PHYSIOLOGIC PERFORMANCE TEST DIFFERENCES BY COMPETITION LEVEL AND PLAYER POSITION IN FEMALE VOLLEYBALL ATHLETES

By

Monique Lynae Schaal

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Exercise and Sport Studies, Biophysical Studies

Boise State University

May 2011

BOISE STATE UNIVERSITY GRADUATE COLLEGE

DEFENSE COMMITTEE AND FINAL READING APPROVALS

of the thesis submitted by

Monique Lynae Schaal

Thesis Title: Physiologic Performance Test Differences by Competition Level and Player Position in Female Volleyball Athletes

Date of Final Oral Examination: 09 March 2011

The following individuals read and discussed the thesis submitted by student Monique Lynae Schaal, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

Lynda Ransdell, Ph.D.	Chair, Supervisory Committee
Yong Gao, Ph.D.	Member, Supervisory Committee
Shawn Simonson, Ph.D.	Member, Supervisory Committee

The final reading approval of the thesis was granted by Lynda Ransdell, Ph.D., Chair of the Supervisory Committee. The thesis was approved for the Graduate College by John R. Pelton, Ph.D., Dean of the Graduate College.

ACKNOWLEDGEMENTS

There are many people who I would like to thank for their help in the completion my master's thesis. I would first like to thank my thesis committee, which is comprised of Dr. Lynda Ransdell, Dr. Yong Gao, and Dr. Shawn Simonson, for their incredible contributions. I would also like to thank the participants from Canyon Ridge High School, Filer High School, Twin Falls High School, and Kimberly High School, Montana State University, and Boise State University for their commitment to performing at their highest level. My family and friends who have been so supportive throughout this process, I couldn't have done it without you. Thank you!

ABSTRACT

Introduction: The game of volleyball, which requires power, strength, speed, agility, and anaerobic fitness, is played around the world. A performance divide is evident between high school and collegiate volleyball athletes, and the physiologic differences have not been extensively studied. Because sport specific test performance data are not available, performance deficits in high school athletes are not well understood. Players striving to improve volleyball performance need clear expectations of skill and performance measures to succeed at higher levels of competition. There are extremely limited data available for female volleyball players that specifically describe how physiological performance test data may vary by position. **Purpose:** The purpose of this study was to examine physiologic performance differences between high school athletes and Division I collegiate athletes and by player position in four specific tests that are related to volleyball performance. **Participants:** Female participants from four Varsity high school volleyball teams and two Division I collegiate volleyball teams were recruited for the study. Participants were recruited through the head coach at each of the chosen six schools. **Methods:** Participants completed four performance-based field tests after completing a standardized dynamic warm-up. The Vertical Jump test, which assesses lower body power, was measured with a Vertec system. The Agility T-Test, which assesses agility, was measured using four cones in a T-shaped pattern and a laser timing device. A 150-Yard as well as a 300-Yard Shuttle run, measures of anaerobic capacity, were assessed using two cones and a laser timing device. All tests were completed as recommended by the National Strength and Conditioning Association (NSCA), from the least fatiguing to most fatiguing test. Each of the performance-based test results was analyzed for each skill grouping (High school and college) and for 3 groupings of positions (setters, hitters, and back row defense). **Data Analysis:** Multiple one-way ANOVAs were conducted with a Bonferroni adjustment for potential inflation of type I error due to multiple comparisons among variables. The statistical analysis was completed using SPSS version 18.0 to examine differences in test performance scores calculated for test by team, position, as well as for the skill grouping (high school varsity and collegiate Division I). **Results:** The most important findings of this study were that: (a) college volleyball athletes were older (19.65 ± 1.64 yrs, $p< 0.01$), heavier (69.96 ± 7.72 kg, $p< 0.01$), and taller (176.88 ± 6.03 cm, $p< 0.01$), than their high school counterparts. (b) compared to collegiate athletes, high school athletes had performance deficiencies in the Vertical Jump (HS: 47.58 ± 8.22 cm, DI: 52.95 ± 6.59 cm, $p< 0.05$), Lower Body Power (HS: 3592.3 ± 522.82 W, DI: 4160.67 ± 598.34 W, $p< 0.05$), and the 150-Yard Shuttle Run (HS: 29.73 ± 6.20 sec, DI: 28.67 ± 5.98 sec, $p<0.05$); (c) there were no differences found between Agility T-Test and 300-Yard Shuttle Run shuttle when collegiate athletes were compared to their high school counterparts; (d) Lower Body Power was the only statistically significant difference in the performance test measures by player position (Hitter: 1070.36 ± 139.47 W, Setter: 1131.36 ± 163.94 W, and Back Row Defense: 881.83 ± 120.54 W, $p< 0.0005$) and (e) the 150-Yard Shuttle Run did not demonstrate convergent validity with the 300-Yard Shuttle Run in volleyball players ($r= 0.488$). **Conclusion:** While there are several significant performance differences by level of play (e.g., High School versus Collegiate players), there was only

one significant difference in physical performance by position (e.g., Hitter, Setter, Back Row Defense,): Lower Body Power. This indicates that high school and collegiate volleyball athletes have different performance levels, especially in lower body power and anaerobic capacity, and that high school athletes who aspire to play collegiate Division I volleyball should consider improving their strength and conditioning programs to achieve better scores in volleyball-specific performance measures. Additionally, Back Row Defensive players have less Lower Body Power than Hitters or Setters. More research needs to be performed in order to fully understand the relationship of the 150 and 300-Yard Shuttle run in relationship to each other, and the ability of the 300-Yard Shuttle run to predict anaerobic capacity in female volleyball athletes. These specific comparative values create a baseline performance measure that now may better equip strength and conditioning coaches to create programs that would address deficits in player performance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

The sport of volleyball incorporates highly specific movement patterns while emphasizing different metabolic systems. Volleyball uses three main positions: front row hitters, front and back row setters, and back row defense (Dyba, 1982). Each position employs unique footwork patterns, muscle recruitment, metabolic systems, and upper and lower extremity positions (Sheppard, Gabbett, Claudio, & Newton, 2010). Volleyball requires mostly anaerobic physiologic components of fitness, as well as agility, speed, and power components.

Elite athletes have mastered both physiologic and skill-related components of volleyball. The metabolic systems predominantly utilized are the phosphagen system and glycolysis due to the duration of each play, on average, lasting less than 120 seconds (Dyba, 1982). Kunstlinger, Ludwig, and Stegmann (1987) determined that the aerobic energy system is not used as a primary fuel source during volleyball performance, but is relied upon for energy replenishment during rest periods.

Time-motion analysis for men's volleyball indicated that the average rally lasted less than 120 seconds (Sheppard et al., 2007). The movements performed are explosive and powerful in order to generate as much force as possible. To produce maximal lower body power, it is the goal of most volleyball players to convert horizontal force into vertical force (Barnes et al., 2007). The goal of pre-competition training is to allow volleyball athletes to maximize performance during the competitive season.

Performance Characteristics of Volleyball Athletes

Lower body power, speed, and agility are important indicators of volleyball performance (Vescovi & Mcguigan, 2008). Volleyball requires athletes to be explosive in the lower limbs; this is especially emphasized in the front row hitting positions when attacking on offense or blocking on defense. Vertical jump emphasizes lower body power, and it is known that Power = (Force x Distance)/Time. Vertical jump is an anaerobic explosive movement that requires recruitment of the highest threshold motor units (Amasay, 2008). The body needs to apply large amounts of muscular force over the largest amount of distance in the smallest amount of time in order to produce the highest vertical jump. Volleyball requires the athlete to jump as high as possible while attacking the ball with upper body movements. Vertical jump is important in volleyball because of the need to hit the ball around the opponent on the opposite side of the net. The higher a players' vertical jump height, the less likely it is that the ball will be blocked by the opponent on defense. Motor unit rate of firing and synchronization of motor units are vital to the dynamic explosive power produced in the quadriceps for jumping. Limiting co-contraction of the hamstrings also increases the ability of the athlete to improve vertical jump (Amasay, 2008).

Vertical jump is a major determinant of volleyball performance and many researchers have studied different aspects of vertical jumping. According to Gutiérrez & Marcos (2009), the factors that affect vertical jump are height reached by the center of gravity, time required for execution, and the spatial orientation of the corporal segments. Because vertical jump is an important performance variable, it is important to have quantifiable data to measure vertical jump. In order to measure the height of the vertical jump, a Vertec measuring system, force plate jumping data, 3-camera system with biomarkers, and other modalities have been used to measure the height of the vertical jump.

In addition to vertical jump as a measure of volleyball performance, in 2010, Sheppard et al. examined other factors related to successful volleyball performance. Prior to this research, there were limited physiologic data regarding volleyball athletes. While the study provided new information regarding physiological characteristics for male volleyball athletes, it did not include information regarding physiologic differences in skill level or competition level for female athletes. The limited research in this area created a need to determine physical and physiologic characteristics of the athletes who compete at a variety of skill levels. The information from the study conducted by Sheppard et al. serves as a starting point to determine physiologic attributes that are important for female volleyball performance.

Physiologic Demands of Female Volleyball Athletes

In order to maximize performance, metabolic pathways must be efficient in converting energy substrates into ATP for energy utilization by the body. Athletic performance relies on the ability of the athlete to produce energy in response to the demands that the exercise stimulus requires. A muscle fiber dominance of type IIa and IIx would be preferred for the volleyball athlete due to the increased diameter and the increased ability to produce force as well as highly developed phosphagen and glycolytic pathways for energy utilization. A higher percentage of type II muscle fibers contribute to increased glycogen storage, which is an important substrate in metabolic pathways. As a primarily anaerobic athlete, glycolysis is one of the essential system used to produce energy in volleyball performance. As was previously mentioned, the average play lasts less than 120 seconds and the body does not heavily rely on aerobic pathways in order to generate ATP for energy (Dyba, 1982). The average collegiate match lasts less than 2 hours (Sheppard et al., 2010). The duration of the match, combined with a short duration of recovery time, theoretically means that the phosphagen system would not be able to fuel all the energy requirements for performance. This creates the need for highly developed glycolytic pathways for energy utilization. The aforementioned physiologic adaptations help to create an explosive and powerful athlete.

Performance-Based Measures

In order to examine the performance indicators and physiologic demands that have been identified as important predictors of volleyball performance, the Agility T-test, vertical jump lower body power test, and anaerobic power tests have been deemed reliable and valid and were used for the analysis of the study. The Agility T-Test has been validated as a measure of agility performance (Sassi et al., 2009). Agility is needed in volleyball performance in order to allow the athletes to change direction quickly and make a proper play. The vertical jump test is used to evaluate lower body power and strength (Vescovi & Mcguigan, 2008). A 300-Yard Shuttle run is used to measure anaerobic capacity, which addresses the need for phosphagen and glycolitic energy system requirements (Baechle & Earle, 2008). Although this test has been used to determine anaerobic capacity, due to the duration of the average volleyball play, the usage of the 300-Yard Shuttle run may not be the most accurate indicator of the energy system that is most dominant. A 300-Yard Shuttle run has an average time of 63 seconds to completion in collegiate athletes (Baechle & Earle, 2008). While the 150-Yard Shuttle run is drastically less utilized, it may provide a better measure of the anaerobic capacity in volleyball athletes based on game requirements and training regimens. The 150-Yard Shuttle run does not have widely available published norms for average times. It could be concluded that average times would be half the duration of the 300-Yard Shuttle run. Approximately 30 seconds to complete the 150-Yard Shuttle run would more closely relate to a volleyball play. In order to examine the usage of the 300-yard in comparison to the 150-Yard Shuttle run, which has not been used in published volleyball studies, both tests were given to all participants. This allowed the information to be examined both in skill grouping (High School Varsity vs. NCAA Division I) and by player position (hitter, setter, and back row defense) to determine which tests are the most appropriate for these athletes. The 150-Yard Shuttle run shows face validity due to the fact that overall time to completion more closely mimics the time it takes to complete an average volleyball play. The relationship between the 300-Yard Shuttle run and the 150-Yard Shuttle run has not been established. Based on the lack of information about the 150-Yard Shuttle run, it is important to determine if the 150-Yard Shuttle run is a valid measure of anaerobic capacity. This information will be beneficial for future testing of female volleyball athletes in order to determine anaerobic capacity in a manner that best suits the population.

