performance in competition,³ including control of balance, strength and motion of the core to

maximize upper and lower limb function.¹ Therefore, in order to identify a possible relationship between core stability and performance, multiple variables must be assessed.⁶

Research has attempted to find a relationship between core stability and performance measures through both the examination of associated tests, and through the use of intervention protocols in both adult and adolescent populations. First, when simply examining results of relevant test measures, conflicting results have been found between Division I football players and Division I female soccer players in regards to core stability and sport performance.^{20,21} Core measurements included back extension, trunk flexion, and bilateral side bridges while performance measures included 1RM squat, 1RM bench press, 1RM power clean, shuttle run, 20 yd sprint, 40 yd sprint, and countermovement vertical jump.²⁰ Significant correlations between core strength and stability and the strength and performance measures were found in football players, however, correlations ranged from weak to moderate and were inconsistent, with correlations between trunk flexion, back extension, and vertical jump being 0.436 and 0.536, respectively, and -0.416 between squat and trunk flexion.²⁰ In Division I female soccer, no significant correlations were found between core strength and stability and the strength and performance measures.²¹ Furthermore, results of cross-sectional areas of trunk muscles in college wrestlers compared to those of judokas revealed significantly larger rectus abdominis in wrestlers and significantly larger obliques and quadrates lumborum in judokas, both of which provide necessary strength in the primary motions of each respective sport.⁴⁶ Absolute and relative trunk flexor strength, peak torque at $120^{\circ}\cdot\text{s}^{-1}$ and work at $90^{\circ}\cdot\text{s}^{-1}$ and $120^{\circ}\cdot\text{s}^{-1}$ were significantly higher in wrestlers, however, no significant differences in performance were found within each sport.⁴⁶ On the other hand, significant correlations were identified between vertical jump height and medicine ball throwing distance, a validated test of athletic performance.⁴⁷

When examining the relationship between isokinetic core strength and athletic performance tests in collegiate baseball players, statistically significant correlations between medicine ball throwing distance and all measures of isokinetic core strength were found, including a correlation of $r = 0.572$ with right trunk rotation and $r = 0.680$ with trunk flexion.¹⁹ Lastly, when cycling is the area of focus, a core fatiguing workout led to a significant decrease of 30.0% to 43.3% in cycling mechanics including peak torque, average peak torque, total work, average power, and maximal repetition total work.²⁷ This suggests that lower extremity cycling mechanics can be directly related to core stability.²⁷

Moving forward to the use of intervention protocols, when looking at the adolescent population, conflicting results have been found. First looking at running economy, a 6 week Swiss ball training program significantly improved core stability as well as time to failure in the Swiss ball prone stabilization core stability test, but showed no statistically significant changes in running performance as measured by $VO_2\text{max}$.²⁴ A four week lumbopelvic-hip complex intervention in active youth resulted in significant improvements in tuck jump assessment scores following the intervention, leading to the conclusion that strengthening hip musculature, particularly the gluteus medius and minimus, increases biomechanical stability related to the tuck jump assessment.³² Lastly, a 6 week core stability program produced significant increases of 4.9% in throwing velocity of adolescent female handball players.²⁶ When looking at the adult population, significant improvements in vertical takeoff velocity from mean \pm standard deviation of 2.22 ± 0.31 to 2.38 ± 0.36 m/s in athletes following a 9 week trunk stability training program have been reported.³³ The effect of a 6 week static core stability training program on field based fitness tests found strong positive relationships of 0.821 between plank/vertical jump height, and 0.820 between standing stork/double leg lowering test, in addition to very strong negative

relationships of -0.927 between plank/20 m sprint test, and -0.822 between double leg lowering/20 m sprint test.³⁴ Finally, following a dynamic core stability training program, strong positive relationships of 0.942 between the plank/20 m sprint test, and moderately strong relationships of 0.805 between medicine ball throw/back extensions were found.³⁴ While results of intervention protocols as well as attempts to find relationships between core stability and performance measures vary from case to case, two possible explanations as to why some cases found no significant results include: 1) Core strength plays no role in strength and performance, and/or 2) The tests used to measure core strength are not performance-specific.²¹

