THE RELATIONSHIP BETWEEN LOWER LIMB POWER AND ANTHROPOMETRIC CHARACTERISTICS AND GYMNASTICS SUCCESS

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To the Dean of the Graduate School:

I am submitting herewith a thesis written by Gretchen Goerlitz entitled "The Relationship Between Lower Limb Power and Anthropometric Characteristics and Gymnastics Success." I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Kinesiology.

David Nichols, Ph.D., Major Professor

We have read this thesis and recommend its acceptance:

Department Chair

Accepted:

Dean of Graduate School

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ABSTRACT

GRETCHEN GOERLITZ

THE RELATIONSHIP BETWEEN LOWER LIMB POWER AND ANTHROPOMETRIC CHARACTERISTICS AND GYMNASTICS SUCCESS IN COLLEGIATE GYMNASTICS

AUGUST 2009

The aim of this study was to determine if there was a relationship between lower limb and upper body power and anthropometric measurements and gymnastics success in collegiate athletes on the vault apparatus. Seven 18-22 year old female gymnasts on the Texas Woman's University gymnastic team performed an arm countermovement vertical jump, a running vertical jump, and a handstand push-off task on a force plate. Participants had circumference measures of calf and thigh and leg length taken. A DXA scan measured fat mass and lean mass. Vault success was measured using the highest vault score of the season as well as a standard vault in which the distance was measured. A regression analysis was performed and no significant results were found. Circumference and fat mass measures had the highest beta weights indicating they had the strongest relationship to gymnastics success.

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CHAPTER I

INTRODUCTION

Each sport has a unique set of characteristics that lead to greater athletic performance. Within each sport there are different events, maneuvers, and positions used. The principal of specificity must be applied in order to fully understand the set of characteristics required for the greatest performance outcome.

Gymnasts can use different types of entry when performing a vault. The entry of a vault is the portion that occurs before the gymnasts hands are placed on the vault. The main entries include the handspring, Tsukahara, and Yurchenko. A handspring entry is a forward entry. A Tsukahara entry is a forward take off position from the springboard followed by a ½ turn position before vault contact. A Yurchenko vault is a round off entry on the board, therefore landing in a backward position, and then vault contact also in a backward position pending any extra twists (Bradshaw, 2004; USA Gymnastics, 2005).

Distance and height of athletic leaps are directly and positively correlated with achieving the highest possible score in a vault. Increased height and distance also lead to the ability to perform skills of greater difficulty, and therefore with a higher start value (Rogers, 2008). The start value is the point value judges deem a vault to be worth, and also the value they begin with when scoring a vault. It is therefore a benefit to the athlete to start from the highest possible mark, with the least amount of deduction, to achieve the highest overall score. Therefore, height and distance of athletic leaps are important factors in vault scores (Rogers).

Running speed and vault take off are of utmost importance to vault performance in gymnastics (Bradshaw, 2004). Vault take off, which is directly related to lower limb power, is important for scoring as well as for completion of the vault. According to the NCAA Rules and Modifications from the USA Gymnastics Code of Points, landing deductions are taken on vault if there is a lack of control and/or movement occurring prior to presenting to the judges. Up to 0.30 points can be taken for failure to maintain stretched body; therefore, enough height to maintain a stretched body position is regarded as highly important (USA Gymnastics, 2005). A deduction of up to 0.50 points can be deducted for insufficient height (USA Gymnastics). In order to land a vault, there must be enough rotation facilitated from the take off of the board as well as the block off the horse. A deduction of up to 0.30 points can be taken off for insufficient length of the vault landing taking into account the size of the gymnast (USA Gymnastics). Another deduction that relates to lower limb power and ability to properly perform a vault is that of incorrect body posture upon landing which can have an up to a 0.20 point deduction and a 0.30 point deduction for lack of an open position of the body prior to landing (USA Gymnastics). An open position is when the body position changes from the one used during rotation, and becomes a straight and vertical posture.

Power is a requirement for most sports at their highest level. It is important to fully understand the relationship of power to gymnastics success in collegiate gymnasts (Stockbrugger & Haennel, 2003). Lower limb power can be measured through the use of a vertical jump task and running vertical jump task (Burkett, Phillip & Ziuraitis, 2005; Hamilton, Sandra, Schmitz & Perrin, 2008; Ray & Khanna, 1991; Vanezis & Lees, 2005). The ability to perform a vertical jump is essential in many sports such as basketball, volleyball, diving, and gymnastics. Increasing lower limb power can increase vertical jump height which can improve the outcome during gymnastics performance (Cochrane & Stannard, 2005; Markovic, 2007; Vanezis & Lees, 2005). Upper body power is needed for the sport of gymnastics where athletes use their arms to propel themselves as well as their legs.

Vertical jump height is often used as a measure to determine power (Burkett, Phillip & Ziuraitis, 2005; Vanezis & Lees, 2005). Lower limb power is a necessary component for the sport of gymnastics. Power is directly related to muscle size. Larger leg muscles generally equal higher lower limb power, but larger leg muscles might be less aesthetically pleasing and aesthetics have been found to be necessary at the elite level of gymnastics (Ackland, Elliott, & Richards, 2003; French et al., 2004; Koutedakis & Sharp, 2004; Richards, Ackland, & Elliot, 1999). Coaches want the best athletes possible, but are worried to use different training methods for fear of detrimental changes in body shape. It is interesting to note that there has not been a study done to look at the relationship between anthropometric measurements and gymnastics success on the vault apparatus. Especially since vault is a power event.

Purpose of the Study

The purpose of this study is to determine what relationships exist between lower limb and upper body power and anthropometric measurements versus gymnastics success in collegiate athletes on the vault apparatus. Lower limb power was measured using a force plate and performing a countermovement vertical jump as well as a running approach vertical jump. Upper body power was measured by performing a handstand push-off task on a force plate. The data were collected in the spring of 2009 semester. The results of this study will aid in the body of knowledge for collegiate gymnastics.

Hypotheses

The hypothesis for this study is that gymnasts that have lower fat mass, smaller anthropometric measurements, and higher power will have greater gymnastics success on the vault apparatus. The null hypothesis is that there will be no relationship between power, and anthropometric measurements, and vault success.

Definitions

Lower limb power – the product of force and velocity that can be used to project the body upward in a vertical motion. In this study lower limb power will be measured using two different tasks; one task will be a standing countermovement vertical jump, while the other will include a four step run and a hurdle into a vertical jump. Both will be performed on a force plate.

Upper body power – the product of force and velocity that can be used to project the body from a handstand position to a horizontal landing position which is performed on a force plate.

Mid-thigh circumference - circumference around the entire thigh. It is measured "with the subject standing and one foot on a bench so the knee is flexed at 90°, a measure is taken midway between the inguinal crease and the proximal border of the patella, perpendicular to the long axis" (American College of Sports Medicine, 2006, p 60).

Calf circumference - circumference of the full perimeter of the calf. It is "measured with the subject standing erect (feet apart ~20 cm), a horizontal measure taken at the level of the maximum circumference between the knee and the ankle, perpendicular to the long axis" (American College of Sports Medicine, 2006, p 60).

Body Composition - measurements of percent lean tissue mass, percent fat mass, and kilograms of both lean and fat mass will be recorded using a dual energy x-ray absorptiometry (DXA) scan. Kilograms of lean muscle mass in the lower limbs will also be recorded.

Gymnastics Success on Vault- for this study is defined as the highest score received on a competition vault from the 2009 competitive season, combined with the average vault distance obtained from a practice vault.

Assumptions

The standardized vault is assumed to represent the best possible efforts by each participant. The vertical jump, running vertical jump, and handstand push off task represented the best effort of the participants.

Limitations

The sample of participants was only female students at TWU in Denton, TX, who were involved on the gymnastics team which is a division II institution. Results from this study cannot be generalized to all gymnasts, as collegiate gymnasts have unique characteristics compared to club or elite level gymnasts. All of the athletes that were tested were using the same training program which may have factored into the results. The athletes performed different vaults which could be a factor. All participants were female collegiate level gymnasts who participated in gymnastics meets with the Texas Woman's University gymnastics team. Participants had different background experiences in gymnastics, but had a similar mean number of years of competition. Another limitation is that of the techniques of the vaults which can affect the success.