Agility, lower body power, and anaerobic capacity have been used repeatedly to measure volleyball performance. These three measures have been evaluated in relationship to each other as well as individually for their role in volleyball performance. It has been determined that agility, lower body power, and anaerobic capacity are necessary to excel in volleyball performance (Pauole, Madole, Garhammer, Lacourse, &

Rozenek, 2000; Sheppard et al., 2008; Sheppard et al., 2010; Vescovi & Mcguigan, 2008).

Need for Study

The physiologic differences between high school and collegiate athletes are not well understood, primarily because of the lack of information regarding the differences between high school varsity female volleyball athletes and NCAA Division I female volleyball athletes. In high school male athletes, testosterone may play a role in physical performance. Because female athletes typically do not participate in significant weight training (Reynolds, Ransdell, Lucas, & Petlichkoff, 2010), the specific nature of these differences is unclear. Additionally, performance differences between high school and collegiate female athletes are not readily available, therefore strength and conditioning specialists may have difficulty developing programs to improve volleyball performance, especially during their first 1-2 years of competition. The information derived from this study serves as a starting point to examine differences in performance, based on player position and competition level. The results of the study help to establish baseline data, and provide a means to test the effectiveness of various training programs designed to address performance deficits. In summary, the lack of information available to female athletes across age, player position, and competition level makes comparison of performance indicators among athletes impossible. Having these specific comparative values available would create a baseline performance measure that would better equip strength and conditioning coaches to create programs that would address deficits in player performance.

Purpose

The primary purpose of this study was to examine physiologic performance test differences between female volleyball players based on level of competition (High School Varsity or Division I collegiate) and player position (setter, hitter, back row defense). This was accomplished by comparing data from four performance-based tests (e.g., Vertical jump, Agility T-Test, 150-Yard Shuttle run, and the 300-Yard Shuttle run) that predict volleyball performance by competition level and player position. The secondary purpose of the study was to examine the relationship between the 150-Yard Shuttle run and the 300-Yard Shuttle run in order to determine convergent validity of the two tests and to establish which test may be the best measure of anaerobic capacity in female volleyball athletes.

Hypotheses

There were three hypotheses for this study:

- First, it was hypothesized that Division I female collegiate athletes would have higher performance scores on all measures when compared to varsity high school female volleyball athletes. Possible reasons for these differences include the amount of time spent in strength and conditioning programs, the quality of the strength and conditioning programs, physical maturation, and increased time playing volleyball due to age.
- Second, it was hypothesized that there would be higher vertical jump scores for hitters, when compared to setters and back row defense. This is due to the large emphases on jumping in the front row hitters, which is not emphasized in setters and back row defensive players.

- Third, it was hypothesized that the 150-Yard Shuttle run would show high convergent validity when compared to the 300-Yard Shuttle run.

Operational Definitions

Agility: Body movements that create the ability to change direction accurately, as well as to start and stop quickly in response to a stimulus; the ability to change direction with a minimal loss of control and/or average speed (Sheppard & Young, 2006, Vescovi & Mcguigan, 2008).

Anaerobic Capacity: Maximal rate of energy production by the phosphagen and lactic acid energy systems (Baechle & Earle, 2008, p. 441).

Lower Body Power: Lower body force divided by time, typically measured through a vertical jump test (Sheppard et al., 2008b).

Vertical Jump Test: A lower body power test used to measure the highest peak that an individual can touch (Baechle & Earle, 2008, p. 441).

Limitations

The comparison measures between high school and collegiate athletes for the four performance measures may not be representative of all high school and Division I female volleyball athletes. The relatively small sample size serves as baseline data to determine physiologic differences in high school varsity volleyball athletes and NCAA Division I athletes. The conference that an athlete competes in could partially explain different performance values. For example, larger schools have a larger student body (and perhaps a larger recruiting budget) from which to select the team. In addition, they may have better facilities, equipment, and more access to coaching. This would theoretically produce better teams comprised of higher skilled individuals. Additionally, these data should not be generalized to male volleyball athletes because of the physiologic and performance differences between female and male athletes. Further study should be done to investigate the physiologic performance measures with a larger sample size that provides a more comprehensive representative sample. This study seeks to create a starting point that would ideally prompt further study in other National Collegiate Athletic Association (NCAA) Division I conferences and high school volleyball teams.

Delimitations

The same testing instruments and trained testers were used to enhance reliability. The primary investigator was the sole data collector in order to ensure that the athletes were measured as accurately as possible. The ground surface was a wood floor in order to ensure that there was limited variation in data due to the ground surface. All athletes were instructed to use the footwear that they utilized for game play, in order to produce testing performances as similar to games as possible.

Significance of Study

Due to the lack of information and the potential benefit of making this information readily available, there is a clear need for descriptive physiologic data indicating the performance differences for female varsity high school and collegiate volleyball athletes. Comparative values for the four tests will be able to provide information about specific measures in three determinants of volleyball performance which are currently not available as published data. The study provides information that is beneficial to current Division I female volleyball athletes, incoming players, strength and conditioning coaches, and volleyball coaches. It also provides information for high school players who seek to advance to the next level of play and related personnel such as athletic trainers, physical education teachers, and others involved in preparing high school athletes for higher levels of play. Finally, the results of the 150-Yard Shuttle run may be highly correlated with the 300-Yard Shuttle run, which would indicate convergent validity. If that hypothesis is confirmed, it is possible that future strength and conditioning coaches who work with volleyball athletes may use the 150-Yard Shuttle run test as a better predictor of volleyball performance and anaerobic capacity.

CHAPTER II: LITERATURE REVIEW

Volleyball is currently the third most popular female sport in high school athletics according to the 2009 National Federation of State High School Association statistics. In the 1970's, female participation in high school volleyball approximated 17,972 female athletes (National Federation of State High School Association, 2010). In 2008-2009, over 404,243 female high school athletes participated in volleyball nationwide (National Federation of State High School Association, 2010). The increased involvement in volleyball has prompted researchers to examine anthropometric, physiologic, and biomechanical measures in order to improve volleyball competition performance. Despite this interest in improving volleyball performance, there is still a dearth of research related to female volleyball players. Given the growth in volleyball participation and the need for additional research related to female volleyball players, this literature review will include: (a) relevant information about previous research and testing in volleyball (or related sports), and (b) test battery information, including rationale for test selection.

Age and Position-Based Performance Differences

Hedrick (2007) determined that volleyball is an explosive, fast-paced sport. Volleyball athletes must be physiologically conditioned for continuous jumps, changes of direction, and repeated attacking of the ball (Herick, 2007). On average, a play lasts approximately six seconds, with an average fourteen second rest period, and a total competition time of 90-120 minutes including rest periods (Hedrick, 2007). This brief performance period requires repeated explosive movements with a relatively short recovery period. Volleyball performance requires both offensive and defensive capabilities. The player must be able to transition between jumping, running and executing a needed skill. Volleyball follows a bump (also known as a forearm pass)-set-hit pattern. The game of volleyball requires the athletes to return the ball over the net in no more than three touches (Seidel, 1975). Volleyball requires 6 athletes on the court at a time; each athlete has a specific role in the game. Volleyball athletes are characterized by positions based on the primary skill that is performed. These positions are:

- Hitter, which can be divided into three categories, outside, middle, and right-side (Marques, Tillaar, Gabbett, Reis, & Badillo, 2009). The functions of hitters are to complete the third touch of the ball when available. This is completed by creating an approach, jump, and contact with the ball in one sequential movement. Another function of the hitter is to block the opponents at the net (Seidel, 1975). When striking the ball for an attack, the hitter increases the speed of the striking arm by performing a loading phase, contact phase, and follow through with landing phase.
- Setter, which controls the second touch of the ball and “set-up” the hitter. The setter primarily performs the overhead set by positioning the hands between the chest and eye-level. A right-leg-forward stride position is assumed while the force is applied through the ball to create an upward trajectory (Seidel, 1975). The setter must be able to set all three hitting positions, while controlling the specific height of the ball.

- Back Row defense, which primarily performs a forearm pass to the setter during offense or defensive situations. The forearm pass is performed with the body positioned with a lowered center of gravity, in order to allow the athlete to pass a low ball. Because of the traveling force of the ball, the athlete typically does not need produce force, but must rather redirect (or absorb and redirect) the force of the ball. The trajectory of the ball needs to be upward so that the setter can place the body under the ball and push the ball towards the hitters (Seidel, 1975). Table 2.1 summarizes the positional requirements for volleyball players (Dyba, 1982).

Table 2.1: Summary of Positional Requirements for Volleyball Athletes

	Hitters	**Setters**	**Back Row Defense**
Typical Ball	3rd	2nd	1st
Offensive Requirements	1. Attack Opponent 2. Forearm Pass 3. Serve 4. Fake Attack	1. Set Hitters 2. Serve	1. Pass to Setter
Defensive Requirements	1. Block Opponent 2. Dig Opponent	1. Block Opponent 2. Dig Opponent	1. Dig Opponent

Based on the physiologic demands for volleyball athletes as a whole, and also by player position, appropriate tests must be utilized in order to measure the performance based measures, which theoretically translates into volleyball performance skills on the court. Performance indicators have been examined in order to improve volleyball performance. It has been shown that there is a physiologic performance difference in highly-skilled athletes compared to non-athlete counterparts; however, the differences between high school and NCAA Division I collegiate female athletes are undetermined.

In 2008, female soccer athletes of different skill levels were compared on anthropometric and physiologic measures (Vescovi & Mcguigan, 2008). The measures that have been recorded for female soccer athletes allow high school female soccer players to use individual anthropometric and performance scores, and compare them against NCAA Division I athletes. Strength and conditioning coaches are now able to create remedial programs for female soccer athletes based on performance measures of sprint speed, vertical jump, agility, and anthropometric data, which can be used to predict soccer performance. This information is revolutionary for female high school soccer athletes. Comparative performance-based measures for female volleyball players will be revolutionary to the sport of volleyball and may serve to improve volleyball performance at the high school level.

Lidor and Ziv (2010) found that the anthropometric measures of height, body mass, and fat-free mass were useful in determining volleyball performance as well as performance indicators such as strength, vertical jump, agility, and speed. Anthropometric and physiologic measures, which have been examined for adolescent female and male volleyball athletes (Prokopec, Padevetová, Remenár, & Zelezný, 2003), allow coaches to compare the stature of a potential recruit against the average height for volleyball players. While this information is useful, there are many physiologic qualities that make up a successful volleyball player. Baseline measures of anthropometric and performance-based values help to prepare high school athletes for the next level of play (Baechle & Earle, 2008). Due to the lack of information available, there is a need for the comparison of anthropometric and performance-based field test results for female high school and NCAA Division I volleyball athletes. Table 2.2 summarizes recent volleyball research and highlights the lack of consistent performance-based field test data and the lack of research related to age-group and player position comparisons. Of the volleyball studies examined, some combined data for male and female athletes (Sheppard et al., 2008a), some reported on only male athletes (Marques et al., 2009), and only one study compared data by player level within the collegiate ranks (e.g., Divisions I, II, and III) (Barnes et al., 2007). Of the female athletes, height ranged from 177.9 cm (college athletes) to 184 cm (selected junior level athletes), mass ranged from 70.9 to 71.1 kg, and vertical jump ranged from 31.8 cm (Division II college females in Barnes et al., 2007) to 40.85 cm (NCAA Volleyball players in Nesser & Demchak, 2007). Scores on the Agility T-Test were very similar (10.1 to 10.49 seconds). Other tests such as body composition (percent body fat) and medicine ball throw distance, and 1 RM bench press have been included but data are not consistent and there is a need to develop a recommended and consistent battery of tests for volleyball performance assessment. Currently, there is no known research that has used a test such as the 150 or 300-Yard Shuttle run to assess the metabolic or anaerobic fitness of volleyball athletes.