Finally, discussion of optimal athletic performance would not be complete without addressing injury prevention. In order for athletes to perform optimally, they must not only display strength in their specific sport, but also be able to prevent injuries to the best of their ability. In the athletic sector, an improved performance may be characterized by enhanced performance in training simply by reporting fewer injuries.³ As discussed above, the core plays a significant role in neuromuscular control, which has been described as highly important in adolescent gymnasts in the performance of landings.⁴³ Previous research has demonstrated that forces produced within the trunk are frequently linked with “inertia from the lower extremities that passes through the trunk into the upper extremities during functional or sport-specific movements.”⁵ In addition, activation of the hip musculature, an important component of core strength and stability, contributes greatly to the ability to generate forces in the upper leg muscles.³ The psoas muscle produces hip flexion in the open chain position while the transverse abdominis, multifidus, and erector spinae work to maintain stability.¹³ Adolescent female gymnasts found value in training the muscles of the lumbar spine to prevent and reduce low back pain.³⁵ Results showed a significant reduction in maximal pain intensity and a reduction of days

with low back pain in the experimental group following an 8 week specific segmental muscle control of the lumbar spine training protocol compared to the control.³⁵ In fact, 8 out of 15 gymnasts reported becoming pain free during the training period.³⁵ Additionally, a 4 week core stability intervention showed alterations in kinetics at the hip joint and kinematics at the knee joint in adolescent female athletes, including a decrease in hip-flexion and hip internal rotation moments.³⁶ Previous research suggests that an increase in the internal moment for hip internal rotation leads to an 8-times greater risk of anterior cruciate ligament (ACL) injury in adolescents.⁴⁸ Therefore, it can be concluded that since increased core stability resulted in decreased hip internal rotation moments, core stability can be directly related to prevention of ACL injuries.³⁶ Neuromuscular training has also been directly linked to ACL injury prevention in adolescent female athletes.^{49,50} In addition, adolescent basketball players with diminished balance, a component of core stability, showed a 7 time increase in ankle sprains compared to players with normal balance.⁵¹ Six weeks of at-home balance training in adolescents was effective in preventing athletic injury over 6 months.⁵² In adults, disruption of core stability lead to altered cycling mechanics and amplified the influence of factors known to contribute to knee pathologies, especially with increased durations of cycling.²⁷ Factors related to core stability have been shown to predict ACL, knee, and ligament risk of injury in collegiate athletes as well.⁵³ Results of a meta-analysis indicate that core stability exercise in adults can be more effective than general exercise in the short term for pain relief and back-specific functional status.³⁷ Core stability measures can also be used to predict risk factors for lower extremity injuries in collegiate athletes.³⁸ Athletes who sustained an injury over the course of one athletic season displayed significantly less hip external rotation and hip abduction strength than those who did not sustain any injury,³⁸ both of which are identified as core strength related tests.² By

testing hip abduction strength, hip external rotation strength, lumbar extension endurance, and side bridge endurance, and tracking all back and lower extremity injuries occurring throughout the course of an athletic season, hip external rotation weakness was found to most closely predict participant injury status.³⁸

After discussing core stability and its relationship to performance in depth, performance variables in competitive cheerleading will now be reviewed in order to draw comparisons to core stability. Performance variables of competitive cheerleading include running tumbling, standing tumbling, jumping, and stunting. To begin, it has been observed that landing errors in the adolescent men's gymnastics floor exercise, comparable to running tumbling in cheer, are produced by characteristics of flight, and that the quality of landing is related to symmetry.^{43,54} The main goal of tumbling is the "stick landing" in which the body's energy produced at the take off phase is absorbed.⁴³ In order to do so, the athlete must properly assess the direction and amount of energy during flight and anticipate these components upon landing.⁴³ Three factors limit a gymnast's ability to control a reaction force during landing: 1) ability to predict the magnitude of loading; 2) coordination of the muscles; and 3) capability to overcome the load generated at landing.⁴³ Landings should be performed with the feet together, creating a very small base of support and challenging stability. Stability is disturbed when the "line of action" of body weight is transferred outside of the base of support.⁴³ In order to increase stability upon landing with feet together, athletes must horizontally position their center of gravity near the edge of the oncoming external force's base of support while also positioning their center of gravity as low as possible vertically.⁴³ In the investigation of 684 landings of saltos, or back-flips, in gymnasts aged 16 and up, 413 were done without error.⁴³ Of those landings performed with error, most were completed with a low initial body landing height.⁴³ Significant differences

