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Correlations Between Anthropometric Measurements and Sport Specific Field-Based Tests in Sitting Volleyball

A Thesis

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Abstract

Introduction: Sitting volleyball is a Paralympic sport widely known for being a game of speed, agility, performance, and endurance. While many fitness tests can be used to assess specificity of sport, the combination of field tests and anthropometric measurements can provide an in depth look into sitting volleyball. **Purpose**: The purpose of this study is to see if there are any correlations between anthropometric parameters and field tests within the game of sitting volleyball. **Methods**: Upon completion of the informed consent document, the participant's demographic and anthropometric measurements were assessed by the researchers. Additionally, the participants completed an assigned survey. Lastly, all athletes were asked to complete the sports-specific field tests in a gymnasium setting. The tests were performed by the U.S. Women's Paralympic sitting volleyball athletes. The specific tests administered were: handgrip (HG) analysis, the seated chest press test (SCP), speed & agility test (SAT), as well as a speed & endurance test (SET). **Results:** According to the Pearson correlation coefficient test, there were significant correlations between the athlete's height and spike position ($r = 0.853$, $p = 0.031$). Other significant correlations found were between handgrip and chest pass (Watts) ($r = 0.913$, $p = 0.011$), which was measured using time and distance from the seated chest pass test, as well as blocking position and the speed and agility test ($r = 0.888$, $p = 0.044$), and blocking position and the speed and endurance test ($r = 0.93$, $p = 0.022$). The strongest correlation was shown between speed and agility and the speed and endurance tests ($r = 0.964$, $p = 0.008$). **Discussion:** The aim of the present study was to identify correlations between sport specific field-based tests and anthropometric measurements. Anthropometric measurements and non-laboratory field tests specific to sitting volleyball can be useful for the coaching staff to determine which player is best suited for a specific position and the athletes' overall performance on the court. The main

findings from the present study were significant correlations with the athletes' height and spike position, hand grip strength and chest pass power, blocking position and SAT, blocking position and SET, and SAT and SET.

Introduction

Background and Significance

The world of Paralympic sitting volleyball consists of a fast paced, exciting, and skilled game (About Sitting Volleyball, 2020). Not long after the creation of the Paralympic Games in 1960, men's sitting volleyball was introduced in 1980 at the Summer Olympics. Twenty-four years later women's sitting volleyball was introduced in 2004 at the Athens Summer Olympics. The most recent Paralympic Games were held in Rio De Janeiro, Brazil in 2016, where ~4,350 athletes from more than 160 countries competed. These athletes competed in 528 medal events in 22 different sports (International Paralympic Committee, 2016).

The game of sitting volleyball began in the Netherlands as a type of rehabilitation for soldiers in 1956 and is now considered one of the most recognized team sports in the Paralympic Games (About Sitting Volleyball, 2020). To be considered a Paralympic athlete, one must have a qualifying disability which is determined by two trained medical classifiers. These two professionals measure the athlete's functional loss and are either categorized as minimally disabled (MD) or disabled (D), (About Sitting Volleyball, 2020). Athlete eligibility is determined by a sports-specific classification system uniquely made for the sport of sitting volleyball (World ParaVolleyball, 2020). For classification standards, impairments or conditions are based on the loss of locomotor function, this also includes other musculoskeletal and neurological conditions. Examples include impaired muscle power and range of motion, limb deficiencies like amputations, as well as appendage length differences (World ParaVolleyball, 2020). Similar to "standing volleyball", sitting volleyball has six athletes on either side of the net with one ball in play. The ball is only allowed three touches, with an exception for a block, for an offensive strategy that involves a dig or a pass, a set, and a spike or a kill to earn the point (World

ParaVolleyball, 2020). One key difference between sitting volleyball compared to standing is the ability for players to block serves. The matches are limited to the best three out of five, in which the first four sets conclude at 25- points with the last set to 15-points and the team must win by two points. While a majority of the rules are similar between sitting and standing volleyball, one major difference includes the height of the net, which is set at 1.15m vs. 2.24m for men and 1.05m vs. 2.19m for women. Additionally, the dimensions of the court have a smaller perimeter compared to a normal size court (10m x 6m vs.18m x 9m). Aside from court specifications, in-game play varies as well. For example, for sitting volleyball, the athlete must maintain contact with the floor with their body between their shoulders and buttocks (Sitting Volleyball, 2020).