Delimitations

The participants were all gymnasts from TWU. The results are sport specific. The participants were all of similar age, making the results age-specific.

Significance of the Study

There is a strong correlation between lower limb power and the vertical jump test (Burkett et al., 2005). Therefore, lower limb power can be measured through the use of a vertical jump task (Ray & Khanna, 1991). Upper body power has previously been measured for gymnasts using a handstand push off task (Bradshaw & Le Rossignol, 2004). A relationship exists between the physique of a gymnast and the performance of the gymnast; larger gymnasts have been found to be able to produce more power, but may lose points because of aesthetic appeal (Ackland et al., 2003). There is a gap in the literature regarding the relationship between thigh circumference and vertical jump height. Using the thigh circumference to see if it impacts the results of a vertical jump task will help determine if the size of the thigh impacts the power of the thigh in collegiate gymnasts. The purpose behind using the vertical jump tasks and handstand push off task is that they are easier to perform, less time consuming, and less detrimental to the body and training of the athlete.

CHAPTER II

REVIEW OF LITERATURE

The following topics were reviewed in the literature: anthropometric measurements, why they were picked and how they relate to athletic performance, gymnast's requirements for anthropometric measurements, thigh length and circumference, calf circumference, body composition and how it relates to athletic performance, power and how it relates to performance, vertical jump tasks, handstand push off task, gymnasts requirement for power, gymnastics training, and gymnastics success.

Gymnastics

An estimated 52,000 girls in the United States alone participate in the traditional artistic style gymnastics. At the college level there have been studies leading to evidence that college age gymnasts have body dissatisfaction. Ideal body shape was most strongly related to body mass index (Poudevigne et al., 2002). It is obvious that athletes in aesthetic sports are subject to pressure to be thin. In fact, female gymnasts tend to have a high prevalence of disordered eating (Nordin, Harris & Cumming, 2003). Rosen & Hough (1988) reported 100% of their sample of competitive gymnasts to be actively dieting. Gymnastics, a sport that starts sport specific training at a very early age, is associated with disorder eating (Sundgot-Borgen, 1994). Many coaches of aesthetic sports believe that the environment in which the training is done can be a trigger for eating disorders (Nowicka, Apitzsh, & Sundgot-Borgen, 2003).

There is a large body of literature on the aesthetic appearance as well as the body composition for athletes in sports with subjective scoring such as figure skating and gymnastics (Ackland et al., 2003; French et al., 2004; Koutedakis & Sharp, 2004; Richards et al., 1999; Szczepanowska, Jarska, Chudecka, & Seinko, 2007). If the relationship between anthropometric characteristics and gymnastics success can be determined, it may help with eating patterns and environmental factors at a stage in life that is sometimes seen as a breeding ground for disordered eating (Nordin et al., 2003).

Previous studies have looked at the effect of anthropometric changes through changes in age and maturation status, morphologic features, and body mass on athletic performance. Anthropometric and not neuro-motor systems were responsible for the changes in power throughout the maturation process (Ackland et al., 2003; Korff & Jensen, 2008; Richards et al., 1999; Szczepanowska et al., 2007). Dynamic movements have gravity and motion forces to contend with while trying to produce resultant force, therefore it is necessary to understand the effect of anthropometric characteristics because changes in these measurements will affect the muscular components essential for producing the same amount of resultant force that was previously produced under the former anthropometric characteristics. These changes include relative segmental mass proportions, radii of gyration, and relative center of mass locations (Korff & Jensen). In line with biomechanical principles, athletes with higher strength to mass ratios should have an easier time during rotational skills involving the whole body as well as segmental rotation (Ackland et al., 2003; Richards et al., 1999).

A study done by Viitasalo, Osterback, Alen, Rahkila, and Havas (1987) found a high correlation between the circumference of the thigh and body weight as it relates to power. Subjects with the largest thigh circumference and body masses had the lowest mechanical power (Viitasalo et al.). A combination of anthropometric and muscular characteristics help elite athletes attain the elite level in their sports realm, having the best physical structure for their sport (Rousanoglu, Nikolaidou, & Boudolos, 2006). Collegiate level gymnastics is different than elite and club level gymnastics, as well as having a different age population. It is unknown if anthropometric measurements and muscular components affect gymnastics success as it relates to the vault apparatus for collegiate level gymnasts.

In a study done by Rousanoglu et al. (2006) the groups measured were female track-and-field athletes, volleyball players, and girls with no activity. Anthropometric, jumping, and muscular strength characteristics were looked at in these adolescent athletes in order to identify which measure or measures varied the most within these three groups. Results showed the track-and-field athletes to have significantly smaller thigh circumferences than the volleyball players, but no difference for body-composition measures between the athletic groups. Lean body mass and jumping ability were the most significant differences between the active and the inactive girls. Jumping ability was higher, and muscular strength was greater in jumping athletes (Rousanoglu et al.).

A study performed on rhythmic gymnasts evaluated physiological and anthropometric measurements as indicators of rhythmic gymnastics performance as measured by the national ranking scores of the athletes. Measured components included anthropometric, flexibility, explosive strength, aerobic capacity, body dimensions, and anaerobic metabolism. It was found that anthropometric and aerobic capacity had significant relationships with performance. Thigh circumference accounted for 13.1% while body mass accounted for 8.5% of the variation in performance for these elite rhythmic gymnasts (Douda, Toubekis, Avloniti & Tokmakidis, 2008).

Anthropometric measurements and how or if they relate to athletic success has been studied in elite Turkish kayakers. The study was performed by Firat Akca and Surhat Muniroglu (2008) titled, "Anthropometric-somatotype and strength profiles and on-water performance in Turkish elite kayakers." The aim of the study was to better understand what physical and strength measurements best related to athletic success, as well as in which ways. Eleven male members of the Turkish national flatwater kayak team paddlers from the 2005 season were tested for the study with a mean (SD) age of 21.5 (2.3) years. Participation was voluntary, consent was given, and the purpose of the study was known for all participants. Measurements were recorded over 5 days of testing. The kayak distances performed included the 200 m, 500 m, and 1000 m events.

Measurement procedure followed those recommended by MacDougall, Wenger, and Green (1991) using the same person and equipment. Anthropometric-somatotype measurements and strength test were recorded on the first day. Standing height was measured to the nearest 0.1 cm and body mass to the nearest 0.01 kg. Mean body composition was determined using right side skinfold measurements from the biceps, triceps, subscapular and surpailiac. Sitting height and arm span were measured. Lean mass and body fat were found using the equation of Durnin and Womersley (1974). Girth measurements were made on the right side of the body for the calf, thigh, and upper arm in a relaxed state as well as in a maximal contraction state. Chest circumference was also measured. Breadth measurements were taken of the femur, humerus, biacromial, and bi-iliac. Bench press and bench pull one repetition maximum (RM) tests and one minute maximum repetition tests at 40% of one RM were conducted. Day 2 and 3 include the kayak races, which were performed under race conditions. Day 2 included the 200 m flatwater kayak tests as well as the 500 m flatwater kayak tests while Day 3 was used for 8-10 km technical water training and the 1000 m flatwater kayak tests. Day 4 was used for 2 x 5 km at 70% K1 water training and 6 km technical and 6 x 50 m start K1 water training. The Cooper running test was performed at a standard athletics' field on Day 5.

Pearson moment correlation coefficients were used to quantify relationships between anthropometric characteristics and flatwater kayak performance. Significance value was set at $< .05$. Performance times for the 500 m and 1000 m and body weight correlations showed a significantly negative relationship ($r = .78$, $r = .71$, $p < .05$; respectively). Negative correlations were also found between the 200 m, 500 m, and 1000 m times and body fat percentage ($r = .69$, $r = .82$, $r = .61$, $p < .05$; respectively) and significantly correlated with endomorphy which was determined using the Heath-Carter procedure ($r = -.70$, $r = -.82$, $r = -.60$, $p < .05$; respectively). Significant relationships

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Gymnasts' Requirements for Anthropometric Measurement

Gymnasts, who tend to be lighter, stronger per body mass, leaner, and more flexible than all other athletes at the Olympic Games (Medved, 1966; Montpetit, 1976), are given scores based on qualitative rather than quantitative data such as tennis players (French et al., 2004). There is a relationship between strength to mass and skills with whole-body rotations (Ackland et al., 2003; Richards et al., 1999). There is a relationship between aesthetic appearance and higher scores (Ackland et al; French et al.; Koutedakis & Sharp, 2004).