Table 2.2: Summary of Previous Volleyball Research

Author	Sample	Height (cm)	Mass (kg)	Vertical Jump (cm)	Agility T-Test (sec)	Other Measures
Amasay (2008)	NCAA Division I female volleyball athletes (n=10)	178.0 ± 6.0	70.9 ± 9.9	n/a	n/a	Body fat %
Barnes et al. (2007)	NCAA division I, II & II female volleyball athletes (n=29)	DI: 177.9 ± 6.3 DII: 174.3 ± 7.7 DIII: 171.0 ± 8.0	DI: 73.3 ± 7.7 DII: 71.5 ± 9.8 DIII: 69.8 ±6.9	DI: 36.4 ± 2.5 DII: 31.8 ± 4.6 DIII: 32.6 ± 5.1	n/a	Custom agility test Drop jump contact time Drop jump height Isometric peak force (quad)
Gabbett et al. (2007)	Junior volleyball "selected" athletes (n=19)	184 ± 0.08	71.1 ± 9.6	46.0 ±11.2	10.49 ± 0.96	Overhead medball throw
Marques et al. (2009)	Professional male volleyball athletes (n=35)	193 ± 3.8	92.3 ±14.0	49.7 ± 5.3	n/a	Overhead medball throw 4RM: bench press and squat
Nesser & Demchak (2007)	NCAA Division I volleyball athletes (n=14)	177.9 ±5.6	79.19 ± 5.6	40.85 ± 3.7	10.01 ± 0.06	Spike vertical jump
Sheppard et al. (2008b)	High performance volleyball players 10 men 6 women (n=16)	195.7 ± 8.7	83.7 ± 4.2	38.9 ± 8.6	n/a	1RM bench press

Note: cm: Centimeters, kg: Kilograms, sec: Seconds

Hendrick (2007) identified power, agility, and anaerobic capacity as key performance indicators in volleyball, which serve as fundamental measures that should be examined. Physical test performance data have been studied in detail by position for elite men's volleyball players (Dyba, 1982; Marques et al., 2009). Measures of height, mass, throwing distance, bench press, and vertical jump have been established by position for men's elite volleyball. Hitters were taller and heavier than other positions. Liberos (back row defense) were the lightest of all positions. Performance measures by player position indicated differences in hitters, setters, and back row defensive players in measures of bench press strength and parallel squat performance, with hitters being significantly stronger than setters or back row defense. Setters showed decreased strength when compared to the hitters. There were no differences in vertical jump by player position in male athletes. These data indicate that male middle blockers are significantly stronger than liberos (back row defense) and setters. Male hitters demonstrated significantly greater upper-body strength than setters. Hitters were able to throw significantly further than liberos (back row defense). The study indicates the need to examine fitness by player position due to the different physiologic requirements to play volleyball at an advanced level.

Rationale for Test Battery

Vertical jump has been used extensively to measure lower body power in both male and female volleyball athletes (Baechle & Earle, 2008; Hedrick, 2007; Lidor & Ziv, 2010; Vescovi & Mcguigan, 2008). The Agility T-Test has also been used extensively to examine agility in soccer, basketball, football, and volleyball athletes (Sassi et al., 2009). The 300-Yard Shuttle run has been widely used by basketball athletes, but it has not been as widely used by volleyball athletes, despite the fact that it is recommended by the NSCA as a valid and reliable measure of anaerobic capacity (Baechle & Earle, 2008). The 150-Yard Shuttle run may challenge the phosphagen and glycolytic metabolic systems more similarly to a volleyball play when compared to the 300-Yard Shuttle run. The 150-Yard Shuttle run has not been used currently in any published performance-based testing protocols but may be more appropriate for volleyball athletes due to the fact that the time it takes to complete the 150-Yard Shuttle more closely mimics that of a typical volleyball play. Test results should yield information that can translate into competition performance for the measures to be of value to the coaches and athletes. The four tests (Vertical jump, Agility T-Test, 300-Yard Shuttle run, and 150-Yard Shuttle run) have been chosen due to the ability of the movements to most closely replicate the movement patterns and physiological systems challenged during volleyball competition.

When morphological characteristics of female volleyball players are examined, they are, on average, taller, more muscular, and lighter than females of similar age and ethnicity (Prokopec et al., 2003). This increased body mass and muscle diameter creates an increased ability to generate force due to the relationship between diameter and muscle fiber contractile units. Increased force production leads to higher acceleration, which is necessary for performance along with vertical jumping, frequent changes in direction, dives, and running short distances (Black, 1995).

Test Battery Background Information

The battery of lower body power, agility, and anaerobic capacity tests was taken from a recommended list designed and approved by the National Strength and Conditioning Association (NSCA) (Baechle & Earle, 2008) and from a synthesis of the published literature (Table 2.2) on tests utilized to assess performance for volleyball athletes. The test parameters (lower body power, agility, and anaerobic capacity) have been evaluated in relationship to each other and individually to determine their role in volleyball performance (Pauole et al., 2000; Sheppard et al., 2008a; Sheppard et al., 2010; Vescovi & Mcguigan, 2008). All parameters are likely necessary to succeed in volleyball performance, as Division I and elite athletes typically demonstrate high levels of agility, lower body power, and anaerobic capacity.

Test Battery

A battery of field tests was administered to measure lower body power, agility, and anaerobic capacity. The field tests that were utilized were the Vertical Jump test, Agility T-Test, the 150-yard, and 300-Yard Shuttle run. Field tests are ideal for large groups of athletes, especially when multiple measures of performance are needed (Baechle & Earle, 2008). When preparing to test athletes for any performance measure, it is important that a specified warm up protocol is implemented for all athletes in order to maintain similar testing parameters (Baechle & Earle, 2008). The athlete profile for volleyball athletes drastically differs from other sports such as football; this creates a need for sport-specific comparison measures.

Note: The specific warm-up protocol is described in the methods section.

Vertical Jump

Vertical jump is a critical component of the jump serve, jump set, jump attack, and blocking an opponent (Molenaar, 2009). The vertical jump test is used to evaluate lower body power and strength (Vescovi & Mcguigan, 2008). Gutiérrez and Marcos

(2009) identified factors that affect vertical jump as the height reached by the center of gravity, time required for execution, and the spatial orientation of the corporal segments. Vertical jump is an anaerobic explosive movement that requires recruitment of the highest threshold motor units (Amasay, 2008). In order to reach maximal height quickly, large amounts of vertical force must be produced as quickly as possible. Barnes et al. (2007) found that optimal production of maximal lower body power was obtained by converting substantial amounts of horizontal force into vertical force. Repeated force production as well as repeated maximal jump height are important in volleyball performance (Hedrick, 2007).

The Vertec vertical jump measurement system provides the user with the ability to measure vertical jump to the nearest 0.5 inch. The Vertec is a reliable measure (r=0.906) of vertical jump height when compared to a 3-camera video system (Leard et al., 2007).

Descriptive data for various subpopulations are currently available for vertical jump height, such as norms that have been established for medical students (Patterson & Peterson, 2004). Competitive high school and female NCAA Division I volleyball athletes have a unique athletic profile, because of the unique physiologic and mechanical demands of volleyball performance. The NSCA has normative data available for competitive female collegiate athletes for vertical jump height, although these data are not presented relative to sport, player position, or level of competition (Baechle & Earle, 2008).

Vertical jump requires anaerobic power, which is supplied through the phosphagen and glyolytic energy systems. Anaerobic power is vital in producing high force generation. Anaerobic power is the muscle's ability to exert high force while contracting at a high speed (Baechle & Earle, 2008). Volleyball performance heavily relies upon force generation from the lower body. Athletes require large amounts of power in order to produce elite level vertical jumps (Sheppard et al., 2008a).

Vertical jump height is an excellent practical measure for determining lower body power because of the obvious need to create a more optimal blocking body position or attack angle with increased vertical distance from the net (Sheppard et al., 2011). Lower body power can be infered through vertical jump performance and it can also be calculated from vertical jump height through a power equation.

In 1999, Sayers, Harackiewicz, Harman, Frykman, and Rosenstein performed a cross validation study using three different lower body power predicting equations. Prior to this piviotal study, mulitple formulas were used to calulate lower body power from vertical jump. Because of the sample population that was used to validate the lower body peak power equation from Sayers et al. (1999) (108 collegiate athletes) and the performance criteria for performing the vertical jump (countermovement versus a squat initiated vertical jump), the peak power equation developed through the cross validation best suits the current sample population. The peak power equation demonstrated an R^2 of 0.78 and an SEE of 561.5 (W) when compared to a force platform and was determined to be a reliable source of preciting lower body peak power output. Therefore, this equation was used to calculate lower body power based upon the countermovement vertical jump.

Agility T-Test

Hendrick (2007) indicated that volleyball requires quick changes of direction, which requires a quick ground contact phase. Agility is a necessary component of volleyball performance that allows the athletes to change direction quickly in reaction to the position of the ball. The Agility T-Test is a standard measure of agility, which requires the athlete to move through a T-shaped pattern in as little time as possible (Baechle & Earle, 2008). The Agility T-Test utilizes lateral movements that are emphasized in volleyball performance. Agility measures are challenging due to the ever changing and dynamic game of volleyball. The Agility T-Test is a valid and reliable measure of agility (Baechle & Earle, 2008). The Agility T-Test incorporates a lateral and linear movement, which closely mimics volleyball footwork patterns. Due to the quick directional change and nature of the test, footwear and floor surface have been a concern. Athletes were advised to wear footwear appropriate for the test environment (e.g., footwear that is normally used in athletic competition on a hard wood floor) (Baechle & Earle, 2008).

<u>300-Yard Shuttle Run</u>

The 300-Yard Shuttle run is recommended by the National Strength and Conditioning Association (NSCA) as a reliable and valid test of the anaerobic endurance capacity and agility of an athlete (Baechle & Earle, 2008). The maximal rate of energy production, which is provided by the phosphagen and glycolytic systems, determines anaerobic capacity (Baechle & Earle, 2008). The volleyball athlete relies on the anaerobic gylcolytic system as the dominant energy production system. Anaerobic capacity is crucial for sustained energy production necessary during a fast-paced game. A 300-Yard Shuttle run utilizes movements in which rapid acceleration is followed by sprinting speed. Acceleration and speed are important for volleyball athletes in order to reach the ball in time to make a play (Vescovi & Mcguigan, 2008). Barnes et al. (2007) showed a high correlation between type II muscle fibers, anaerobic capacity, and sprinting speed through maximal running velocity. The 300-Yard Shuttle run is preferable to the linear direction sprint because the continuous change in direction more closely mimics that of volleyball performance. There are no known volleyball studies that have examined anaerobic capacity through the use of the 300-Yard Shuttle run.

150-Yard Shuttle Run

Due to the average duration of a rally (on average, less than 120 seconds), the 300-Yard Shuttle run may be less appropriate for determining the anaerobic capacity that volleyball athletes need to excel in their sport. Because of this, the 150-Yard Shuttle run will be used to determine anaerobic capacity in addition to the recommended standard of the 300-Yard Shuttle run. The 150-Yard Shuttle run has been used in ice hockey (USA Hockey, Personal communication) because it better fits the physiologic parameters necessary for ice hockey performance, which is similar to volleyball performance in terms of duration of play.