between the degree of error and initial landing height we revealed, that is, higher landing heights displayed smaller errors.⁴³ In order to land higher, one must perform a higher vertical jump during takeoff. As previously reported, multiple studies found relationships and/or improvements in vertical jump and vertical takeoff velocity in adolescents and adults attributed to core stability.^{15,33,34} Combining these results, it can be hypothesized that core stability contributes to optimal performance of jumping and tumbling skills in competitive cheerleading.

The final component of competitive cheerleading performance, stunting, is a skill requiring bases to lift a flyer by holding the foot from the ground to an overhead position with their arms extended, while the flyer must maintain balance in the air for various amounts of time. In regards to core stability, forces must be efficiently transferred through the body of bases from the lower extremities to the upper extremities in order to lift the flyer successfully. Similar techniques in weight lifting include the push press and the snatch lift. A stepwise regression revealed that the only predictor of push press power was the 1RM squat.³⁹ The authors deduced that a significant transfer of forces through the core has to be occurring in order for a lower body exercise to be the best predictor of an upper body strength measurement.³⁹ In regards to the snatch lift, electromyographic activation of the leg and back muscles were perceived to occur 0.2 s prior to the lift,⁵⁵ again indicating a feedforward mechanism of muscle activation. During practice, bases are required to lift flyers repeatedly over a duration of multiple hours, several days per week. Similar high frequency lifting may cause micro-trauma in the lumbar region, leading to failure and associated LBP.⁵⁶ In fact, the trunk was the most frequently injured body part in weight lifting incidents reporting to the Emergency Room, accounting for 36.9% of injuries in males and 27.4% in females.⁵⁷ Moreover, injuries to the low back accounted for 50% of all injuries in adolescent powerlifting.⁴¹ In regards to the severity of pain, 18.2% to 22.8% of

athletes reported this pain as being somewhat severe to severe.⁴¹ Patients with chronic LBP display modified movement patterns in an attempt to minimize pain.⁵⁶ Six weeks of core strengthening and extension exercises in weight lifters with LBP proved effective for relieving pain and disability.⁵⁸ For flyers, the importance of core stability related to balance and postural stability has been strongly supported in the literature, where results show significant increases in these measures following core training.¹⁴⁻¹⁸

In conclusion, through reviewing the literature of core strength and stability and making comparisons to variables of competitive cheer performance, it appears evident that a relationship should exist between the two. Core stability involves the spine, hips, shoulder girdles, and pelvis.⁴ It is being able to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities, such as a standing back somersault or the lifting of a flyer.^{1,2} Stability of the core incorporates five components including strength, endurance, flexibility, motor control, and function, of which motor control may be most predictive of tumbling skills.^{2,59} Hodges and Richardson found a feed forward mechanism of muscle activation in which core muscles are activated prior to the primary movers in lower limb movements.⁷ McNitt-Gray et al also found a feed forward technique when comparing between-task differences amongst the landings of a front tucked somersault, back tucked somersault, and drop landing.⁵⁹ Muscle activation prior to contact allowed researchers to anticipate differences in mechanical demands upon landing.⁵⁹ Dale et al present the concept of proximal stability for distal mobility of the extremities by implying that successful extremity movement relies on the stability of the trunk.⁵ In addition, this feedforward mechanism has been identified in weight lifting activities similar to the lifting of a flyer in basing.⁵⁵ Assessments of core strength and endurance have produced