Thigh Length

In a study done on 60 female Junior National Kho-Kho players leg explosive strength, as measured by a vertical jump, was measured as it relates to anthropometric measures. There was no relationship in length measurements with explosive strength (Ray & Khanna, 1991). It is however biomechanically advantageous to have shorter limbs when trying to perform rotational movements about a joint, therefore it is still important to look at leg lengths for the present study as it is gymnasts we are looking at who do perform many rotations. A study done on 14-16-yr-old gymnasts found a positive relationship between thigh length to body height measurements and vault success (Bradshaw & Le Rossignol, 2004). This states that long thighs relative to height are good. It is important to look at leg length in collegiate level gymnasts to determine if there is a similar finding.

Thigh Circumference

Circumference measurements are studied in a variety of different sports. For example, one study looked at body builders as compared with other power athletes and found the body builders to have significantly larger arm and thigh circumferences. In using the best measure, anthropometric equations, especially those involving more skinfold sites, were more accurate for estimating body composition than bioelectrical impedance (BIA) in extreme power athletes (Huygens et al., 2002). A study by

Koutedakis and Sharp (2004) was performed on professional ballerinas to determine if a training program involving thigh and hamstring muscle strength components affected torque. As with gymnastics, ballet involves aesthetic appearance which leads to a fear of using a strength training program due to the fear of the impact it may have on aesthetic appearance. Therefore, it is important to the body of literature for dance to measure the effects of a strength training program on torque as well as anthropometric measurements. Anthropometric measurements included body mass, sum of skinfolds, and thigh circumference (Koutedakis & Sharp). Thigh circumferences were measured in this study using a technique similar to that found in the ACSM Guidelines used for the present study, horizontally around the thigh halfway between the midpoint of the inguinal crease and the proximal border of the patella. The fear was that increased muscular strength would negatively affect the aesthetic appearance of the dancer, which in fact it did not (American College of Sports Medicine, 2006; Koutedakis & Sharp). Another study looked at the thigh circumference of 38 professional club soccer player's non-dominant leg compared with their dominant kicking leg. It was found that there was a statistically significant difference of thigh circumference between dominant and non-dominant legs, the non-dominant leg having a larger thigh circumference (Bennet, O'Donohoe, Young, & Bennet, 2005).

Calf Circumference

In a study done on 60 female Junior National Kho-Kho players leg explosive strength, as measured by a vertical jump, was measured as it relates to anthropometric measures. It was found that there was a significant relationship between vertical jump and calf circumference ($p < .05$; Ray & Khanna, 1991). This warrants the inclusion of calf circumference measurements for the present study.

Body Composition and How it Relates to Athletic Performance

Body composition is a major component that correlates with vertical jumping power (Pandy, 1990) therefore it will be important to include body weight as an anthropometric measurement. In a study done by Nichols et al. (1994) DXA measurements were used on gymnasts to determine values of percent body fat and total leg, and arm lean tissue. A study was performed on high school athletes to look at the relationship between the anthropometric measure of body fat and functional test of vertical jump height and its relationship to athletics performance. It was found that vertical jump height decreased as percentage of body fat increased above 10% in men and 19% in women making it an inverse relationship (McLeod, Hunter & Etchison, 1983). A study done on NCAA Division I college football players found an inverse relationship between body fat and vertical jump performance (Miller, Kinley, Congleton & Clark, 2002).

A study looked at athletic performance and anthropometric and body mass index measures for ultratriathlon athletes that competed in the First Triple Iron Triathlon Moosburn in Karnten, Austria in 2006. There were 16 participants involved in the statistical analysis. Measures taken included body mass, body height, circumference of upper arm, thigh and calf, skin fold thickness, BMI, skeletal muscle mass, and fat mass in kilograms and the relationship to race performance. Results showed that race time was not significantly influenced by anthropometric measures, BMI, body fat, and skeletal mass in athletes in an ultratriathlon (Knechtle & Duff, 2007). There have been different results for body composition and its relationship with athletic performance; therefore it is necessary to include it in the present study.

Power and How it Relates to Athletic Performance

Many sports rely on short bursts of intense power production for higher performance outcomes. These very short, high intensity bursts of power lasting from 1-6 s use adenosine triphosphate (ATP) stores in the muscles and creatine phosphate (Bencke et al., 2002; McArdle, Katch & Katch, 2007). Performance of these short bursts is dependent on the area of the muscle fibers, type of muscle fibers, and ability to excite these fibers through glycolytic pathways at a rapid rate (Bencke et al.).

General leg muscle power and vertical jump are essential elements in the success of athletic performances for many different sports as well as for the ordinary daily tasks (Markovic, 2007;). Power, one's capability to exert force, is imperative for achievement in sports requiring high force generation in a short amount of time (Kawamaroi et al., 2005; Liebermann & Katz, 2003). Power is the rate of doing work, expressed by the product of force and velocity (Kawamaroi et al.).

Data from a meta-analytical regression pointed toward the idea that there was a positive transfer affect from vertical jump ability to other athletic performance, not regarding jumping (Markovic, 2007). In a study performed on five elite gymnasts aged 13-15 years the Yurchenko entry vault performance was analyzed. The measures included the kinematic post-flight measures of time, peak height, and landing distance from the vault as well as judges score from two international judges (Bradshaw, 2004).

Two significant results were noted. The first is that a fast take-off from the board was the result of early visual utilization in the approach kinematics ($p = .02$) such as visual control distance, hurdle to the board velocity, and take off velocity. Second, high take-off velocity was directly related to judges score ($p = .03$). Both results led to an increased performance score both from the judge and from a higher start value. Therefore, it is important to include a measure involving velocity when measuring power.

Vertical Jump Tasks

Vertical jump height is a functional measure of lower limb muscular power (Cochrane & Stannard, 2005; Stockbrugger & Haennel, 2003). Arm countermovement vertical jump (ACMVJ) is a common test used by coaches in order to gain an understanding of where athletes fall in training programs as well as in rehab programs. Consequently the ACMVJ test is an established measure for testing lower limb power (Cochrane & Stannard). Arm countermovement vertical jump allows the participant to perform a motion of jumping he or she is used to, therefore making it a valid measure of power with less practice time (Cochrane & Stannard). Small improvements in ACMVJ tasks tend to create a huge difference in athletic advantage for elite athletes and their athletic performance (Cochrane & Stannard).

In a study done on 50 male soccer players, jump ability and jump technique on a ACMVJ were observed to decipher whether a higher jump was the result of more power, or better technique. Results indicated that it was in fact power, and not technique that was the main indicator of jump height. Therefore, ACMVJ is a solid measure of lower limb vertical power (Vanezis & Lees, 2005); in fact, it is highly reliable and a recommended measure of lower limb power performance (Burkett et al., 2005; Liebermann & Katz, 2003; Vanezis & Lees).

An ACMVJ begins with the body erect in a standing position, followed by the lowering of the body at the participants determined speed until there is an approximate 45° angle of flexion at the knee and hip, also known as a squat position. Participants ultimately determine the knee-flexion, 45° is an approximation. At this point the upward motion of the jump accelerates and the push-off phase is completed. The jump concludes with both feet landing on the ground at the same time (Bencke et al., 2002; Kawamaroi et al., 2005). Because gymnasts often times have velocity upon the entry of power output it is important to factor velocity into a power movement. Therefore, this study will include a running entry vertical jump. Participants will be allowed to perform four steps and a hurdle before doing a vertical jump. A forceplate will be used to measure the power of this task.

Handstand Push-Off Task

Upper body power is needed for the sport of gymnastics where athletes use their arms to propel themselves as well as their legs. For the vault apparatus this is especially important because the impact on the vault and the beginning of the flight phase is initiated with the hand contact on the vault. Performing skills from a handstand position is a unique characteristic of gymnastics that is important to include.