Need for Comparison Measures

Field test measures help to define performance standards and to create clear physiologic adaptations necessary to excel in sport. Comparative values are useful for comparing a current athlete’s level of performance to set performance standards that have been developed based on higher level athletes. Various types of data (comparative, normative, etc.) have been extensively used in football to assess individual and team performance against criterion data that were previously developed (Carbuhn et al., 2008; Secora, Latin, Berg, & Noble, 2004). For example, Secora and colleagues (2004) examined performance data developed for junior and senior football athletes, and compared it to performance data from incoming football freshman. The data were examined by team, as well as for all the teams that were examined, and then were further broken down by player position (Secora et al., 2004).

The position and sport-specific testing and training protocols used in football could undoubtedly be utilized to enhance volleyball strength and conditioning efforts, but to date, no similar studies have been conducted. Coaches use the performance values to compare the specific athlete to a set of predetermined performance standards. While these data are not available, creating comparative physiologic data will serve to provide information that will benefit high school and collegiate volleyball athletes, coaches, and conditioning specialists. Comparative measures quantifiably show the difference in performance between players who are proficient at a Division I collegiate level, and athletes who are striving to excel at that level. Because these values have not been created, performance deficiencies may not be addressed in remedial programs.

Warm-Up Procedures

The NSCA has indicated that broadly speaking, there are two types of warm up procedures that can be utilized prior to performance testing: specific and non-specific warm ups. There are many conflicting performance results regarding stretching prior to conducting performance-based testing procedures (Burkett, Phillips, & Ziuratits, 2005). There has been a substantial amount of research conducted regarding optimal warm-up conditions for performing the vertical jump. For example, Burkett et al. (2005) compared four different warm-up protocols in terms of their effect on vertical jump height. It was determined that a performance-specific warm-up, consisting of aerobic activities, jumping, and lunging, produced statistically significantly higher vertical jump values when compared to other commonly used warm-up protocols (Burkett et al., 2005). Static stretching was not used. In order to obtain the optimal vertical jump values, the warm up that was used in the current study focused on using similar exercises. To ensure consistency of the athletes who performed this battery of tests, a standardized warm-up was used for all participants. The specific warm up protocol is explained in greater detail in the Methods section.

Summary of Literature

Volleyball is a popular sport in the U.S. for both female and male athletes. Unfortunately, the research related to volleyball has not kept pace with the interest in participation. Volleyball requires many physiologic adaptations that include lower body power, agility, and anaerobic capacity in order to achieve optimal performance on the court. So that strength and conditioning specialists can develop optimal training programs for female volleyball athletes, more information is needed. Therefore, in this study, the vertical jump test, Agility T-Test, the 300-Yard, and the 150-Yard Shuttle run were used to measure lower body power, agility, and anaerobic capacity in female volleyball athletes at the high school and collegiate NCAA Division I level. Results were then further examined by player position. Sport-specific comparative values have been established for many male-oriented sports such as football, and female sports such as soccer, but these data have not been presented for female volleyball athletes.

CHAPTER III: METHODOLOGY

Participant Recruitment

High school-aged volleyball athletes were recruited from two schools in the Idaho 4A classification (enrollment 640 to 1,279) and two schools in the 3A classification (enrollment 320 to 639). The Idaho High School Athletic Association classifications are based on four-year enrollments in grades 9-12 with 5A as the largest classification and 1A is the smallest. Twenty-seven female varsity high school volleyball athletes were recruited from these four high school teams. Twenty-six NCAA Division I female volleyball athletes were also recruited from Boise State University (Western Athletic Conference) and Montana State University (Big Sky Conference). After Institutional Review Board (IRB) approval, the participants were contacted through the Head Coach at each school or University and individually asked for their participation. For the collegiate teams, participants were selected based on good-standing with the NCAA (NCAA eligible) and on their collegiate volleyball teams. NCAA ruled "Red-shirts" were excluded from the study due to their inability to compete in the season (typically due to medical or other reasons). Although these players may be included in the team roster, the red-shirts are ineligible to play a game in season. Because red-shirts are not eligible for competition, they may not represent the level of physiologic capabilities that are required for competition.

This study sought to examine the performance variations between high school and collegiate athletes. The NCAA allows all athletes to compete for a total of 4 years, over a 5 year period. The participants were selected from the collegiate volleyball teams because they demonstrated the necessary physiologic needs to sustain a high level of performance. The female volleyball team players from the selected schools represent high level performance in NCAA Division I volleyball. Logistically, it would be impossible to test all NCAA Division I volleyball teams, and these selected athletes will serve as baseline data and a foundation from which more high school and collegiate teams can be examined.

Participant Screening

Prior to completing the study, all participants signed an IRB approved consent form that indicated that they understood the purpose of the study, were healthy enough to perform vigorous physical activity, and were willing to participate in the experimental procedures. Because all participants were currently in their competitive season during data collection, they were performing vigorous physical activity on a daily basis. To be cleared for participation, participants had to answer "no" to all questions on the Physical Activity Readiness Questionnaire (PAR-Q; See Appendix), a medical health questionnaire that screens participants for pre-existing conditions that could potentially interfere with participation in the study. None of the potential recruits answered "yes" to any of the questions of the PAR-Q, therefore further clearance was not necessary for participation.

The study was reviewed and approved by the Boise State University IRB prior to data collection. Participants were informed that participation was voluntary and would not affect playing time, scholarships, or any team position. The volleyball athletes from both playing levels were not compensated for their involvement in the study. All participants were fully informed of the purpose of the study and of the testing procedures and benefits derived from participation. The PAR-Q and informed consent forms were obtained from all of the participants prior to the initiation of data collection. Participants were informed that they could withdraw from the study at any time without adverse consequences. Data collection and storage took precautions to uphold participant confidentiality (i.e., code numbers were used to identify athletes and data was be stored in a locked file cabinet). As an additional precaution, data were entered into a Microsoft Excel file and then transferred to an SPSS 18.0 file and stored on a portable external hard drive that was locked in the Boise State University Kinesiology building.

Data Collection Protocol

Field test performance tends to decline in the off season, especially for measures of agility (Moleenar, 2009); therefore, in order to show an accurate representation of performance capabilities in-season, data were collected from two teams during the end of the competitive season (October-November 2010) and, for two teams, within a two week period after their competitive season had ended. The tests were completed in the following order as recommended by the NSCA (least fatiguing to most fatiguing): Height, Mass, Vertical Jump, Agility T-Test, 150-Yard Shuttle run, and the 300-Yard Shuttle run. This test order was utilized, instead of random order, to mimic test protocols that are typically used by strength and conditioning coaches and to ensure that the tests can be accurately replicated. All tests are described later in this section.

Anthropometric Measures

Height and mass were measured using standardized procedures as recommended by the American College of Sports Medicine (ACSM) (2006). Participants were asked to remove shoes in order to obtain a height measurement. Height was measured using a stadiometer (Seca) to the nearest 0.1 cm. Mass was measured to the nearest 0.1 kg on a Tanita scale (model C 800), also without shoes.

Standardized Warm-Up Procedures

All participants performed a standardized warm up, followed by the testing protocol for all four tests. The standardized warm up included dynamic movements in order to properly warm up the body before testing. Sub-maximal jumps, active and dynamic stretching, and dynamic motions emphasizing quadriceps and hamstrings as agonistic muscle groups were included in the sport specific warm up. All athletes experienced an identical warm-up protocol prior to any testing procedures to limit the potentially confounding effect of using different warm-up procedures. All participants were asked to not participate in any physical activity 24 hours prior to testing. The standardized warm up consisted of the following activities. First, participants engaged in a brief warm-up jog around the perimeter of the gymnasium (i.e., two laps around the perimeter of the gym). Next, a series of 7 dynamic warm-up activities were performed over a 50 yard distance. The warm-up activities included: high knee jog, butt kicking jog, walking straight leg soldier kicks, lunges (both forward and backward directions), lateral shuffles, sprints at 50% and 80% of maximum speed, and 10 vertical warm-up jumps in place. Trained specialists led all warm-up activities in order to ensure that all participants were properly warmed up before testing.

Vertical Jump

After completing the warm-up procedure, vertical jump was assessed through a Vertec measurement system, which allowed the investigator to measure vertical jump to the nearest 0.5 inch. All participants were instructed on how to perform the vertical jump with a countermovement prior to beginning the vertical jump test. According to the NSCA, the vertical jump requires an individual to begin in an upright posture with feet shoulder width apart (Baechle & Earle, 2008). The height of the Vertec was then adjusted to the standing reach height, with the highest vane that could be reached and pushed forward with the dominant hand, while the the athlete stood flat footed. The athlete then moved into a semisquat position while simultaneously swinging the arms back in preparation for the jump. The arms were then swung forward above the head, while simultaneously jumping straight up into the air, reaching to touch the highest vane possible. The vertical jump test was terminated when the athletes landed on both feet at the same time (Baechle & Earle, 2008). All athletes took 2 practice trials after a warm-up period, and then data collection began. All participants performed 3 trials and the best score of the 3 trials was used in data analysis. All trials were recorded as to examine the variance between the trials. The vertical jump test was measured by a Vertec measurement system because it is a valid and reliable measure of vertical jump performance, with a Pearson correlation of .97 when compared to a 3-camera video system (Leard et al., 2007).

Figure 3.1: Vertec Measuring System

Calculated Lower Body Power

Upon completion of the data collection, peak lower body power was calculated using the following formula developed in 1999 by Sayers et al.

Peak Power (W) = 51.9 (jump height [cm]) + 48.9 (body mass [kg]) – 2007

Agility T-Test

According to the NSCA, the Agility T-Test is a used as a standard measure of agility requiring participants to move through a T-shaped pattern in as little time as possible. The cones were placed in a T-shaped pattern, as seen in Figure 2. An electronic timing device was used to initiate and terminate the time. An auditory signal was used to start the test, however, the timer actually started when the participant crossed the laser beam, and was terminated when the participant passed through the laser beam to complete the test. The athletes began the test by starting at cone A, sprinting forward to cone B, and touching the base of the cone with the dominant hand. The athletes then shuffled to the left 5 yards, to touch the base of cone C with the left hand. After touching cone C, the athlete then shuffled to the right 10 yards, to touch the base of cone D with the right hand. The athlete then shuffled to the left 5 yards and touched the base of cone B with the left hand. Finally, the athlete sprinted in reverse (also known as back-pedaling) to cone A, which terminated the time (Baechle & Earle, 2008). All athletes completed 2 practice trials and then performed 3 test trials. The best of the 3 trials (to the nearest 0.1 second) was used in data analysis. All trials were recorded so the variance between each trial could be examined. The Agility T-Test is a valid and reliable measure of agility performance with a reliability of 0.97 (95% CI: 0.93–0.98) and 0.90 (95% CI: 0.82–0.94) in women and men, respectively (Sassi et al., 2009).

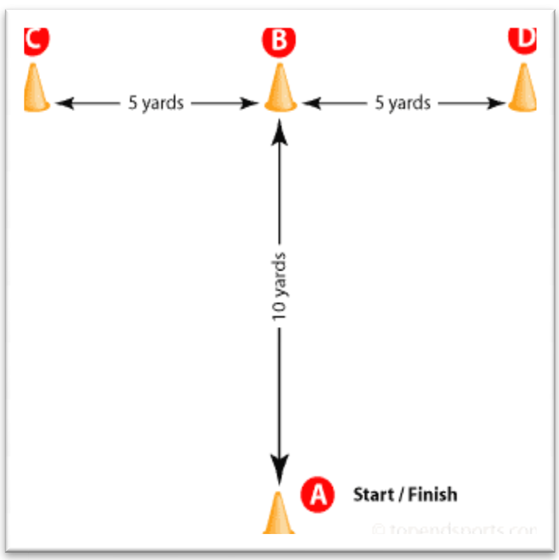

Figure 3.2: Agility T-Test

Anaerobic Capacity Tests (300-Yard and 150-Yard Shuttle Runs)

The 300-Yard Shuttle run, used to determine anaerobic capacity for each athlete, required setting up two clearly marked, parallel lines, 25 yards apart. Each participant started directly behind the initial line and began the test by sprinting forward 25 yards to the marked line, making foot contact with the line, and then immediately changing directions and sprinting forward back to the initial line. Each participant ran 6 round trips as quickly as possible (12 x 25 yards = 300 yards). Foot contact was required to touch the starting line and on the 25 yard line when changing directions. The time was terminated after the final trip was completed, as the body crossed the laser beam that was directly over the starting line (Baechle & Earle, 2008). The time was recorded to the nearest 0.1 second. All athletes performed 2 trials with a 5 minute rest in between trials to ensure recovery. Both trials were used in data analysis as to examine the variance between the trials, the consistency of the times, and the fastest time to completion. The 300-Yard Shuttle run has been repeatedly used as a form of measurement of anaerobic capacity (Baechle & Earle, 2008).