moderate to very high reliabilities, ranging from 0.61 to 0.96.² Muscles of stability are responsible for absorbing and distributing force in the body, which can be up to 12 times body weight in female adolescents upon landing of tumbling skills.⁶⁰ In addition to these similarities, Marinsek et al concluded that successful landings of back somersaults were dependent upon landing height.⁴³ In order to achieve a higher landing height, take-off height must also be higher. Researchers have found the vertical jump to accentuate the significance of core power and strength in athletes. Moderate correlations between core strength and vertical jump heights were found in collegiate football players,²⁰ and increases in vertical jump performance following a high load training program focused on core strength improvement were found in recreationally active individuals.¹³ Nearly all performance related studies suggest that a true understanding of the core's role in sport requires sport-specific testing.^{3,6,10,11,20,21,26,27,30,31,34,39,40,46} In addition, efficient functioning of the core is necessary for effective use of strength and power as individuals develop through adolescence.⁶¹ Bringing all of this information together, it can be hypothesized that there is a relationship between core stability and various measures of competitive cheerleading performance, including jumping, tumbling, and stunting in female adolescent cheerleaders. Therefore, the purpose of this study is to explore these relationships through various testing measures.

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APPENDIX E
INSTITUTIONAL REVIEW BOARD

Georgia Southern University Office of Research Services & Sponsored Programs		
Institutional Review Board (IRB)		
Phone: 912-478-0843		Veazey Hall 2021
		P.O. Box 8005
Fax: 912-478-0719	IRB@GeorgiaSouthern.edu	Statesboro, GA 30460

To: Rachel Leitz
Dr. Barry Munkasy
Dr. Kristina Kendall
Dr. Barry Joyner
Dr. Li Li

CC: Charles E. Patterson
Vice President for Research and Dean of the Graduate College

From: Office of Research Services and Sponsored Programs
Administrative Support Office for Research Oversight Committees
(IACUC/IBC/IRB)

Initial Approval Date: 10/16/14

Expiration Date: 9/30/15


Subject: Status of Application for Approval to Utilize Human Subjects in Research –
Expedited Process

After a review of your proposed research project numbered **H15096** and titled "**How Core Stability Related Measures Predict Performance in Adolescent All-Star Cheerleaders**" it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of 100 subjects.

*Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research. –**Description:** This study will determine if a relationship exists between core stability related measures and measures of competitive cheer performance and if a relationship between core stability, performance, and low back pain exists.*

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. Total project approval on this application may not exceed 36 months. If additional time is required, a new application may be submitted for continuing work. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to notify the IRB Coordinator, so your file may be closed.

Sincerely,


Eleanor Haynes
Compliance Officer

Georgia Southern University Office of Research Services & Sponsored Programs		
Institutional Review Board (IRB)		
Phone: 912-478-5465		Veazey Hall 2021
Fax: 912-478-0719	IRB@GeorgiaSouthern.edu	P. O. Box 8005 Statesboro, GA 30460-8005

To: Rachel Leitz
Mary Beth Winningham
Dr. Barry Munkasy
Dr. Kristina Kendall
Dr. Barry Joyner
Dr. Li Li

Cc: Charles E. Patterson
Vice President for Research and Dean of the Graduate College

From: Office of Research Services and Sponsored Programs
Administrative Support Office for Research Oversight Committees (IACUC/IBC/IRB)

Date: 12/2/14

Initial Approval Date: 10/16/14

Expiration Date: 9/30/15

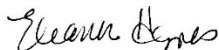
Subject: Status of Research Study Modification Request – Amendment 1

After a review of your Research Study Modification Request on research project numbered **H15096** and titled "**How Core Stability Related Measures Predict Performance in Adolescent All-Star Cheerleaders**," your request for modification appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your modification request. This amendment added Mary Beth Winningham to this study to assist with data collection.

The expiration date of your original application approval remains in effect. If additional time beyond your expiration date is required to complete your data collection and analysis and there have been no further changes to the research protocol; you may request an extension of the approval period. If your project will require approval beyond 36 months from the initial approval date, a new submission and review will be required. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, another change or modification of the approved methodology becomes necessary; you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to provide the final information to allow your file to be closed.