Gymnasts Require Power

Each sport has a unique set of characteristics that lead to the best possible performance outcome (Baker & Nance, 1999a; Baker & Nance, 1999b; Ferris, Signorile & Caruso, 1996; Hakkinen, 1989; Mayhew et al., 1993; Mayhew, Bemben, Rohrs & Bemben, 1994; McBride, Triplett-McBride, Davie & Newton, 1999; Neptune, Wright & Van Den Gogert, 1999; Roetert, Brown, Piorkowski & Woods, 1996; Roetert, McCormick, Brown & Ellenbecker, 1996; Schmidt, 1999; Stockbrugger & Haennel, 2003). One such characteristic is the ability to generate and transfer lower limb power which is thought to be used for gymnastics success (Stockbrugger & Haennel).

Gymnastics is a power sport involving changes of direction, acceleration, and jumping (Tricoli, Lamas, Carnevale & Ugrinowitsch, 2005). The vault in particular involves changes of direction, acceleration, and jumping, and therefore power is a necessary component (Rousanoglou, et al., 2006). The vault is short in duration, therefore not utilizing the aerobic pathways (Bencke et al., 2002; McArdle, Katch & Katch, 2007). There is a positive correlation between maximum strength and power; as maximal strength improves so does relative strength and power (Adams, O'Shea, O'Shea & Climstein, 1992; Bauer, Thayer & Baras, 1990; Cronin, McNair & Marshall, 2000; Hakkinen, Komi & Allen, 1985; Newton et al., 1997; Schmidtbleicher, 1992; Young & Bilby, 1993). There is a high power production in jumping movements with just the body weight such as vertical jumps; therefore a vertical jump is a good test of power production (Canavan, Garret &Armstrong, 1996; Newton et al.). Vertical jump has been used before to measure vault success (Bradshaw & Le Rossignol, 2004). A study done by Sharma (1992) found increased vault performance with increased vertical jump height.

In a study done between athletes in gymnastics, team handball, tennis and swimming, gymnasts have a significantly higher amount of power as shown with the CMVJ and squat jump leading to the assumptions that CMVJ is an important measure for gymnasts since they excel at them when compared with other sports. However, no actual analysis has been done on this as it relates to gymnastics success (Bencke et al., 2002).

In a study done on 60 female Junior National Kho-Kho players leg explosive strength, as measured by a vertical jump, was measured as it relates to anthropometric measures. The conclusion of the study was that leg explosive strength is thought to have a significant relationship with knee width, hip width, thigh circumference and calf circumference (Ray & Khanna, 1991).

Gymnastics Training Programs

Very few studies have reported training protocols of gymnasts. In a previous study done on the collegiate gymnastics team at Texas Woman's University the training schedule during the year was recorded (Nichols et al. 1994). During the school year there are approximately 144 days of practice with an average of 4 hr/day, 5 days/week including weight training, running, stretching, and formal gymnastic training. During the time of the Nichols et al. study the fall semester, or preseason, weight training took place 3 days/week and lasted about 1 hr/session. During the spring semester, season, weight training reduced to 2 days/week and the number of exercises went from 14 to 10. Repetitions increased to 25-30 as a goal of targeting muscular endurance. Running time was greater in the fall semester than the spring semester (Nichols et al.). According to the head coach Frank Kudlac, the weight training and running program has significantly changed since the study done in 1994. Currently weight training is performed to gain muscular strength, therefore repetitions are substantially lower (approximately 2-6), and the number of exercises decreased because the exercises currently performed train more of the body rather than just one muscle group. Running for the 2007-2008, and 2008-2009 teams never exceeded 3.0 miles. Sprinting became a top priority as well as various jumps.

Gymnastics Vault Success

Because there are different characteristic requirements for each gymnastics event, it is important to look at each event individual. In order to successfully perform a high-scoring vault, large amplitude in the post-flight portion of the vault is essential (Takei, Dunn & Blucker, 2007). A previous study was down by Bradshaw (2004) looking at how the vault run affects vault performance. The vault was compared with jumping events in track in field that require a certain take-off foot position. These events are known as target-direct running events, just as the vault apparatus is for gymnastics. The study concluded that being able to visually regulate a gait for the vault is important to control approach kinematics and therefore should be practiced along with the vault itself.

In a study done by Bradshaw and Le Rossignol (2004) the prerequisites for vault and tumbling success were looked at as they pertain to talent-selection of gymnasts for particular events. Talent selection is used in countries such as Russia, Canada, Australia, and the gold medal record holder from the 2008 Olympic Games, China. For the study, 20 national-class 8-14 yr old female gymnasts were used. Testing was completed within six regular practice sessions. To measure vault run infra-red timing lights were placed every 6 m along the vault runway and recorded the last 18 m of the vault run-up sprints. Actual sprinting trials were performed facing the opposite direction of the vault; therefore they were not the actual sprint used to perform the vault. The take off from the board was measured using a Sony 50 Hz digital camera during vault performances. A 3.0 m high rod with marked 0.50 m intervals was filmed in two positions, 2.5 m apart as a two-dimensional scale reference. Take-off angle and horizontal and vertical velocities were looked at for the vaults using a stationary camera. Vertical handstand push-offs were performed on a portable force plate and broad jump distance was measured horizontally from starting point of their toes to ending point of their heels, which were marked with chalk, with hands on the hips. Squat jumps were performed holding the 90° knee bend for 3 s before jumping. A straight leg jumping series of 5 was performed with arms held loosely straight at the side and a bend leg jumping series of 5 jumps was performed with hands on the hips. A bent leg series of jumps was also performed for a 30 s interval. Countermovement jumps were performed with hands on the hips. Five trials were performed of the vaults, sprints, squat jumps, countermovement jumps, broad jumps, and vertical handstand push offs.

Height, weight, and bone lengths were also measured. The bone lengths that were measured were trochanterion to tibiale-lateral length, tibiale-laterale to floor length, tibiale-mediale to sphyrion tibiale length, acromial-radial to floor length, biacromial breadth, and biiliocristal breadth. The V-shape in the torso was calculated by dividing biacromial breadth by biilliocristal breadth.

Vertical displacement, peak take-off force, ground contact time, and power were determined by using the curves from squat jump, countermovement jump, series of five bent leg jumps, series of five straight leg jumps, and handstand push-off data. The first 5 and the last 5 jumps from the 30 s bent leg jump series were analyzed by subtracting body weight from the force time curve to determine vertical displacement, peak take-off force, and power. Equations were as follows: $v = I/m$, $h = v^2/2g$, and $P = F \cdot v$. The Women's Artistic Gymnastics Code of Points 2001 was used to score the vaults and tumbling passes. Statistical analysis included a one-way analysis of variance and a linear regression analysis in order to find an equation that led to the highest vault performance.

Results indicated that the best regression model for vault ability included velocity at take off from the board, squat jump force and power, and average power during the last five jumps in the 30 s bent leg series. Anthropometric predictors included body mass, and ratio of leg length to height. The indicators for tumbling ability included age, vault running velocity, and reduced ground contact time in a handstand push-off, countermovement jump power, and last five jumps during the 30 s bent leg jump test. The best anthropometric predictor for tumbling ability was the ratio of arm length to height (Bradshaw & LeRossignol, 2004).

How Vaults are Scored: Code of Points

The highest score from the 2009 season for each individual participant will be used as a measure of vault success. Vaults are judged on many different variables.

Distance of a Vault

Vault distance is an important variable in the performance of a vault. Full maximizations of one's power results in height, rotation and distance. The rule of thumb is that the vault height should be approximately the body length of the gymnast. A deduction of up to 0.30 can be taken for insufficient vault length (USA Gymnastics, 2005). A practice vault measured during season is a valid measure of a true competition vault because at this point in the season gymnasts are consistent with the skills they are performing and are at their peak gymnastics ability. There is still pressure for the gymnasts to do well because they know they are being measured, but it is also a time that a researcher can be involved and measure the distance.