Similar to the 300-Yard Shuttle run, the 150-Yard Shuttle run requires two clearly marked, parallel lines, 25 yards apart. Each participant began the test by starting directly behind the initial line. The participant sprinted forward 25 yards to the next line, making foot contact with the line, and then immediately changed directions and sprinted forward back to the initial line. Each participant ran 3 rounds trips as quickly as possible (6 x 25 yards = 150 yards). Foot contact was required on the starting line and on the 25 yard line when changing directions. The time was terminated when the final trip was completed, as the body broke the laser beam, which sat directly above the initial line. Time was calculated to the nearest 0.1 second, and all athletes performed 2 trials with a 3 minute rest between trials to ensure recovery. Both test trials were recorded to examine trial variance. The best of the 2 trials was used to calculate group means. While the 300-Yard Shuttle run is used more frequently in perfomance testing, adjusting the test to fit the needs of the volleyball athlete may provide better information regarding anaerobic performance based on training programs.

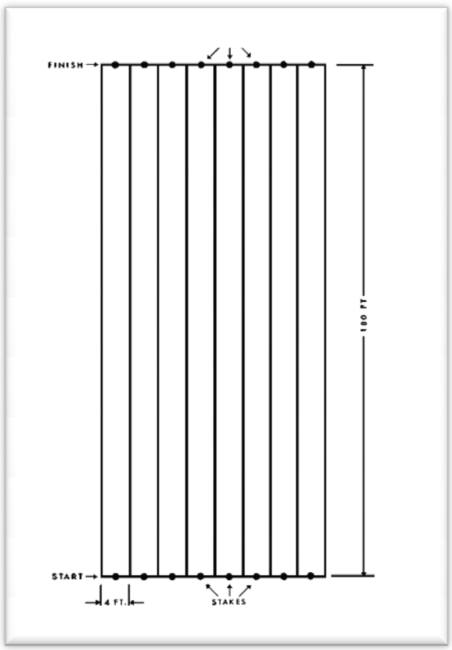

Figure 3.3: 300-Yard Shuttle Run

<u>Data Collection</u>

The data were collected at the location of the school for each team of athletes. Travel arrangements were made to collect data at the specific school's gymnasium. Each testing session took approximately 100 minutes including warm up and cool down periods. This time period depended upon the number of athletes who were tested together. After pilot data were collected, it was determined that groups of four athletes being tested together provided the optimal amount of rest and testing time. In the High School Varsity group, there were two testing sessions during which only two athletes were tested together. This was due to one team only having four participants in the study, and the participants could not attend the same testing session. All testing procedures and informed consent documents were provided to the head coach of each team. A recruiting flyer was also given to the head coach of each school or university.

The testing session consisted of:

- Informative discussion with question and answers: 15 minutes
- Height: 1 minute
- Mass: 1 minute
- Dynamic warm up: 10 minutes

The following three performance-based field tests were performed by each individual in a predetermined order to reduce the amount of fatigue from each subsequent test:

- Vertical Jump practice trials (2 trials): 5 seconds x 2= ~10 seconds
- Vertical Jump test (3 trials): 5 second x 3 = ~15 seconds
- Rest period: (3 trials x 1 minute rest) = ~3 minutes
- Agility T-Test practice trials (2 trials): 30 seconds x 2 = ~ 1 minutes
- Agility T-Test (3 trials): 30 seconds x 3 = ~1.5 minutes
- Rest period: (3 trials x 1 minute rest) = ~3 minutes
- 150- Yard Shuttle run (2 trials): 1 minute x 2 = ~2 minutes
- Rest period (2 trials x 3 minute rest) = ~6 minutes
- 300-Yard Shuttle run (2 trials): 1 minute x 2 = ~3 minutes
- Rest period (2 trials x 5 minute rest) = ~10 minutes

- Cool down: ~5 minutes

Due to the exhaustive nature of the tests, a five minute cool down was implemented, consisting of walking and static stretching. The principal investigator was the primary data collector. For the schools that required travel, certified strength and conditioning specialists helped to set up equipment.

Data Analysis

Data were collected and coded so it could be compared by competition level (High School Varsity and NCAA Division I) and player position (hitter, setter, back row specialist). To run these comparisons, a series of one-way ANOVAs with a Bonferroni post-hoc adjustment for potential inflation of type I error due to multiple comparisons among variables were used in tests that had more than two groups. A Cronbach's alpha test is a coefficient of reliability. The test is used to determine internal consistency which is also known as reliability. In order for a test to be considered reliable, a Cronbach's alpha of 0.80 or higher is needed (Cronbach, 1951). A Cronbach's alpha test for reliability was performed for Vertical Jump, Agility T-Test, the 150- Yard Shuttle run, and 300-Yard Shuttle run. The statistical analyses were completed using SPSS version 18.0 (SPSS Inc., Chicago, IL) to examine differences in test performance scores calculated for test by team, position, as well as for the skill grouping (High School Varsity and NCAA Division I).

To address hypothesis I (e.g., to determine differences in age, height, mass, agility, vertical jump, calculated lower body power, and anaerobic capacity between High School Varsity and Division I female volleyball athletes), a one-way ANOVA was used.

To address hypothesis II (e.g., to determine differences in age, height, mass, agility, vertical jump, calculated lower body power, and anaerobic capacity for positional differences (hitter, setters, and back row defense) in the sample population), a one-way ANOVA was used with a Bonferroni post-hoc adjustment for potential inflation of type I error.

To test hypothesis III and establish convergent validity between the 150-Yard Shuttle run and the 300-Yard Shuttle run, a Pearson Correlation was used.

CHAPTER IV: RESULTS

Sample Characteristics

Fifty-three high school varsity and NCAA Division I female volleyball players participated in the study. One NCAA Division I and four high school varsity participants were not physically cleared through their athletic trainer to perform all of the tests. Therefore, the results from the Agility T-Test, 150-Yard Shuttle Run, and the 300-Yard Shuttle Run were analyzed using 48 participants. The 53 test participants were 17.96 ± 2.029 years old, 172.48 ± 7.93 cm tall, 66.54 ± 7.798 kilograms in mass, and had played volleyball for an average of 7.69 ± 2.59 years. College athletes were significantly older, taller, and heavier, with more years of experience than their high school counterparts (see Table 4.1). The detailed characteristics of the sample population by skill grouping are outlined in Table 4.1. The detailed characteristics of the sample population by player position are outlined in Table 4.2.

Table 4.1: Demographic, Anthropometric, and Playing Information for Volleyball Athletes by Competition Level

	N	Age (yrs)	Height (cm)	Mass (kg)	BMI	Yrs Played
HS Varsity	27	16.25 ± 1.02	169.11 ± 7.61	63.30 ± 6.31	22.41 ± 2.18	6.48 ±1.74
NCAA DI	26	19.65 ± 1.64*** ($F_{(1,51)}$ = 127.46)	176.88 ± 6.03*** ($F_{(1,51)}$ = 18.14)	69.96 ± 7.72*** ($F_{(1,51)}$ = 11.89)	22.3 ± 1.88	9.04 ± 2.75
Combined	53	17.92 ± 2.03	172.48 ± 7.93	66.57 ± 7.74	22.36 ± 2.04	7.69 ± 2.59

Notes: Results are reported by Mean ± Standard Deviation. Levene's tests for homogeneity of variance indicated that variances for age (p = 0.821), height (p= 0.290), mass (p = 0.106), and BMI (p=0.331) were homogeneous.
Key. Differences between HS Varsity and NCAA DI are denoted by:
***p $\leq$ .001 revealing that NCAA Division I athletes were older, taller, and heavier than High School Varsity athletes

Table 4.2: Demographic and Anthropometric Information for Volleyball Athletes by Player Position

	N	Age (yrs)	Height (cm)	Mass (kg)	BMI
Hitters	31	18.06 ± 1.95	176.52 ± 6.24	69.29 ± 6.91	22.24 ± 1.84
Setters	5	16.80 ± 2.28	171.36 ± 7.70	71.52 ± 5.19	24.45 ± 2.34
BR Defense	13	18.00 ± 1.96	164.43 ± 4.99*** ($F_{(1,51)}$ = 18.14)	58.62 ± 5.13^{+++} ($F_{(1,51)}$ = 14.52)	21.71 ± 1.96$^{>>>}$ ($F_{(1,51)}$ = 3.77)

Note: Results are reported by Mean ± Standard Deviation
Key. Differences by player position are denoted by:
***p $\leq$ .001 with post-hoc testing revealing that hitters were significantly taller than back row defense
$^{+++}$p < .001 with post-hoc testing revealing that hitters and setters were significantly heavier than back row defense
$^{>>>}$p < .005 with post-hoc testing revealing that setters had significantly higher BMI values than back row defense

Test-Retest Reliability of Performance Test Results

The three Vertical Jump trials had a reliability coefficient of 0.932, which indicates that all three trials were reliable and consistent. The three Agility T-Test trials had a reliability coefficient of 0.762, which indicates that the three trials were not as reliable and consistent as is desirable (e.g., desired coefficient = 0.80 and higher). The two 150-Yard Shuttle Run trials had a reliability coefficient of 0.801, which indicates that the 150-Yard Shuttle demonstrates acceptable test-retest reliability. The two 300-Yard Shuttle Run trials had a reliability coefficient of 0.839, which indicates that test-retest reliability between the two trials was acceptable. These results were anticipated because of the anaerobic fitness level of the athletes. The results indicate that the anaerobic energy systems were rapidly replenished between trials, as fatigue was relatively low between each trial. Performance consistency was examined between trials of both the 150 and 300-Yard Shuttle run. Table 4.3 shows a visual representation of the 150 and 300-Yard Shuttle run trials and the differences between the trials by competition level. No significant differences were found between the differences in time to completion of the 150-Yard Shuttle run for competition level. No significant differences were found between the differences in time to completion of the 300-Yard Shuttle run for competition level. Table 4.4 shows a visual representation of the 150 and 300-Yard Shuttle run trials and the differences between the trials by player position.