Knowing that sitting volleyball athletes are required to perform numerous athletic movements throughout a game, researchers have attempted to assess sport-specific field tests to see if the tests do in fact have positive utility for performance (Marszalek et al, 2015). While these aforementioned studies and publications have occurred in different countries throughout the world, to our knowledge, no literature has been performed for the United States National Paralympic Sitting Volleyball teams. Field test data and anthropometric measurements can allow coaches and athletes information to design or change current fitness programs, determine which player is more effective on the court, as well as analyze and develop individual's skills and understanding of the game.

Hypothesis and Purpose

The purpose of this study is to see if there are any correlations between anthropometric parameters and field tests within the game of sitting volleyball.

Research Question: Are there any correlations between the sport specific field tests and anthropometric measurements in sitting volleyball?

Null Hypothesis: There are no correlations between sport specific field tests and anthropometric measurements within the game of sitting volleyball.

Research Hypothesis: There will be non-directional correlations between sport specific field tests and anthropometric measurements in sitting volleyball.

Limitations, Delimitations, and Assumptions

Limitations of this study include the location of testing within the University of Central Oklahoma Wellness Center, which could produce outside factors interfering with testing. These factors could include bystanders and other individuals visiting the gymnasium floor while the tests were being administered. Other limitations could include the testing environment, such as sun-light from large windows, time of day, air temperature, humidity, as well as floor conditions like cleanliness and proper maintenance issues. Another limitation of this study is that of the participants and the willingness to provide maximal effort and full participation of the tests being performed. Lastly, this study is being conducted during the Covid-19 Pandemic, which was a direct impact on participation rates, and overall accessibility to the athletes.

Delimitations of this study include the sample of participants who are sitting volleyball athletes and have passed classification criteria from the International Paralympic Committee (IPC). The athletes also must be able to perform all physical requirements of each field test without pain or discomfort. Specific inclusion criteria for the Women's U.S. National sitting volleyball teams are individuals aged 18 to 40. The participants voluntarily arrived the day of testing, ready to perform all field tests and understand directions of the researchers.

Operational Definitions

- Anaerobic Performance: The body's ability to produce mean power output (MP), peak power (PP), relative peak power (rPP) and relative mean power (rMP), as well as fatigue index (FI) (Marszalek et al., 2015).
- Anthropometric Measurements: Basic measurements that are recorded to indicate the participant's individual height, weight, and body mass index (BMI) (Riebe, Ehrman, Liguori, & Magal, 2018). (As well as arm reach, blocking height, and attack height)
- Unilateral Transfemoral Amputation: A transfemoral amputation is the process in which the lower-limb has been removed at or above the knee joint, unilateral meaning it is only impacted one side of the body (Zane, 2019).
- VO_{2max}: The maximum amount of oxygen consumed per unit time and is recorded as $mL/kg/min^{-1}$ (Riebe et al., 2018).
- VO_{2peak}: The maximum performance limited by muscular factors when VO_2 does not level off (Riebe et al., 2018).

Systematic Literature Review

Introduction

Sport specific field-based tests are conducted for many different reasons. Sitting volleyball requires athletes to play with a high level of physical fitness, along with technical and tactical skills to maintain the highest level of competition. The game involves speed, endurance, agility, and dynamic movements, along with court awareness and mental toughness (Jadczak, Śliwowski, Wieczorek, & Wieczorek, 2009). With the use of field-tests and anthropometric measurements, coaches can accurately observe and record athletes' individual results, which can provide viable information regarding the athletes' position and skill performance. This systematic literature review will summarize the findings and results from multiple articles, discussions, as well as limitations and gaps in the literature.