CHAPTER III

METHODS

This study was approved by Texas Woman's University Institutional Review Board (IRB) to be compliant with institution and federal guidelines for research using human participants. All research members completed training in Human Participants Protections.

Participants

Seven collegiate female gymnasts were the participants. Ages ranged from 18-21 years of age. The participant's competitive background experience was similar as measured by the age the gymnasts started gymnastics and the years of competitive gymnastics experience. Participation in this study was optional and completely voluntary. Each participant was assigned an identification number that was used for all data records.

Recruitment was done by creating a handout with an explanation of the study on it, and awaiting replies via email or phone call stating participant's willingness to participate. Participants in this study had a similar baseline level of strength from repeatedly performing skills with their own body mass (French et al., 2004). Gymnasts that participated were not limited to the events that they trained. The ranges of events trained were from one event to all four with variations in the actual event that is trained for each athlete.

Instruments

An electronic weighing system (Tanita Corporation in Japan model BWB-800) in the Institute for Woman's Health (IWH) and at Texas Woman's University was used as well as a DXA scan machine (GE Medical Systems, Lunar model DPX-IQ). A force plate (Advanced Mechanical Technologies Incorporated, Massachusetts) located in the TWU biomechanics lab was used to determine the peak force and velocity during a vertical jump, running vertical jump, and handstand push-off task in order to find the peak power. A standard cloth tape measure was used to measure vault distance. An Executive Diameter Steel tape by Cooper Tools (Lufkin Executive Thinline 2 m W606PM, North Carolina) was used to measure thigh and calf circumference as well as leg length.

Procedures

Anthropometric measurements were taken on Day 1 of data collection as well as power measurements. Anthropometric measurements were taken before the power measurements. On Day 2 of data collection vault distance was measured.

Circumference measures of thigh and calf were made and recorded in centimeters. The order of measurements was first the thigh, then the calf, and finally the leg length. Circumference measurements were taken according to the seventh edition ACSM Guidelines. Leg length was measured from the inguinal crease to the floor. For all measurements a minimum of two trials were recorded. If there was a difference greater than a 0.5 cm, another measurement was taken. The right side of the body was measured for each measurement on all participants. Participants did not participate in any sort of training yet that day. Participation occurred on the same date so there was no advantage or disadvantage in where the athletes fell in their training program.

Lower limb power was measured by the vertical jump and running vertical jump. Both procedures were performed on a force plate. Participants practiced the task at least one time in order to become familiar with the movement. Participants wore the same footwear (team shoes provided by TWU Athletics), black spandex shorts, and a black sports bra. To perform the vertical jump participants began and ended on the force plate. Participants had three attempts for each task. There was a rest period of approximately 2 min between jump attempts to enable a recovery of the ATP-PC energy system. Two participants came into the lab and alternated turns for each task since there was a rest period between each attempt. The highest measure of the three attempts was the data that was recorded.

Lower limb power was measured with a countermovement vertical jump. Participants began with their bodies erect in a standing position, followed by the lowering of the body at the participants determined speed until there is an approximate 45° angle of flexion at the knee and hip, also known as a squat position. The 45° measurement is an approximation however, as participants ultimately determined the knee-flexion according to personal preference. At this point the upward motion of the jump was accelerated and the push-off phase was completed. The jump concluded with both feet landing on the ground at the same time (Bencke et al., 2002; Kawamori et al., 2005).

Lower limb power was also measured using a running vertical jump task. A four step approach was used followed by a hurdle onto a forceplate and a vertical jump landing on an 8" landing mat. After the participants practiced their steps as well as the jump task, three trials were performed and recorded. The highest amount of force from the three trials was recorded and used as the data.

Upper body power was measured using a handstand push off task. Participants began in a lunge position (one leg in front of the other in an athletic stance with the front leg bent and the back leg straight) then circled the arms backward and placed hands on the force plate. Once both hands were placed on the force plate the participant tried to generate the greatest amount of force possible in order maximize height off the force plate. The landing position was in a supine position on an 8" landing mat. Three trials were recorded.

Gymnastics success on the vault apparatus for the purpose of this study was the farthest distance reached on a standardized vault during practice in the 2009 season and the highest vault score received during the 2009 season. The distance of the vault was measured during a practice at TWU. All participants were in the same portion of the competitive season when data was collected, except one. One participant was not present during the data collection of the vault distance due to illness; therefore her vault was recorded at a later date. However, all data was collected during the post season competition portion of the season which includes conference and national championships. The warm up for practice before going over to the vault was as follows:

1. 5-min run around the spring floor with intermittent skipping and jumping, and a sprint on the last lap.
2. Walk on high toe with knees straight across floor.

3. Walk on high toe with knees bent across floor.
4. Walk on heels across floor.
5. Partner massage of shoulders, feet, and legs.
6. Static stretching on panel mats.

Once this warm up was completed athletes had a break for approximately 5 min before the vault rotation began. The vault warm up was as follows:

1. Five flips off the vault for a landing drill.
2. Two runs on the vault runway.
3. Three timers onto 2, 8" mats.

A timer was defined as the entry portion of the vault in which a gymnast runs, contacts the board, and in some manner contacts the horse. Immediately after hand contact the gymnast propels her body through the air and either lands on her back (for a back somersault vault), or lands on her feet and runs forward (for a vault with a front somersault), but the actual somersault or twist is not completed. All participants completed a normal vault warm-up which consisted of the above mentioned.

Once all participants properly warmed up, vaults were completed. Participants put chalk on the bottoms of their feet to aid in locating the exact spot of landing. Based on a thorough literature review, this method has not yet been used to measure vault distance, but has been used for measuring broad jump distances in gymnasts (Bradshaw, 2004). Measurements were taken from the base of the vault to the closest chalk mark to the vault left by the participant during the landing. The heel was the portion of the body used as the measuring point for forward landing vaults and the toes were used as the measuring point for backward landing vaults. Distances were recorded in centimeters using a standard cloth tape measure. Each participant performed three vaults with distance measurements recorded. The farthest distance was the data used.

The vault apparatus used was constant for each participant including the American Athletic Incorporated (AAI) runway made in the USA. AAI, made in the USA, was the brand of the tape measure, Tac/10 springboard, safety zone, TAC-10 round off pad, Tac/10 LZT vault, vault pads, and FIG model landing mats. Participants used the vault with a height of 125 cm from the ground. The landing surface was a thick 20.23 cm mat made by Speith Anderson in Canada on top of a Resilite brand resi pit that was made in Sunbury, PA. A resi pit is a large block of foam that is enclosed with a vinyl cover and mesh top. The Resilite mat had the harder side facing upwards. Measurement from the base and the floor intersection and the top of the mat will be 17.8 cm when no one is standing on the mat. Because the mat is placed on top of a resi, the surface will lower when an athlete lands on it, however this did not affect vault distance obtained.

The same person marked, measured, and recorded the distances for all participants. This study was performed after preseason had commenced, and the gymnasts were considered to be at their best gymnastics level. Measurements were taken after regular season was over, and postseason competition was being trained for. The highest score for the vault apparatus in the 2009 season was added to the farthest vault distance during the practice in order to find the total gymnastics success score. This measurement has not been used before for measuring vault distance, however it has been utilized by others when measuring horizontal jump distance (Bradshaw, 2004). It was a valid measure, because it measured the actual distance obtained each time, which is exactly what the goal of measuring was.

To my knowledge, no other study has measured the distance of a vault. There have been video analyses done on vault techniques, vault run, and take off, but nothing about measuring the actual distance of the vault. However, vault distance is important because of the implications it has on the score the gymnast is awarded by the judge. In the NCAA Code of Points it states that up to a 0.30 deduction may be taken for insufficient distance (USA Gymnastics, 2005).

Body composition and body mass scores as well as participant heights were extracted from the IWH at TWU. Height was measured using a stadiometer at TWU made by Perspective Enterprises in Portage, Michigan rounded to the nearest 0.1 cm. Body composition measurements were found using a DXA scan, and body mass using an electronic scale rounded to the nearest 0.01 kg. Permission from participants was given in order to receive this confidential information. Researcher emailed a data sheet with all of the other information from the participants and the IWH coordinator filled in the blanks from the DXA scan with the grams of lean and grams of fat mass as well height in centimeters. Next, the coordinator changed the participant numbers to letters on the data sheet in order to make them unidentifiable to the researcher, and rearranged the data so researcher could not identify any participants.