Table 4.3: Raw Score Differences in Trials for the 150 and 300-Yard Shuttle Run by Competition Level

	N	150 SR Trial 1 (sec)	150 SR Trial 2 (sec)	Difference in Trials (sec)	300 SR Trial 1 (sec)	300 SR Trial 2 (sec)	Difference In Trials (sec)
HS Varsity	27	31.35 ± 2.15	31.74 ± 2.03	-0.354 ± 1.63	69.61 ± 6.20	70.42 ± 7.96	-0.812 ± 5.28
NCAA D I	26	30.45 ± 1.33	29.99 ± 1.40	0.711 ± 1.57	68.57 ± 3.55	69.42 ± 7.96	-1.45 ± 2.74

Note: Results are reported by Mean ± Standard Deviation

Table 4.4: Raw Score Differences in Trials for the 150 and 300-Yard Shuttle Run by Player Position

	N	150 SR Trial 1 (sec)	150 SR Trial 2 (sec)	Difference in Trials (sec)	300 SR Trial 1 (sec)	300 SR Trial 2 (sec)	300 SR Difference In Trials (sec)
Hitters	31	31.31 ± 1.99	30.83 ± 1.69	0.6607 ± 1.65	69.39 ± 5.38	69.88 ± 6.48	-0.883 ± 3.56
Setters	5	30.37 ± 1.46	30.12 ± 1.63	0.270 ±1.96	69.16 ± 5.62	69.82 ± 3.56	-1.56 ± 2.25
BR Defense	13	30.29 ± 1.59	31.09 ± 2.39	-0.203 ± 1.33	69.40 ± 4.80	71.27 ± 7.25	-1.862 ± 6.10

Note: Results are reported by Mean ± Standard Deviation

Performance Test Results by Skill Grouping

Vertical Jump Test

Levene's test for homogeneity of variance was not statistically significant (p= 0.192), indicating that the variances in vertical jump scores were consistent. A one-way ANOVA comparing vertical jump between high school varsity athletes (M= 47.58 ± 8.22 cm) and Division I (M= 52.95 ± 6.59 cm) athletes revealed that differences in Vertical Jump scores were statistically significant ($F_{(2,46)}$ = 0.86, p= 0.008). The high school varsity athletes had significantly less vertical jumping ability than the college athletes. Calculated lower body power was examined using data from the vertical jump test. A one-way ANOVA between high school varsity (M= 3592.3 ± 522.82 W) and Division I (M=4160.67 ± 598.34 W) revealed that differences in Lower Body Power were statistically significant ($F_{(2,46)}$ = 19.02, p=0.001). High school athletes had significantly less lower body power than their collegiate counterparts.

Agility T-Test

Levene's test for homogeneity of variance was not statistically significant (p=0.708), indicating that variances were similar. A one-way ANOVA between Agility T-Test scores for high school varsity (M=10.55 ± 2.19) and Division I athletes (M=10.24 ± 2.15) revealed that the Agility T-Test was not statistically different between groups ($F_{(1,49)}$ = 4.13, p=0.065).

150-Yard Shuttle Run

Levene's test for homogeneity of variance was not statistically significant (p=0.708), indicating that the variances were similar. A one-way ANOVA comparing 150-Yard Shuttle run scores for high school varsity athletes (M=29.73 ± 6.20 sec) and Division I athletes (M=28.67 ± 5.98 sec) revealed that the 150-Yard Shuttle run ($F_{(1,49)}$ = 5.77, p=0.021) was significantly different by competition level.

300-Yard Shuttle Run

Levene's test for homogeneity of variance indicated that variances for the 300-Yard Shuttle run were not statistically different (p=0.477). A one-way ANOVA comparing 300- Yard Shuttle run scores for high school varsity athletes (M=62.92 ± 19.10 sec) and Division I athletes (M=65.05 ± 13.77) revealed that the 300-Yard Shuttle run ($F_{(1,48)}$ = 0.043, p= 0.723) scores were not significantly different in high school and college athletes. Table 4.5 provides a visual presentation of the detailed information regarding the performance measures, which have been listed by competition level.

Table 4.5: Performance Information for Volleyball Athletes by Competition Level

	N	CMVJ (cm)	Power (W)	T-Test (sec)	150 SR (sec)	300 SR (sec)
HS Varsity	27	47.58 ± 8.22	3592.3 ± 522.82	10.55 ± 2.19	29.73 ± 6.20	62.92 ± 19.10
NCAA D I	26	52.95 ± 6.59*** ($F_{(2,46)}$ = 0.86)	4160.67 ± 598.34^{+++} ($F_{(2,46)}$ = 19.02)	10.24 ± 2.15	28.67 ± 5.98$^{>>>}$ ($F_{(1,49)}$ = 5.77)	65.05 ± 13.77
Combined	53	49.91 ± 7.95	3838.95 ± 620.31	10.39 ± 2.15	29.21 ± 6.06	63.96 ± 16.58

Note: Results are reported by Mean ± Standard Deviation
Key. Differences by player position are denoted by:
***p ≤ 0.05. NCAA DI athletes jumped significantly higher than high school athletes
$^{+++}$p ≤ 0.05. NCAA DI athletes had significantly higher lower body power than high school athletes
$^{>>>}$p ≤ 0.05 NCAA DI athletes had significantly faster 150-Yard shuttle run times than high school athletes

<u>Performance Test Results by Player Position</u>

<u>Vertical Jump Test</u>

A one-way ANOVA comparing vertical jump by Player Position (Hitter: M= 50.92 ± 7.09 cm, Setter: M= 53.34 ± 9.99 cm, and Back Row Defense: M= 48.46 ± 8.90 cm) revealed that Vertical Jump was not significantly different by player position ($F_{(2,46)}$= 0.81, p=0.453). Lower body power was examined in the Vertical Jump test using a one-way ANOVA between Player Position (Hitter: M= 4025.46 ± 531.17, Setter: M= 4260.63 ± 673.24, and Back Row Defense: M= 3374.88 ± 552.12). Lower body power was significantly different by player position ($F_{(2,46)}$= 7.75, p < 0.0005). A Bonferroni post-hoc test revealed that both Hitters (p< 0.0005) and Setters (p= 0.004) demonstrated higher levels of lower body power when compared to Back Row Defenses.

Agility T-Test

A one-way ANOVA comparing the agility test results by Player Position (Hitter: M=10.85 ± 0.51 sec, Setter: M= 10.42 ± 0.46 sec, and Back Row Defense: M=10.76 ± 0.68 sec) revealed that agility was not significantly different by player position ($F_{(2,46)}$= 1.28, p= 0.289.

150-Yard Shuttle Run

A one-way ANOVA compared 150-Yard Shuttle run scores by Player Position (Hitter: M=30.59 ± 1.66 sec, Setter: M= 29.61 ± 1.37 sec, and Back Row Defense: M=30.08 ± 1.73 sec) revealed that there were no significant differences in 150-Yard Shuttle run by player position ($F_{(2,44)}$= 0.99, p= 0.381).

300-Yard Shuttle Run

A one-way ANOVA comparing 300-Yard Shuttle run scores by Player Position (Hitter: M= 68.08 ± 5.40 sec, Setter: M= 68.47 ± 4.87 sec, and Back Row Defense: M= 67.84 ± 5.074 sec) revealed that there were no significant differences between scores on the 300-Yard Shuttle run ($F_{(2,44)}$= 0.026, p= 0.974) .

Table 4.6 provides a visual presentation of the detailed information regarding the performance measures, which have been listed by player position.

Table 4.6: Performance Measures by Player Position

	N	CMVJ (cm)	Power (W)	T Test (sec)	150 SR (sec)	300 SR (sec)
Hitters	31	50.92 ± 7.09	4025.46 ± 531.16	10.85 ± 0.51	30.59 ± 1.66	68.08 ± 5.40
Setters	5	53.34 ± 9.99	4260.63 ± 673.23	10.42 ± 0.46	29.61 ± 1.37	68.47 ± 4.87
BR Defense	13	48.46 ± 8.90	3374 ± 552.12 ***($F_{(2,46)}$= 7.75, $p < 0.05$)	10.76 ± 0.68	30.08 ± 1.73	67.84 ± 5.074

Note: Results are reported by Mean ± Standard Deviation
Key. Differences between HS Varsity and NCAA DI were denoted by:
*** post hoc test revealed that both Hitters ($p< 0.0005$) and Setters ($p= 0.004$) demonstrated higher lower body power when compared to Back Row Defenses.

Convergent Validity Correlation between the 300 and 150-Yard Shuttle Run

A Pearson Correlation between the 300 and 150-Yard Shuttle Run revealed a correlation of 0.488, which corresponds to a moderate correlation. The results of this test do not establish convergent reliability.

CHAPTER V: DISCUSSION AND CONCLUSIONS

Discussion

The primary purpose of this study was to examine physiologic performance test differences between female volleyball players based on level of competition and player position. This was accomplished by comparing data from four performance-based tests (e.g., Vertical jump, Agility T-Test 150-Yard Shuttle run, and 300-Yard Shuttle run) that predict volleyball performance by competition level and player position. The results of the study can be used to identify the deficiencies in performance in high school volleyball athletes. The secondary purpose of the study was to examine the relationship between the 150-Yard Shuttle run and the 300-Yard Shuttle run in order to determine convergent validity of the two tests and to establish whether the 150-Yard Shuttle run can be used in the same manner as the 300- Yard Shuttle test to establish anaerobic capacity. An additional question to consider is which test is the best test for anaerobic capacity that is needed in volleyball game play.

The most important findings of this study were that: (a) college volleyball athletes were older, heavier, and taller, than their high school counterparts; (b) compared to collegiate athletes, high school athletes had performance deficiencies in the Vertical Jump, Lower Body Power, and the 150-Yard Shuttle run; (c) there were no differences found between Agility T-Test and 300-Yard Shuttle run when collegiate athletes were compared to their high school counterparts; (d) back row defensive players had less lower body power than hitters or setters and other performance measures were not statistically different; and, (d) the 150-Yard Shuttle run did not demonstrate convergent validity with the 300-Yard Shuttle run in volleyball players.

The expected findings from the study were that age, height, and mass differed by skill grouping and that height and mass differed by player position but not age. Results from data analysis from anthropometric measures indicated that Division I players were older, taller, and heavier than high school varsity players. These results may be due to increased age, as NCAA Division I players are on average 3 years older than the participants from the High School Varsity population. Taller players may be at a greater advantage and could be better suited for the demands of volleyball, especially for hitters. Lidor & Ziv (2010) found similar results when performing a review of current volleyball literature. Typically, increased body height is associated with increased body mass. The results from the current study indicated that hitters are taller than back row defensive players. Hitters and setters are heavier than back row defensive players. These anthropometric results coincide with previous literature that cites the importance of increased stature for volleyball performance (Fry et al., 1991; Sheppard et al., 2010). The anthropometric measures in volleyball positions however, have not been well established in female volleyball athletes. Anthropometric information is currently available for elite male volleyball athletes by player position (Sheppard et al., 2010). Further examination is needed to establish positional requirements and normative values for anthropometric measures.

It was hypothesized that Division I female collegiate athletes would have higher performance scores on all measures when compared to varsity high school female volleyball athletes. Based upon the results, the first hypothesis was only partially supported. The Vertical Jump test scores and lower body power were consistently higher and 150-Yard Shuttle run scores were faster in NCAA Division I athletes compared to high school varsity volleyball athletes. The fact that Division I players jumped higher and had higher lower body power than high school varsity players could be indicative of better strength and conditioning programs for the NCAA Division I volleyball players. Recent research has noted that strength and conditioning programs for high school female athletes are lacking (Reynolds et al., in press). NCAA Division I volleyball athletes are typically older, and heavier, which also may indicate more muscle mass. The strength and conditioning programs that enhance physiologic adaptations necessary for volleyball and these programs have been shown to increase sport performance (Nesser & Demchak, 2007; Sheppard et al., 2008).

Kasabalis (2005) compared lower body power in vertical jump to anaerobic power in the Wingate Anaerobic Test (WAnt) in 56 adults (18-25 yr.), juniors (15-16 yr.), and youth (10-11 yr.). After the effect age was accounted for, it was determined that there was a group difference in peak power between juniors, youth and adults (A: 10.13± 1.23 W/kg, J: 10.4 ± 0.71 W/kg, Y: 7.45 ± 1.0 W/kg, $p<0.05$); a post-hoc test indicated that adults and juniors were able to produce higher lower body peak power than youth. There was not a group difference between juniors and adults for lower body power. It was also determined that there was a group difference in vertical jump height between all age categories, which indicated that adults were able to jump higher than juniors, and both groups were able to jump higher than youth (A= 46.68 ± 4.47 cm, J= 44.41 ± 6.69 cm, Y= 25.44 ± 4.13 W/kg, $p<0.01$). These results for male volleyball athletes were compared to a non-athletic population in the same age groupings. Volleyball athletes had higher lower body peak power and vertical jump scores in all age categories. (Kasabalis, 2005). Nesser and Demchak (2007) reported vertical jump scores for 14 NCAA Division I volleyball athletes as 40.85 +/- 3.7 cm. Barnes et al. (2007) reported values for Division I, II, and III females volleyball athletes of DI: 36.4 +/- 2.5 cm, DII: 31.8 +/- 4.6 cm, and DIII: 32.6 +/- 5.1 cm which is lower than both the high school varsity and the Division I groups that were used in the current study.