Sincerely,



Eleanor Haynes
Compliance Officer

APPENDIX F
LETTER OF COOPERATION

Team Name Here

Street Address
City, State and Zip Code
Phone Number
E-mail Address

/ /2014

Letter of cooperation for Data collection
Human Subjects- Institutional Review Board
Georgia Southern University
P.O. Box 8005
Statesboro, GA 30461

To Whom It May Concern:

Rachel Leitz has requested permission to collect research data from the All-Star Competitive Cheerleading program at _____ through a project entitled "How Core Stability Related Measures Predict Performance in Adolescent All-Star Cheerleaders." I have been informed of the purpose of the study and the nature of the research procedures. I have also been given the opportunity to ask questions of the researcher.

Data collection may include: core stability tests including the timed sit-up test, the trunk extensor test, trunk flexibility tests, dominant limb single leg stance test, dominant limb hop distance test, the dumbbell lift for base performance test, the Micheli Functional Scale for low back pain, and a current health status form. The data can be collected by the researcher after receiving parental informed consent and minor assent from each participant. No identifiable patient information is to be abstracted. The researcher will be video recording and will gain permission from each participant to record and obtain the data collection session.

As a representative of _____, I am authorized to grant permission to have the researcher recruit research participants from our competitive cheerleading program. Rachel Leitz is also permitted to collect research data here at the _____ facility. The researcher has agreed to the following restrictions:

If you have any questions, please contact me at

Sincerely,

APPENDIX G

CONSENT FORMS



COLLEGE OF HEALTH AND HUMAN SCIENCES

SCHOOL OF HEALTH AND KINESIOLOGY

PARENTAL INFORMED CONSENT

Dear Parent or Guardian:

A study will be conducted at your child's All-Star Cheer gym in the next few weeks entitled "How Core Stability Related Measures Predict Performance in Adolescent All-Star Cheerleaders." Its purpose is to determine if a relationship exists between core stability related measures, low back pain, and measures of competitive cheer performance; including tumbling, jumping, and stunting. A secondary purpose will be to determine if these variables can be predicted by each other. Core stability helps to produce and transfer forces through the body when participating in sports. In particular, we will be assessing five core stability related tests, a functional cheerleading base test, and performance of standing tumbling, running tumbling, and a toe-touch. We will also be distributing a current health status form and a low back pain form to your child.

If you give permission, your child will have the opportunity to participate in core stability related tests and a base performance test, including: 1) timed sit-up test; 2) trunk extension hold time; 3) trunk flexibility; 4) a single leg balance test; 5) a single leg hop distance test; and 6) the lifting of a dumbbell weighing 1/3 of your child's body weight from the ground to an overhead position, similar to the motions of basing. In addition, the primary investigator will be video recording skills including standing and running tumbling and toe-touch performance. This study will require one testing session lasting approximately 30 minutes, and one video-recording session lasting approximately 10 minutes.

Your child's participation in this study is completely voluntary with you and your child's permission. The risks from participating in this study are no more than would be encountered in normal cheerleading practice or competition; however, your child will be told that she may stop participating at any time without any penalty. Your child may choose to not answer any question(s) she does not wish to for any reason. Your child may refuse to participate even if you agree to her participation.

In order to protect the confidentiality of your child, a number and not your child's name will appear on all of the information recorded during the experiment. All information pertaining to the study will be kept in a locked filing cabinet in an office at Georgia Southern University. No one at your child's gym will see the information recorded about your child.

If you have any questions or concerns regarding this study at any time, please feel free to contact Rachel Leitz, Graduate Assistant Athletic Trainer, at (321)626-3596, or Dr. Barry Munkasy, advisor, at (912)478-0200.

To contact the Office of Research Services and Sponsored Programs for answers to questions about the rights of research participants please email IRB@georgiasouthern.edu or call (912) 478-0843. The Institutional Review Board tracking number assigned to this project is H15096.

If you are giving permission for your child to participate in the experiment, please sign the form below. Thank you very much for your time.

Rachel Leitz
Graduate Assistant Athletic Trainer

Dr. Barry Munkasy
Health & Kinesiology
Assistant Professor of Biomechanics



COLLEGE OF HEALTH AND HUMAN SCIENCES

SCHOOL OF HEALTH AND KINESIOLOGY

MINOR'S ASSENT

Hello,

I am Rachel Leitz a graduate student at Georgia Southern University and I am conducting a study on "How Core Stability Related Measures Predict Performance in Adolescent All-Star Cheerleaders."