Calculations

In order to come up with one value for power, a constant formula was used. To begin with, all video had to be digitized which was done using Kwon3D. Videos were cut down to a smaller portion, digitized, and the peak force and peak velocity values were found. These two values were then multiplied in order to find the peak force for each participant because the definition of power is velocity times force. Once this was done for each participant and each trial, the highest trial was stored for each task. The highest value for each task was then added together to find the power value.

There was a minimum of two calf and thigh circumference and leg length measurements taken for each participant. If the two values were within a half centimeter of each other, no other measurements were taken. If the values were not within range, other measurements were taken until there were two values recorded within range. Once this was done, the average of the two values was used. From here, both the calf and the thigh circumference measurements were divided by the leg length value independently. These two values that were calculated were then added together to find the circumference value. The other two anthropometric values were found using the DXA scan and provided to the researcher by the ESN clinic at TWU from previously recorded data.

Gymnastics success values are a combination of two things: distance on a standardized vault and a score from a competition in 2009. The final distance value that was used was the farthest distance reached. The score that was used was the highest score the participant had received on a vault in the 2009 competition season as of March

30, 2009. These two values were then added together to find the gymnastics success score.

Statistical Analysis

A multiple regression analysis was performed using the power components, anthropometric measurements, and gymnastics success scores using SPSS 15.0 for Windows to determine if there is a significant relationship. There were four linear regressions done. One regression used gymnastics success as the dependent variable and circumference, DXA lean, DXA fat, and power as the independent variables. Another regression used vault score as the dependent variable and DXA fat, DXA lean, circumference, and power as the independent variables. Another regression used these same independent variables, but used vault distance as the dependent variable. The other regression was performed using vault distance as the dependent variable and for the independent variables used percent fat, upper body power, lower body power, and circumference.

CHAPTER IV

RESULTS

Description of Participants

The average age of participants was 19.7 years, and the average amount of competitive experience was 12.4 years. The average height was 159 cm, and the average weight was 59.94 kg. The average amount of lean mass found using the DXA scan was 43.73 kg, and the average amount of fat was 12.12 kg. All recorded data can be found in Appendix A. Descriptive data is presented in Table 1. Table 2 show shows the individual results for the dependent and independent variables. Table 3 shows the coefficients with the dependent variable being gymnastics success and the independent variables being combined power, fat mass, lean mass, and circumference measures. A scatterplot was performed using the circumference data and the lower body power data. This is labeled as Figure 1. Figure 2 shows a scatter plot of fat mass versus vault distance and Figure 3 shows a scatter plot of fat mass versus highest vault distance reached during a standardized vault.

Table 1

Descriptive Statistics of Participants Experience (N = 7)

	Mean	SD	Min	Max
Age (years)	19.7	1.60	18.0	22.0
Mean Height (cm)	159.0	3.19	154.9	164.50
Mean Weight (kg)	59.94	4.74	53.64	67.56
Competitive Experience (years)	12.4	1.90	10.0	16.0

Table 2

Dependent and Independent Variables

Participant	Power	Calf Circumference (cm)	Thigh Circumference (cm)	Lean (g)	Fat (g)	Gym. Success	%Fat
A	30009.7	34.5	45.25	40211	9538	190.8	19.2
B	33424	38	53.75	45713	15007	203.575	24.7
C	31507.4	34	44.25	43917	10217	216.85	18.9
D	30299.7	36.25	49	43962	10792	184.65	19.7
E	31860.8	35.5	48	39526	15258	207.85	27.9
F	28386.2	35.5	49.75	42369	12542	195.625	22.8
G	30002.5	38	49.75	50729	11463	203.775	18.4

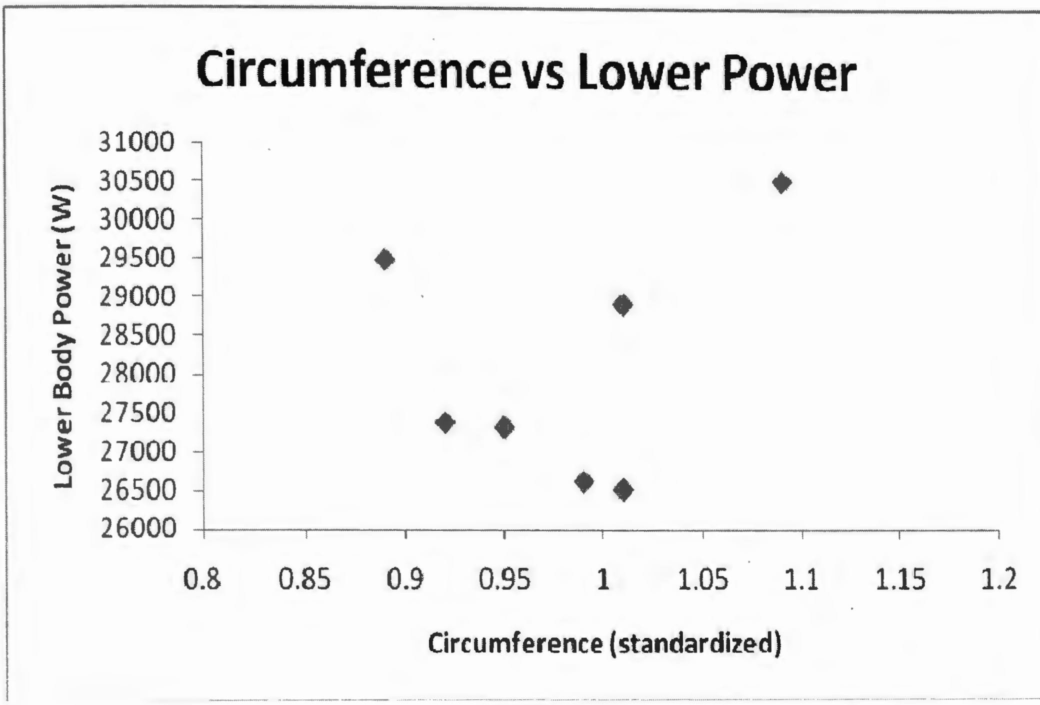

Figure 1. Scatter plot of circumference versus lower body power.

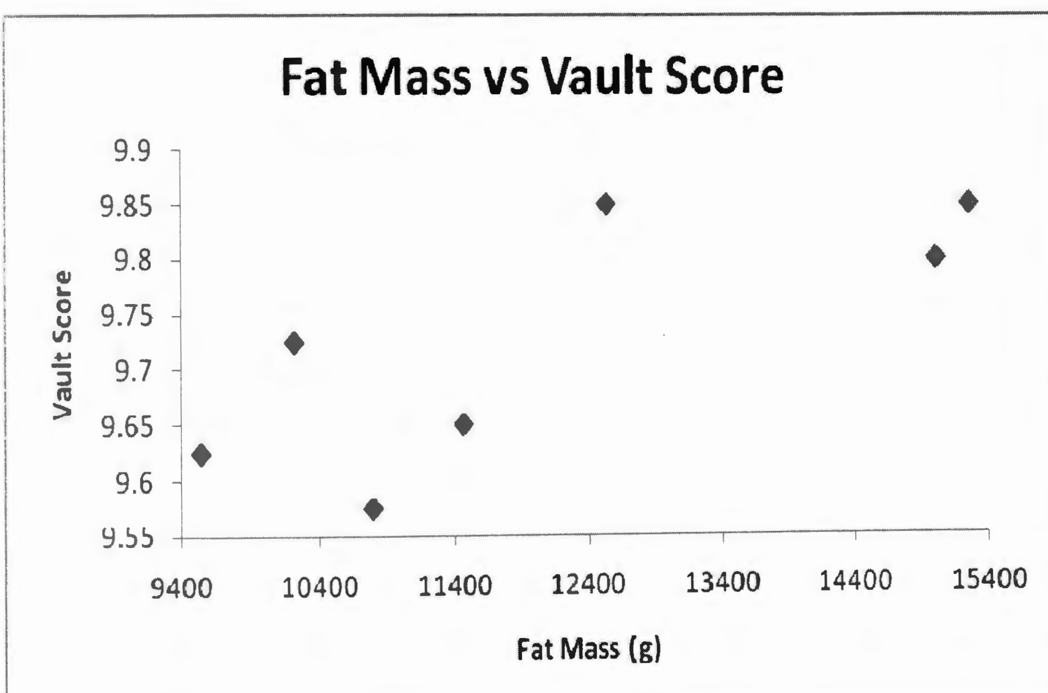

Figure 2. Scatter plot of fat mass versus vault score.