Vertical jump was examined in 16 high school female volleyball athletes (ages 15.5 ± 1.5 yrs) after performing a following stepping off of a box of a specified height. The highest vertical jumps were reported after stepping off of the lowest box height of 15 cm, the highest vertical jump values were 38.4 ± 3.5 cm (Ford, Myer, Brent, & Hewett, 2009). These values are substantially lower than the results from the current sample of high school varsity players. In 2007, talent identified junior volleyball athletes reported vertical jump scores of 46.0 +/- 11.2 cm (Gabbett, Georgieff, & Domrow, 2007); this is extremely similar to the 47.58 ± 8.22 cm that is reported in the current sample of high school volleyball athletes. Table 5.1 summarizes previous vertical jump literature in comparison to the current findings from the study.

Table 5.1: Comparison of Previous Vertical Jump Literature to Current Findings

CMVJ (cm)			
		Previous	Current
Similar Population	HS Varsity	Gabbett et al. (2007): 46.0 ±11.2	47.58 ± 8.22
	Division I	Nesser & Demchak (2007): 40.85 ± 3.7 Sheppard et al. (2008a): 38.9 ± 8.6 Barnes et al. (2007): 36.4 ± 2.5	52.95 ± 6.59
Dissimilar Population	Male Elite	Marques et al. (2009): 49.7 ± 5.3 Dyba (1982): USA: 71.4 ± 6.33 Canada: 71.0 ± (nr)	X
	Female Division: II, & II	Barnes et al. (2007): DII: 31.8 ± 4.6 DIII: 32.6 ± 5.1	52.95 ± 6.59

The lacking component in previous studies that examined vertical jump is the position-specific vertical jump scores. If a coach were to select athletes based upon the criteria from Gabbett et al. findings in 2007, they may skip over qualified back row defensive players who did not demonstrate a similar vertical jump score. Having this information available for coaches and athletes by player position would theoretically increase the ability of the coach to recognize volleyball performance talent in players by position and help the athlete know what specific performance areas need improvement.

The Agility T-Test performance measure indicated that Division I and high school varsity players have statistically similar times to completion. Many of the high school varsity athletes had never performed this test before, and even with the practice trials, the results showed high variability between each test trial. Results for the Vertical Jump, 150-Yard Shuttle Run, and 300-Yard Shuttle Run demonstrated acceptable test-retest reliability, while the Agility T-Test did not show acceptable test-retest reliability. The lack of reliable trials may have contributed to the lack of group and positional differences. The lack of reliable trials may be due to the Agility T-Test mimicking footwork that is necessary in back row defensive positions, but may not be as emphasized in Hitters and Setters. The sample population consisted of 36 players who did not specialize in back row defense, and 13 back row defensive players. In 2007, talent identified junior volleyball athletes reported times of 10.49 ± 0.96 seconds (Gabbett et al., 2007), which is very similar to the findings from the current study for high school athletes who are of similar age. Nesser and Demchak (2007) reported times of 10.01 ± 0.06 seconds, which is also very similar to the current findings for NCAA Division I athletes. Table 5.2 summarizes pervious Agility T-Test literature and the current findings.

Table 5.2: Comparison of Previous Agility T-Test Literature to Current Findings

Agility T-Test (sec)			
		Previous	Current
Similar Population	HS Varsity	Gabbett, et al. (2007): 10.49 ± 0.96	10.55 ± 2.19
	Division I	Nesser & Demchak (2007): 10.01 ± 0.06	10.24 ± 2.15
Dissimilar Population	Males	Jarvis et al. (2009): 12.5 ± 1.3 Sassi et al. (2009): 10.08 ± 0.46	X
	College Females	Baechle & Earle (2008): Competitive: 10.8 ± (nr) Recreational: 12.5± (nr) Sassi et al. (2009): 11.92 6 0.52	10.24 ± 2.15

More information about the Agility T-Test needs to be examined with a larger sample size to determine agility by player position.

The 150-Yard Shuttle run performance measure indicated that Division I players have faster 150-Yard Shuttle run times when compared to high school varsity players. This may be due to increased emphasis in sprinting in collegiate strength and conditioning programs. Player position had no effect on 150-Yard Shuttle run scores, which indicates that all positions had statistically similar times to completion. The 300-Yard Shuttle run performance measure indicated that Division I and high school varsity players have statistically similar times. Player position had no effect on 300-Yard Shuttle run scores, which indicates that all positions had statistically similar times to completion. Table 5.3 summarizes previous 300-Yard Shuttle run times to completion in comparison to the current 300-Yard Shuttle run times. The Pearson correlation indicated a moderate relationship between the two tests.

Table 5.3: Comparison of Previous 300-Yard Shuttle Run Literature to Current Findings

300-Yard Shuttle Run (sec)			
		Previous	Current
Similar Population	HS Varsity	X	62.92 ± 19.10
	Division I	X	65.05 ± 13.77
Dissimilar Population	Males	Sporis et al. (2008): Soccer Pre: 56.99 ± 1.64 Soccer Post: 55.74 ± 1.63	X
	College Females	Teitelbaum (2004) Pre: 70.45 ± (nr) Post: 75.45 ± (nr)	65.05 ± 13.77

Because there were no differences between the two groups, it is possible that the 300-Yard Shuttle is too long of a test to adequately measure the anaerobic capacity of volleyball athletes. It is significantly longer than the typical rally during play. The lack of difference between the groups may be due to training that does not consistently require volleyball athletes to run for that long of a distance. Another potential explanation is that the two tests may be measuring two different variables. Because convergent validity was not established through a Pearson correlation, further investigation should be performed on the 150-Yard and 300-Yard Shuttle run to determine the ability to measure anaerobic capacity in volleyball athletes.

The second hypothesis was that there would be higher Vertical Jump scores for hitters, when compared to setters and back row defensive players. This hypothesis was not supported as Vertical Jump scores were not statistically different by player position.

Player position had no effect on Vertical Jump scores, which indicates that all positions jumped statistically similar heights. All player positions demonstrated similar vertical jump heights, which may represent the lack of specificity in current strength and conditioning programs. In communication with the coaches of the participants, all players from the same team experience the identical training program. The lack of specificity in strength and conditioning programs indicates that training time is possibly not being used optimally to create the highest level of performance in all positions. If all of the players have the same training stimulus, even through performance demands are different by player position, similar performance outcomes may be a result. Another explanation for these results may be that taller players rely on their height, while shorter players may have to increase vertical jump in order to be competitive players. The lack of differences seen in vertical jump between player positions may indicate that shorter players (often found in defensive players) have adapted to the increase in performance demand during training sessions, even though this is not an important performance component for defensive players.

It was interesting that vertical jump was not different by player position, yet calculated lower body power was lower in Back Row defensive players compared to Hitters and Setters. Because both Hitters and Setters rely on jumping (Hitters with a greater emphasis on jumping than Setters) for performance, this result is not surprising. Lower body power is not emphasized as much in volleyball performance for back row defensive players.

Player position had no effect on Agility T-Test scores, which indicates that all positions had statistically similar time to completion. NCAA Division I athletes indicated that they regularly performed this type of drill, but often the test was not timed. There are many reasons why no differences were found between player positions for the Agility T-Test. As was specified previously, the strength and conditioning programs for athletes are not position specific. When all of the athletes perform the same program, similar adaptations are expected. Limited data is available for movement patterns required by player position. Another potential explanation for the lack of difference found between positions is that there may not be a large difference in movement patters. Typically hitters, setters, and back row defensive players all practice defensive footwork and movement patterns, while defensive players typically do not practice attacking patterns and footwork. The Agility T-Test mimics typical footwork patterns that are required for defensive volleyball performance. While all positions typically practice these skills, it would not be surprising that all positions performed statically similar in times to completion.

The results from the Levene's test for homogeneity of variance for the Agility T-Test indicated that the three trials did not have homogeneous variances. Additionally, the Agility T- Test was not deemed reliable in this sample. A possible explanation of this could be that only three trials may not capture true group and positional differences because of high variability of the scores. Additional familiarity trials and performance trials of the Agility T-Test may be necessary to capture reliable scores.

The third hypothesis was that the 150-Yard Shuttle run would show high convergent validity when compared to the 300-Yard Shuttle run. The data did not support this hypothesis due to a Pearson Correlation of 0.488, which corresponds to a moderate correlation. The results from this study are not able to determine if the 150-Yard Shuttle run is more appropriate for volleyball athletes. Further testing is needed to evaluate the 150-Yard Shuttle run in relationship to volleyball performance. Fry et al. (1991) determined that a 2-mile run showed no differences in starters and non-starters in NCAA Division I female volleyball athletes. Their conclusion was that the distance was too long to reflect any differences between groups (starters and non-starters). In conversations with the coaches of the current sample populations, strength and conditioning programs focus on short distance sprinting, anaerobic weight lifting, and plyometrics for increased power. The 300-Yard distance that is used in the 300-Yard Shuttle run is not a distance that is used for training purposes in a typical strength and conditioning program for volleyball athletes. The athletes that performed the test commented on the difficulty of the test, and primarily that they had not had to sprint 300 yards during season. More information is needed to determine the validity of the 150 and the 300-Yard Shuttle run in female volleyball athletes. No known studies have compared the 300-Yard Shuttle run to a Wingate Anaerobic Test (WAnT), a highly reputable test for measuring anaerobic capacity, in female volleyball athletes. The 150-Yard Shuttle run had an average time to completion of 29.21 ± 6.06 seconds. The WAnT is a 30-second test that primarily relies upon the phosphagen system (with minimal additional energy supplied from the glycolytic energy system) that more closely mimics the average time to completion in the 150-Yard Shuttle run. The 300-Yard Shuttle run had an average time to completion of 63.96 ± 16.58 seconds. Based upon the time to completion in the 300-Yard Shuttle run, the aerobic energy system may have been relied upon to complete the test. The aerobic energy system is not used as a primary fuel source during volleyball performance, but is relied upon for energy replenishment during rest periods (Kunstlinger et al., 1987). Based on this information, the 300-Yard Shuttle run should be reviewed for use in female volleyball athletes for validity in measuring anaerobic capacity.

This study has presented numerous interesting findings. Nevertheless, it is not without limitations. The high school and NCAA Division I sample may not be representative of all high school and Division I female volleyball athletes simply because there were only two NCAA Division I teams that were included in the study. Because of this sample, only two strength and conditioning programs were employed with the collegiate athletes. While both teams employ a full-time certified strength and conditioning coach, the programs that were implemented during the pre-season and season training periods may not represent the training stimulus for all NCAA Division I volleyball teams. This relatively small sample size provides baseline data to begin to examine physiologic differences in high school varsity volleyball athletes and NCAA Division I athletes. The NCAA Division I teams play in different conferences, yet neither of these conferences (Western Athletic Conference and the Big Sky Conference) regularly produce NCAA Championship caliber teams with the exclusion of the University of Hawaii. This limitation also applies to the selected high school teams: three of the schools that were selected went on to the State Tournament, however, none of the teams went on to win the State Championship.

Further study should be done to investigate the physiologic performance measures with a larger sample size that provides a more representative sample of volleyball players across the country. This study seeks to create a starting point that would ideally prompt further study of other NCAA Division I conferences and high school volleyball teams. Further information should be collected to facilitate learning more about the use of performance-based tests and how they relate to volleyball performance. There is currently very little information about how performance-based testing translates into on court performance. Future studies should examine the importance on performance-based testing for volleyball game performance. It is also important to examine the anthropometric and physiologic characteristics of high school athletes who go on to play NCAA Division I volleyball. It is currently difficult to draw conclusions if NCAA Division I are selected because of their increased physiologic performance or if the players develop these qualities upon participation in the program.