You are being asked to participate in a project that will be used to learn about core stability and performance in cheerleading. Core stability helps to produce and transfer forces through your body when participating in sports. If you agree to be part of the project, you will perform a timed sit-up test, a back extension test, a back flexibility test, a single leg balance test, a single leg hop distance test, and a test to measure base performance. I will also ask you to perform a standing tumbling skill, a running tumbling skill, and a toe-touch. I will also ask you to complete a form about any current injuries and a form about low back pain. It will take about 30 minutes to complete the testing. Also, it will take about 10 minutes on a separate day to video-record your cheerleading skills.

You do not have to do this project. You can stop whenever you want for whatever reason. If you do not want to complete some or any of the tests or skills, it is ok, and you can go back to practice, and nothing bad will happen. You can refuse to do the project even if your parents have said that you can.

None of the coaches or other people at your gym will see the results to the tests that you perform, the video of your skills, or the forms you complete. All of the forms that you give me, results of the tests, and video-recordings will be kept in a locked cabinet in a room at Georgia Southern University, and only I or the four teachers helping me with this project will see your results and information. We are not going to put your name on any of your material, so no one will be able to know which material is yours.

If you or your parent/guardian has any questions about this form or the project, please call me at (321)626-3596 or my advisor, Dr. Munkasy, at (912)478-0200. Thank you!

If you understand the information above and want to do the project, please sign your name on the line below:

Yes, I will participate in this project: _____

Child's Name: _____

Investigator's Signature: _____

Date: _____

APPENDIX H

RECRUITMENT LETTER



COLLEGE OF HEALTH AND HUMAN SCIENCES

SCHOOL OF HEALTH AND KINESIOLOGY

To Whom It May Concern,

My name is Rachel Leitz and I am currently a Graduate Assistant Athletic Trainer at Georgia Southern University and a former All-Star competitive cheerleader. I am conducting research as a Master's Thesis and would like to request your permission for recruiting participants from your All-Star competitive cheer program.

The purpose of this research is to determine if a relationship exists between core stability measures and measures of competitive cheer performance; including tumbling, jumping, and stunting. A secondary purpose will be to determine if a relationship exists between core stability measures, performance, and low back pain. The core assists in optimal production and transfer of forces in athletic movements.

Participation in this research will include completion of five core stability measures and a functional cheerleading base test. These tests include: 1) timed sit-up test; 2) trunk extension time; 3) trunk flexion and extension flexibility; 4) dominant limb single leg stance test; 5) dominant limb single leg hop distance; and 6) the lifting of a pre-determined weight dumbbell from the ground to an overhead position, similar to the motions of basing. In addition, I will be video recording cheerleading performance skills, including standing and running tumbling and a toe-touch for analysis. Data collection will be performed during two separate sessions, one session involving testing of core stability measures that should take approximately 30 minutes, the other involving video recording of skills that should take no more than 10 minutes. Each participant will also be given a current health status form and the Micheli Functional Scale for low back pain for completion.

Core stability has been linked to increased performance and decreased risk of injury. The results of this study may be used to help guide strength and conditioning programs for competitive cheerleading teams to achieve optimum performance. In addition, results may be used to help predict and prevent those who may develop low back pain or help reduce low back pain in pre-existing conditions.

Participation in this study is completely voluntary. You may end your participation at any time by telling the person in charge, or by not completing the necessary testing.

If you would like to participate in this study, a letter of cooperation will be provided to you to be signed. In addition, each possible participant will be given a parental informed consent form as well as a minor assent form, outlining project procedures. Participation of each individual is completely voluntary. Upon completion of this study, results will be provided to you upon request.

I believe this project will provide crucial information for the competitive cheer population not only for improved performance, but also for the prevention of injuries. I would greatly appreciate your cooperation and support for participant recruitment!

If you have any further questions or concerns, please do not hesitate to contact me via phone or e-mail.

Thank you for your time and consideration,
Rachel Leitz ATC, LAT

Principal Investigator: Rachel Leitz
Graduate Assistant in Kinesiology
(321) 626-3596
R102281@georgiasouthern.edu

Faculty Advisor: Barry Munkasy
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