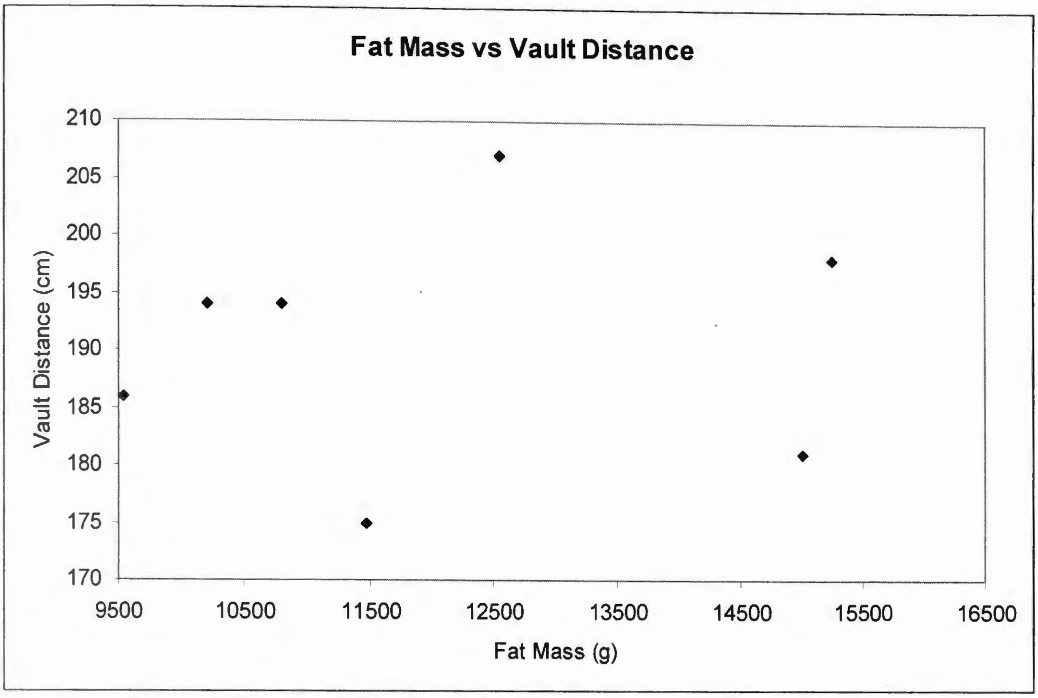

Figure 3. Scatter plot of fat mass versus highest vault distance .

Statistical Analysis

When using gymnastics success as the dependent variable and power, lean mass, fat mass, and circumference as the independent variables, the R value was .889, the R^2 was .789, the F was 1.875 and the p value was .377. When using vault score from the 2009 regular season as the dependent variable and power, lean mass, fat mass, and circumference as the independent variables, the R value was .849, the R square was .721, the F was 1.293 and the p value was .480. With vault distance as the dependent variable and lean mass, fat mass, circumference, and power as the independent variables, the R value was .844, the R square was .712, the F was 1.238 and the p value was .493. When vault distance was the dependent variable and the independent variables were percent fat, upper body power, lower body power, and circumference, the R value was .983, the R square was .692, the F was 1.125 and the p value was .521. In table 3a, 3b, 3c and 3d, a more extensive list of the results is found including the B, standard error (SE), beta, t, and p values.

Table 3

Coefficients Using Gymnastics Success as Dependent Variable

	B	SE	Beta	t	p
Constant	241.432	105.541		2.288	.149
Circumference	-190.069	85.022	-1.163	-2.236	.155
DXA lean (g)	1.48×10^{-5}	.005	.015	.989	
DXA fat (g)	.005	.003	.957	1.717	.228
Power	.003	.003	.432	1.121	.379

Table 4

Coefficients Using Vault Score as Dependent Variable

	B	SE	Beta	t	p
Constant	9.963	.999		9.969	.010
DXA Fat (g)	5.60×10^{-5}	.000	1.135	1.747	.223
DXA Lean (g)	-3.28×10^{-7}	.000	-.011	-.016	.989
Circumference	- .893	1.219	-.532	-.733	.540
Power	-3.93×10^{-7}	.000	-.358	-.4522	.695

Table 5.

Coefficients Using Vault Distance as Dependent Variable

	B	SE	Beta	t	p
Constant	350.384	115.186		3.042	.093
Circumference	-286.578	140.428	-1.504	-2.041	.178
DXA lean (g)	.002	.002	.538	.750	.531
DXA fat (g)	.005	.004	.822	1.246	.339
Power	-9.22×10^{-5}	.000	-.739	-.920	.455

Table 6.

Coefficients Using Vault Distance as Dependent Variable

	B	SE	Beta	t	p
Constant	365.835	122.271		2.992	.096
Circumference	-148.592	117.030	-.784	-1.270	.332
Percent Fat	1.352	2.193	.383	.616	.601
Upper Body Power	-.009	.009	-.420	-.991	.426
Lower Body Power	.001	.004	-.120	-.275	.809

CHAPTER V

DISCUSSION

The purpose of the study was to determine if there was a significant relationship between gymnastics success (the dependent variable) and circumference measures, power, lean mass, and fat mass which were independent variables. There was not a significant relationship between the dependent and independent variables.

Having a high R value but still not having significant findings could be a result of the small sample size. The characteristics with the highest beta weights were circumference (-1.163) and fat mass (.957); therefore these variables had the strongest associations with gymnastics success in the realm of this study.

In a study done by Bradshaw and Le Rossignol (2004), the prerequisites for vault success were velocity at take-off from the board, squat jump power, and average power during the last five jumps in a continuous bent-leg jump series. This does not line up with the results of the current study which did not find an association between power and gymnastics success. However, the current study looked at gymnasts ages 18-22 while the previous study looked at gymnasts ranging from 8-14 years of age. Age can have an impact on the level of gymnastics being performed, and perhaps explains the difference between studies.

In this study there were three different vault entries that were measured. This can make it difficult to see a true gymnastics success score, because different vault entries have different techniques and therefore different distances that can be reached. It is important that another study be done with more participants so that the three different vault entries can be looked at as separate entities.

Circumference Measurements

Although there were no significant predictors of gymnastics success, circumference was more strongly related to gymnastics success than other measures. The circumference measurements were standardized to the leg length of each participant. The association with the circumference measurements was an inverse relationship; therefore the smaller the circumference measurements the greater the gymnastics success score. This is in line with a study done on elite level athletes that found anthropometric measurements do in fact impact the success for their individual sports (Rousanoglu et al., 2006). In this same study it was found that volleyball players have a greater thigh circumference than track athletes; therefore the study is in line with the results of the present study (Rousanogl et al.). It has also been previously documented that smaller gymnasts can out perform larger gymnasts (Ackland et al., 2003) which is congruent with the present study as far as circumference measures. Previous studies found a relationship between aesthetic appearance and higher scores (Ackland et al; French et al., 2004 ; Kutedakis & Sharp, 2004; Richards et al., 1999; Szszepanowska, Jarska, Chudecka & Seinko, 2007) which is similar to the present study in that gymnastics success scores, which include vault scores, were associated with circumference measurements.

As was found in the study by Koutedakis & Sharp in 2004, ballerinas can have increased muscular strength without negatively affecting aesthetic appearance such as body mass, sum of skinfolds, and thigh circumference and therefore success in ballet. This is in agreement with the present study which showed an inverse association between circumference measurements and gymnastics success meaning gymnasts can be powerful and successful on the vault apparatus, but still maintain small circumference measurements. However, the present study and previously discussed studies do not align with results from a study done on ultratriathlon athletes which found that circumference measurements had no relationship to race time (Knechtle & Duff, 2007).