Future research projects should also consider comparing the results of the 150 and 300-Yard Shuttle run with volleyball performance to determine whether the 150-Yard Shuttle run is an adequate performance measure for anaerobic capacity.

Sport specific norms have been developed for male athletes in sports such as basketball, baseball, and football and have been published through the National Strength and Conditioning Association (Baechle & Earle, 2008. Mayhew, McCormick, Levy, & Evans, 1987). The established norms help to create a benchmark by which incoming and current athletes can measure performance. Sport-specific performance values give strength and conditioning specialists performance and comparative measures that are quantifiable. Players striving to improve volleyball performance need clear expectations of skill and performance measures to succeed. Normative values have not been established for collegiate or high school female volleyball athletes, which creates a major deficit for the strength and conditioning programs designed to improve the performance of volleyball athletes.

Conclusions

The results of the study indicate that college volleyball athletes were older, heavier, and taller, than their high school counterparts. While this is an expected outcome, it does not explain if these results are the effect of age, or if taller, heavier players perform better in volleyball competition. It has been shown that increased stature is advantageous for volleyball performance (Marques et al., 2009). These values may help coaches prepare high school athletes for the height and weight demands that they will be facing when considering playing at the collegiate level. Collegiate athletes showed higher vertical jump, lower body power, and time to completion in the 150-Yard Shuttle run than high school athletes. These tests indicate that high school athletes showed decreased lower body power and anaerobic capacity. It is important that future volleyball training programs address lower body power as a performance component so that high school athletes are able to generate more force in the lower limbs and position themselves more optimally for hitting and blocking. Because NCAA Division I players have increased lower body power, they have a mechanical advantage because of their increased stature and position with the ball when attacking. Replicating these physiologic components in high school athletes would theoretically improve volleyball performance in hitters. Anaerobic capacity was lower in high school athletes, which may also be reflective of the training program. Because NCAA Division I players have increased anaerobic capacity, they have an increased ability to sustain performance at high physiologic demands. Replicating these physiologic components in high school athletes would theoretically improve volleyball performance in all positions.

The only statistically significant difference in the performance test measures by player position was calculated lower body power. This may be reflective of the decreased need for or decreased development of lower body power in back row defensive players.

The 150-Yard Shuttle run did not demonstrate convergent validity with the 300-Yard Shuttle run in volleyball players. This indicates that more research needs to be performed in order to fully understand the relationship of the tests in relationship to each other, and the ability of the 300-Yard Shuttle run to predict anaerobic capacity in female volleyball athletes.

This information that has been obtained through this study has served to begin a more comprehensive understanding about the performance differences between high school and collegiate athletes. A feature of the study is that performance test differences are available to athletes and to strength and conditioning specialists that would serve to improve programs to improve volleyball performance. Specifically high school strength and conditioning programs can focus on improving vertical jump, lower body power, and anaerobic capacity. These programs should include position-specific exercises that emphasize the physiologic adaptations that are necessary to excel in that position for volleyball performance. The information derived from this study serves as a starting point to examine differences in performance, based on player position and competition level, which should be expanded by future research to fully understand the performance differences in competition level, and by player position. The results of the study help to establish baseline data, and provide a means to test the effectiveness of various training programs designed to address performance deficits. The information that is reported through this study makes test values available to female athletes across age, player position, and competition level. These specific comparative values creates a baseline performance measure that now may better equip strength and conditioning coaches to create programs that would address deficits in player performance.

REFERENCES

Amasay, T. (2008). Static block jump techniques in volleyball: Upright versus squat starting positions. *Journal of Strength and Conditioning Research*, *22*(4), 1242-1248.

Baechle, T., & Earle, R. (2008). *Essentials of strength training and conditioning* (3rd ed.).Champaign, IL: Human Kinetics, 292-304.

Barnes, J., Schilling, B., Falvo, M., Weiss, L. Creasy, A., & Fry, A. (2007). Relationship of jumping and agility performance in female volleyball athletes. *Journal of Strength and Conditioning Research*, *21*(4),1192–1196.

Black, B. (1995). Conditioning for volleyball. *Strength and Conditioning Journal*, *17*(5), 53-55.

Burkett, L., Phillips, W., & Ziuraitis, J. (2005). The best warm-up for the vertical jump in college-age athletic men. *Journal of Strength and Conditioning Research*, *19*(3), 673–676.

Carbuhn, A., Womack, J., Green, J., Morgan, K., Miller, G., & Crouse, S. (2008). Performance and blood pressure characteristics of first-year National Collegiate Athletic Association division I football players. *Journal of Strength and Conditioning Research*, *22*(4), 1347-1354.

Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297-334.

Dyba, W. (1982). Physiological and activity characteristics of volleyball. *Volleyball Technical Journal*, *6*(3), 33-51.

Ford, K., Myer, G., Brent, J. & Hewett, T. (2009). Hip and knee extensor moments predict vertical jump height in adolescent girls. *Journal of Strength and Conditioning*, *23*(4),1327-1331.

Fry, A. Kraemer, W., Weseman, C., Conroy, B., Gordon, S., Hoffman, J., & Maresh, C. (1991). The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *Journal of Applied Sport Science Research*, *5*(4), 174-181.

Gabbett, T., Georgieff, B., & Domrow, N. (2007). The use of physiological, anthropometric, and skill data to predict selection in a talent-identified junior volleyball squad. *Journal of Sports Sciences*, *25*(12), 1337-1344.

Gutiérrez, D. & Marcos, M. (2009). A comparison of two landing styles in a two-foot vertical jump. *Journal of Strength and Conditioning Research*, *23*(1), 325-331.

Hedrick, A. (2007). Training for high level performance in women's collegiate volleyball: Part 1 training requirements. *Strength and Conditioning Journal, 29*(6), 50-53.

Jarvis, S., Sullivan, L., Davies, B., Wiltshire, H., & Baker, J. (2009). Interrelationships between measured running intensities and agility performance in subelite rugby union players. *Research in sports medicine*, *17*(4), 217-230.

Kasabalis, A. (2005). Relationship between anaerobic power and jumping of selected male volleyball players of difference ages. *Perceptual and Motor Skills*, *100*(1),607-614

Kunstlinger, U., Ludwig, H., & Stegmann, J. (1987). Metabolic changes during volleyball matches. *International Journal of Sports Medicine*, *8*(5), 315-322.

Leard, J., Cirillo, M., Katsnelson, E., Kimiatek, D., Miller, T., Trebincevic, K., & Garbalosa, J. (2007). Validity of two alternative systems for measuring vertical jump height. *Journal of Strength and Conditioning Research*, *21*(4), 1296-1299.

Lidor, R., & Ziv, G. (2010). Physical and physiological attributes of female volleyball players- A review. *Journal of Strength and Conditioning Research*, *24*(7), 1963-1973.

Marques, M., Tillaar, R., Gabbett, T., Reis, V., Badillo, J. (2009). Physical fitness qualities of professional volleyball players: Determination of positional differences. *Journal of strength and conditioning research*, *23*(4), 1106-1112.

Mayhew, JL., McCormick, T., Levy, T. & Evans, G. (1987) Strength norms: Strength norms for NCAA Division II college football players. *Strength and Conditioning Journal*, *9*(3), 67-69.

Molenaar, A. (2009). A comparison of conditioning levels between off-season and competition season for division II women's volleyball. Unpublished master's thesis, Northern Michigan University, Ann Arbor, Michigan. Retrieved April 3, 2010 from ERIC database.

National Federation of State High School Associations. (2010). 2008-09 High School Athletics Participations Survey: Based on Competition at the High School Level in the 2008-09 School Year. Retrieved from: http://www.nfhs.org/content.aspx?id==3282&linkidentifier=

Nesser, T., & Demchak, T. (2007). Variations of preseason conditioning on volleyball performance. *Journal of Exercise Physiology Online*, *10*(5), 35-42.

Patterson, D., & Peterson, F. (2004). Vertical jump and leg power norms for young adults. *Measurement in Physical Education & Exercise Science*, *8*(1), 33-41.

Pauole, K., Madole, J., Garhammer, M., Lacourse, M., & Rozenek, R. (2000). Reliability and validity of agility, leg power, and leg speed in college aged men and women. *Journal of Strength and Conditioning Research*, *14*(4), 443-450.

Prokopec, M., Padevetová, M., Remenár, M., & Zelezný, J. (2003). Morpho-physiological characteristics of young female volleyball players. *Papers on Anthropology*, 12, 202-218.

Reynolds, M. Ransdell, L., Lucas, S., & Petlichkoff, L. (2010). An examination of strength training practices in a sample of varsity high school athletic programs in Idaho. NSCA Conference Proceedings, p. 720.

Sassi, R. Haj, D., Wajdi, Y.,Haj, M., Gmada, N., Mahfoudhi, M., & Gharbi, Z. (2009). Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. *Journal of Strength and Conditioning Research*, *23*(6), 1644-1651.

Sayers, S. Harackiewicz, D., Harman, E., Frykman, P., Rosenstein, M., (1999). Cross-validation of three jump power equations. *Medicine and Science in Sports and Exercise*, *31*(4), 572-577.

Secora, C., Latin, R., Berg, K., & Noble, J. (2004). Comparison of physical and performance characteristics of NCAA Division I football players: 1987 and 2000. *Journal of Strength and Conditioning Research, 18*(2), 286-291.

Seidel, B. L. (1975). *Sports skills: A conceptual approach to meaningful movement.* Dubuque, Iowa: W.C. Brown Co.

Sheppard, J. Cronin, J., Gabbett, T., McGuigan, M., Etxebarria, N., & Newton, R. (2008a). Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. *Journal of Strength and Conditioning Research*, *22*(3), 758–765.

Sheppard, J., Dingley, A., Janssen, I., Spratford, W., Chapman, D., & Netwon, R. (2011). The effect of assisted jumping on vertical jump height in high-performance volleyball players. *Journal of Science and Medicine in Sport*, *14*(1), 85-90.

Sheppard, J., Gabbett, T., Claudio, R., & Newton, R. (2010). An analysis of playing positions in elite international men's volleyball: Considerations for competition demands and physiologic characteristics. *Journal of Strength and Conditioning Research*, *24*(1), 1-21.

Sheppard, J., Gabbett, T., Kristie-Lee, T., Dorman, J., Lebedew, A., Borgeaurd, R. (2007). Development of repeated-effort tests for elite men's volleyball. *International Journal of Sports Physiological Performance,* 2, 292-304.

Sheppard, J., Hobson, S., Barker, M., Taylor, K., Chapman, D., McGuigan, M., & Newton, R. (2008b). The effect of training with accentuated eccentric load counter-movement jumps on strength and power characteristics of high-performance volleyball players. *International Journal of Sports Science & Coaching*, *3*(3), 355-363.

Sheppard, J. & Young, W. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, *24*(9), 919-932.

Sporis, G., Ruzic, L., & Leko, G. (2008). The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning program. *Journal of Strength and Conditioning Research*, 22(2), 559-566.

Teitelbaum, S. (2004). Adherence and physiological responses to an unsupervised summer training program for a collegiate women's volleyball team. Unpublished master's thesis, University of Oregon. Eugene, Oregon

Vescovi, J. & Mcguigan, M. (2008). Relationships between sprinting, agility, and jump ability in female athletes. *Journal of Sports Sciences*, *26*(1), 97-107**.**

Whaley, M., Brubaker, P., Otto, R., & Armstrong, L. (2006). *ACSM's guidelines for exercise testing and prescription*. Philadelphia, Pa: Lippincott Williams & Wilkins.

APPENDIX

Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire (PAR-Q) & YOU

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before starting to become much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by your doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of any other reason why you should not do physical activity?

If you answered

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may able to any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful to you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

Participant Code____

SIGNATURE ____

SIGNATURE OF PARENT____
Or GUARDIAN (for participants under the age 18)