Methods

Current Sport-Specific Field Tests

A study performed by Marszalek et al. (2015) examined the relationships between field tests, anaerobic performance, as well as game performance in sitting volleyball players. Twenty Polish sitting volleyball athletes (12 males, 8 females) participated in a Wingate Anaerobic Test (WAnT) with an arm crank ergometer, along with six different field tests. These tests included: (1) 3m sprint, (2) 5m sprints, (3) chest pass, (4) a modified T-test for shuffling along the court, (5) a speed and agility test, and (6) a speed and endurance test. All tests were recorded along with anthropometric measurements, which included seated block position, arm reach length, and spiking position. Next, the players were observed during the World Championship in Elblag 2014. A professional volleyball league statistician recorded the results using the Games Observation Sheet in Sitting Volleyball. Results suggested a strong correlation between peak power, chest pass, and mean peak power ($r = .846$; $p = .001$ and $r = .708$; $p = .005$) and performance parameters. While rapidly performed movements are important for sitting volleyball, it is also suggested that anthropometric measurements can be directly correlated with one's arm reach, and location of the block in accordance with the spike.

A similar study to Marszalek et al. (2015) was Jeoung (2017) who explored the relationship between field fitness and game performance of sitting volleyball players in Korea. The study included forty-five participants from the Korean National Sitting Volleyball team, ages 27-50. Based upon graded exercise tests (GXT) and coaching assessments (blocking, serving, defense, and serve receive), the results showed that all assessments had a positive relationship on the athletes' abilities to attack, block or perform a serve. The results of the chest pass, overhand throw, one-handed throw, one-handed side throw, splint, speed endurance, reaction time, and total graded exercise test time ($p < 0.01$) all attributed to athletes' abilities to serve, block, and attack the ball. Anthropometric measurements included were waist circumference, seated vertical reach, height, weight, and shoulder back scratch. These measurements were not tested for a correlation to the other variables.

Previous literature suggests agility and speed tests can be valid and reliable. For example, Souto, Oliveira, Neto, & Greguol (2015) examined the reliability and validity of an Agility Test for Sitting Volleyball (ATSV). A modified 6m movement analysis was performed by eight participants (44 ± 12 years) in two separate trials by four different examiners. The T-shaped course was performed at maximal speed while the participant stayed in a sitting position. Results showed ICC > 0.90, which suggests this assessment is reliable and valid based on the instruments used in this study. In addition to specific speed and mobility tests, Molik et al. (2008) suggests speed, power, and agility can be assessed by a battery of sport-specific field-tests. Other studies have tested reliability and validity of agility, speed, endurance, seated chest pass, and handgrip analysis tests. For example, Ahmadi, Uchida, and Gutierrez (2019) assessed fifteen total athletes from the Brazilian National Sitting Volleyball team (*n* = 7 males and *n* = 8 females). Within this study, five different tests were assessed (1) agility, (2) speed & agility, (3) speed & endurance, (4) seated chest pass, and (5) handgrip analysis. The results showed that the men had statistically significant differences in agility, speed & agility, speed & endurance, and seated chest pass test performance compared to the female athletes ($p = 0.001\text{-}0.03$), however no differences were seen between handgrip scores. An interesting finding from Singhal et al. (2013) suggests that agility may also be linked to hand-positioning. Specifically, it is suggested that hands positioned on the lateral sides of the body show to be significantly quicker compared to other hand positioning near the body.

Jadczak, Śliwowski, Wieczorek, and Wieczorek (2009) examined Polish sitting volleyball athletes anthropometric and fitness levels. Specifically, the participants' level of physical fitness in accordance with an athlete's degree of disability along with coordination abilities. An assessment of physical fitness included a handgrip test, upper limb dynamic strength and endurance tests, core muscle strength and flexibility, as well as speed and endurance tests. Coordination abilities assessed reaction time, orientation tests, attention divisibility, and one's perception. The group of athletes with medium disability showed on average higher handgrip and core muscular strength values compared to the healthy and significantly disabled groups. These findings are quite novel as it is the author's opinion this is the first study to assess athletes' abilities based upon one's degree of disability.