Body Composition

Results of the present study indicate that fat mass may be associated with gymnastics success. In a previous study on vertical jump height and body fat, it was found that body fat did in fact significantly affect the athletes ability to perform a vertical jump, with vertical jump implying athletic performance (McLeod, Hunter & Etchison, 1983). This is in line with the present study in which body fat was directly associated with athletic performance; however the present study did not have significant results due to the low number of participants.

Power

Results from the present study do not support the majority of the previous research that has been done that found power to be essential in sports, especially those requiring high force in short time periods (Liebermann & Katz, 2003; Kawamaroi et al,. 2005; Markovic, 2007). This could be due to the fact that both static lower body power and moving lower body power were combined into one number because of the small number of participants. It may have been wise to separate these components. During one analysis all power measurements were combined because it was thought gymnasts required all three components for a successful vault as well as the small sample size. Results showed power measurements combined or separate were not significant. In a previous study done on gymnasts and vault success, vault approach speed was found to be important to success because the faster run leads to a fast-takeoff which leads to greater vault performances (Bradshaw, 2004). This same study measured post-flight distance and found a standard deviation of 0.13 and a standard deviation for rear horse to landing distance to be 0.16, but did not directly incorporate these into vault success. Vault success was measured by judge's scores. The present study did not find an association between power and gymnastics success score. Again this could be due to a low number of participants as well as lack of breakdown of the power components.

Future Research

From an observation standpoint, gymnasts performing a round off entry vault tend to gain greater distance on their vaults than those performing a front handspring entry or half on entry vault. Therefore, it may be a good idea for future research to look at the different vault entries separately with a larger sample. It would also be interesting to create a drill for a Yurchenko entry vault as it is a very different entry than either the handspring or the half-on entry. Technique plays a large role in all of these vaults, therefore it would be wise to look at the top Division I programs in the U.S. and measure a standard vault.

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APPENDIX A

Participant Data

Participant Data

Variables	A	B	C	D	E	F	G
VJ 1 (W)	1990.07	2961.15	3944.48	1519.12	1689.86	2216.97	2466.7
VJ 2 (W)	2409.5	6719.81	1952.79	905.77	922.82	1295.2	3412.61
VJ 3 (W)	2446.73	1259.68	3939.95	726.49	1379.03	2410.95	3188.79
RJ 1 (W)	24883.2	23805.22	22920.95	----------	26707.81	24113.17	14148.81
RJ 2 (W)	----------	22145.01	25551.19	24633.39	25996.87	23189.93	-----------
RJ 3 (W)	21678.1	19289.95	24257.69	25106.73	27235.59	23616.69	23977.26
HS 1 (W)	2651.62	2653.3	2011.79	38603	2653.3	1069.04	2612.72
HS 2 (W)	2679.83	2899.06	1626.04	3037.47	2899.06	815.12	2573.64
HS 3 (W)	2153.1	2510.05	1909.15	3673.93	2510.05	1862.15	2259.66
Thigh (cm)	45.5	53.5	44	49	48	49.5	50
Thigh (cm)	45	54	44.5	49	48	50	49.5
Calf (cm)	34.5	38	34	36.5	35.5	35.5	38
Calf (cm)	34.5	38	34	36	35.5	35.5	38
Length (cm)	84	84	88	86	83.5	84	95
Length (cm)	84.5	83.5	88.5	86	83	84	96
Distance (cm)	174	101	207	194	162	207	204
Distance (cm)	155	136	218	186	183	177	195
Distance (cm)	186	181	207	192	198	207	191
Fat mass (g)	9538	15007	10217	10792	15258	12542	11463
Lean mass (g)	40211	45713	43917	43962	39526	42369	50729
% fat	19.2	24.7	18.9	19.7	27.9	22.8	18.4
Height (cm)	160	156.8	160.7	159.4	154.9	156.7	164.5
Weight (kg)	53.64	64.87	58.47	59.77	57.74	57.54	67.56
Gym success	190.8	203.575	216.85	184.65	207.85	195.625	203.775
Vault score	9.625	9.8	9.725	9.575	9.85	9.85	9.65
Lower power	27329.9	30525.03	29495.67	26625.85	28925.45	26524.12	27389.87

APPENDIX B

IRB Approval

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 Fax 940-898-3416
e-mail: IRB@twu.edu

March 4, 2009

Ms. Gretchen Goerlitz
1501 May St.
Denton, TX 76209

Dear Ms. Goerlitz:

Re: *The Relationship Between Lower Limb and Upper Body Power and Anthropometric Characteristics and Vault Success in Collegiate Gymnastics*

The above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. A copy of the approved consent form with the IRB approval stamp and a copy of the annual/final report are enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. The signed consent forms and final report must be filed with the Institutional Review Board at the completion of the study.

This approval is valid one year from March 4, 2009. According to regulations from the Department of Health and Human Services, another review by the IRB is required if your project changes in any way, and the IRB must be notified immediately regarding any adverse events. If you have any questions, feel free to call the TWU Institutional Review Board.

Sincerely,

Kathy DeOrnellas, PhD.

Dr. Kathy DeOrnellas, Co-Chair
Institutional Review Board - Denton

enc.

cc. Dr. Charlotte Sanborn, Department of Kinesiology
Dr. David Nichols, Department of Kinesiology
Graduate School

APPENDIX C

Consent Form

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title: The relationship of lower limb and upper body power and anthropometric characteristics and vault success in collegiate gymnastics

Investigator: Gretchen Goerlitz..435/512-5683
Advisor: David Nichols, Ph.D...940/898-2522

Explanation and Purpose of the Research

You are being asked to participate in a research study for Ms. Goerlitz's thesis at Texas Woman's University. The purpose of this research is to determine the relationship of lower limb and upper body power and anthropometric characteristics and vault success in female collegiate gymnastics. In particular, the study will look at vertical jump, running vertical jump, a handstand push off task, thigh and calf circumference, height, leg length, lean tissue mass, and fat tissue mass and how it relates to vault success.

Research Procedures

For this study, the investigator will collect data from participation in performing a vault, vertical jump and running vertical jump task, a handstand push off task, calf and thigh circumference, and leg length measurements. Data from previously performed DXA scan is requested upon your consent; however data will be unidentifiable to Ms. Goerlitz. Forceplate data will be given to Carolyn Rogan who is the works in the ESN Clinic and is the Practicum Coordinator. She will enter the DXA scan data, remove all names and assign a code and then mix the data so it will be unidentifiable to me. Data will be rearranged due to the small data set being used in case the researcher remembers the order the participants were recorded in. The purpose of this research is to provide insight regarding the relationship of these characteristics to vault success. Your maximum total time commitment in the study is approximately 150 minutes which will be spread over three days of data collection.

Potential Risks

Potential risks related to your participation in the study include injury. Precautions will be taken such as warm up, athletic taping, and cool down. While the possibility of injury exists all procedures used for this research are performed by gymnasts on a routine basis. Athletic trainers are available during all practices and meets.

Another possible risk to you as a result of your participation in this study is the release of confidential information. Confidentiality will be protected by assignment of code numbers and rearranging of numbers will be performed. Data will be stored in the researcher's personal computer that requires a password to log onto.

____
Participant Initials
Page 1 of 2

The researcher will try to prevent any problem that could happen because of this research. You should let the researchers know at once if there is a problem and they will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

Participation and Benefits

Your involvement in this research study is completely voluntary, and you may discontinue your participation in the study at any time without penalty. The benefit of participation in this study is receiving data from all procedures performed and therefore gaining knowledge about personal anthropometric and power characteristics. Future coaches will be able to use the data found in their talent selection process as well as their training for the vault apparatus. This study could also lead to a body of knowledge focusing on a healthier self-image of collegiate gymnasts.

Questions Regarding the Study

If you have any questions about the research study you may ask the researchers; their phone numbers are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conduced, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu. You will be given a copy of this signed and dated consent form to keep.

Name of Participant________________________________

Signature of Participant ______________________________ Date ____________