A recent study from Nunes de Araújo et al. (2019) examined static and dynamic postural control within a group of 16 participants, the study divided amputees with unilateral transfemoral amputations ($n = 8$) and physically active individuals with no form of amputations ($n = 8$). Using a stable and unstable surface balance assessment differences were seen between the amputee and control group. Specifically, the eight amputees performed worse on the static and dynamic postural control analysis tests, with exceptions of the Rhythmic Weight Shift (RWS) and the center of gravity velocity Sit-to-Stand (STS) test. Interestingly, no differences were seen for the STS test between the groups. Additionally, center of gravity (COG) sway was higher for amputees compared to non-amputees.

The importance of anthropometric measurements, such as height, seated vertical height, weight, and arm range is apparent in many sitting volleyball studies. An example of this comes from a study by Marszałe, Molik, and Gomez (2018), which examined the differences in game efficacy in male and female volleyball players, in terms of their physical impairment. The researchers classified the athletes into categories with players having minimal disabilities, single above knee amputation, and lateral below knee amputation, as well as upper limb impairments. This study observed no differences in range of motion of arm spike, block, or attack related to players' physical impairments. There were not any statistically significant differences in the athletes' anthropometric parameters and physical impairments.

Molik, Kosmol, and Skucas (2008) examined different sport-specific and general physical fitness tests among the Lithuanian sitting volleyball club ($n = 7$) and players from the Polish National sitting volleyball team ($n = 14$). A total of six sport-specific and general physical fitness tests were conducted. These tests included serving accuracy, moving a distance of 5m, serving the ball with both hands, as well as moving around the court using a rectangle envelope 1.5m x 2.5m. Results showed significant differences between the two teams in the modified envelope test and the 5m distance test. The Polish athletes had an eight second difference during the envelope tests, on average, it was also confirmed that the Polish team had better locomotor skills ($p = 0.006$). Height was an important dependent variable that showed a positive correlation to the athletes' ability to serve the ball ($r = 0.527$, $p < 0.05$). Additionally, age presented a positive relationship on the 5m sprint, serving, and the envelope test ($p = 0.05$). The authors confirmed the three tests: (1) sprint for 5m, (2) the modified envelope test for moving around the court, (3) serving the ball with both hands from the chest position, were reliable to evaluate fitness as well as skill-level in the game of sitting volleyball.

Field Test Comparison to Other Sitting Sports

Adapting physical fitness to those with disabilities is a continuous challenge. Thanks to the guidance and research by Byankina et al. (2018), there is now a strategy for implementing this for athletes. Specifically, Byankina et al. (2018) created a list of exercises for major muscles and joints. To see if the aforementioned exercises made a positive impact on performance, all athletes' general fitness was assessed using a pull-up test, elbow flexion/extensions, and other upper body strength tests. The authors concluded that it may be important to spend more time on the general physical fitness of an athlete who may have limited mobility due to their disability. The author also suggests the largest amount of time, 48-52%, be spent on general physical fitness during the initial stage f the time. Following the initial stage, general physical fitness drops to 20-24% of the time during the actual training stage, and finally 15-19% of the time during the athletic perfection stage. The decrease in general fitness over time is related to the change of training stages from initial training to the training stage, then concluding with the athletic perfection stage.

Bernardi, Guerra, Di Giacinto, Di Cesare, Castellano, & Bhambhani. (2010), studied different Paralympic athletes in their respective sports to determine field evaluations. The teams that they studied were Nordic sit skiing (*n* = 5), wheelchair distance racing (*n* = 6), wheelchair tennis (*n* = 4), wheelchair basketball (*n* = 13), and wheelchair fencing (*n* = 6). This study analyzed five different sitting sports to determine the relationship between aerobic fitness measured in the laboratory and field-test performance. The results showed that all five sports delivered exercise intensities that surpassed the minimum exercise intensity recommendations from the American College of Sports Medicine. It is important to note that each athlete completed the given field-tests according to their sport. An incremental arm crank (ACE) test was recorded, then each sport had its own sport-specific field test completed. This included (1) Nordic sit skiing completing a simulated 5km outdoor cross-country skiing race, (2) Wheelchair racing completed a simulated 5km outdoor track event, (3) Wheelchair fencing completed tests within pairs with real fencing weapons, (4) Wheelchair tennis completed a normal two-set tennis match lasting around 50-70 minutes, and lastly (5) Wheelchair basketball completed the evaluation within an indoor gymnasium during the first or second half of a game. Results suggest that regardless of sport type, these aforementioned sports rely heavily on aerobic fitness. Peak values of heart rate and VO2 were significantly higher for Nordic sit skiing and wheelchair racing.

Marszałek et al. (2019) examined sport-specific field-tests within the world of wheelchair basketball. The purpose of this study was to determine the validity of different laboratory versus non-laboratory anaerobic assessments with elite male wheelchair basketball players. The participants (*n* = 61) performed the WAnT, along with a 3 m sprint, 5 m sprint, 10 m sprint, 20 m sprint, chest pass test using a basketball as well as a 3kg medicine ball, handgrip analysis, and agility drills. Significant differences were found in the 3m sprint (p = 0.004), 5m sprint (p =

0.004), as well as the basketball chest pass ($p = 0.001$) and the medicine ball chest pass ($p = 0.001$).

De Witte et al. (2018) examined field-based wheelchair mobility performance tests along with the validity and reliability of the tests. The subjects ($n = 46$) were organized in two separate groups of 23 participants. One group was asked to perform the test twice to determine the test retest reliability. Based on the norms, the researchers found that the males performed better than the female subjects ($p < 0.001$) considering the absolute scores, as well as the international wheelchair basketball athletes scored better compared to the national team athletes ($p < 0.001$). This study found that validity could be tested by creating a mobility performance field-based test known as the Wheelchair Mobility Performance (WMP) test. This 15 activity based test was designed to be easy without the use of advanced equipment and conducted in a realistic wheelchair basketball setting.

Marszałek et al. (2019) found that four out of the eleven field-tests, 3m and 5m sprints, basketball and medicine ball chest pass tests were statistically significant between the higher and lower categories in wheelchair basketball athletes. This study showed that individuals who scored higher in the sprints and chest pass tests had higher levels of power, peak power, and relative peak power.

A study by Molik et al. (2013) compared the relationship between field-tests, functional levels, and anaerobic performance of female wheelchair basketball athletes. This study used a handgrip analysis, chest pass, 5m sprint, and 20m sprint for their sport-specific field-tests. The participants were categorized into two groups, group A ($n = 9$) and group B ($n = 14$) according to their classification level according to the International Wheelchair Basketball Federation (IWBF). Group A was made up of 1.0-2.5 point players and Group B was made up of 3.0-4.5

point players. The results showed that Group B scored significantly better in all of the tests except for the shooting test. The researchers believed that there was a strong relationship between mean power (MP) and peak power output using the two-handed chest pass test, which can be used to indirectly assess anaerobic performance in wheelchair basketball athletes.

In summary, the literature review highlighted many different studies that utilized anthropometric measurements and field-based tests shows correlations between the two variables and to understand athletes' levels of physical fitness. The most common current sport-specific field tests in sitting volleyball include, but are not limited to, handgrip analysis, modified speed and endurance and agility drills, and the seated chest pass test. Tests were compared to anthropometric parameters, showing a direct or indirect relationship between them. Some of the common field-based tests were also used in other sitting sports, such as wheelchair basketball. Although the sports may differ, these tests can provide researchers modifications that can be utilized to assess physical fitness within the sport of sitting volleyball.

Methodology

Participants

Six females from the U.S. National Women's Sitting Volleyball Team volunteered to participate in the study, ages were 25.5 ± 4.51 years, height 170.15 ± 6.44cm, and weight 80.89 ± 25.67kg. All athletes, coaches, and athletic trainers were familiarized with the procedures and protocols for each test being administered. Participant inclusion criteria states that individuals must be cleared for play by the coaches and medical staff to participate in testing and all tests will be performed at the University of Central Oklahoma's Wellness Center. An exclusion criterion states that any athletes who have existing injuries and individuals who have been declassified by the IPC standards will not be able to participate in the study. For the present study, one participant was not able to perform the SAT or SET, all other variables have a total sample of 6 participants, while the SAT and SET only had 5. Due to COVID-19, there were a limited number of participants. The participants for this study included resident teammates who were able to make it to practice that day.

Pretest Survey

A short pretest survey was given to the participants prior to the start of field testing (Appendix A). The survey entails demographic questions and exercise experience/status. The participants reported how many days of the week they train, for volleyball specifically, as well as the hours and/or minutes for each training session. The first question on the survey asks if the athletes have any existing injuries and if they do, they indicated the injury and pain associated. The second question asks if the athlete is currently involved in any other training, such as resistance training, muscular endurance, balance or flexibility programs and if so, how many hours per week the training sessions last. The third question asks how long the athlete has been playing competitive volleyball. Lastly, the survey asked their degree of amputation or limitation. The pretest survey was given to the athletes before data collection began.

On average, the participants train for 5.4 days/week with an additional average of total hours spent training was equal to 14.4 hours each week. Five out of the six participants indicated that they participate in some sort of exercise outside of practice. The average years of playing competitive volleyball accumulated to 10.5 years between the six participants. The amputation or limitation type ranged from lower limb, specifically, below-knee amputations on either leg to congenital missing hands and club foot with limited flexion and rotation in the lower limb.

Procedures

Upon completion of the informed consent document (Appendix A) and assent form (Appendix B), the individuals completed the assigned survey (Appendix C), then had their anthropometric measurements completed by the researchers. Following these measurements, the athletes completed the sports-specific field tests. All tests were conducted in a gymnasium setting (around 29-31 degrees Celsius). The four tests were: A handgrip (HG) analysis, seated chest press test (SCP), speed & agility test (SAT), as well as a speed & endurance test (SET). Anthropometric measurements and field-based test were recorded on the Data Collection Document (Appendix D). The order of the field-tests was conducted in accordance with the National Strength and Conditioning Association (NSCA) guidelines, of non-fatiguing tests first, maximum strength test second, maximum power third, sprint test fourth, and aerobic capacity tests last (Haff and Triplett, 2015).

Testing

Strength

The athletes began with their normal warm-up routine with dynamic movements with their partners. Handgrip (HG) strength was measured using a handheld dynamometer. Participants held the dynamometer by their side and squeezed the handgrip as hard as they could for ~5-seconds. Three different trials were conducted for the participant's dominant hand, an average of the three trials was recorded in kilograms (kg). The rest period between trials was 30-seconds. A seated chest pass (SCP) test was designed to measure upper-body strength while the shoulders are horizontally adducted and the elbows are fully extended.

Power

A 3kg medicine ball was thrown by the athletes with their feet positioned 60 cm apart, seated with their legs extended and back against a wall. The athletes held the ball with both hands on either side of the ball, centered against the chest with elbows at their sides. Upon verbal command, the participants threw the ball as hard as they could, the distance from the wall to where the ball landed was recorded in centimeters. Two maximal efforts were given; the best score out of the two trials was recorded. Rest period between trials was 30 seconds. Calculations for Watts was expressed as (3kg converted to newtons) multiplied by distance (meters) divided by time (seconds)

The speed and agility test (SAT) was conducted to assess movement on the volleyball court. The protocol for this test is defined by Marszalek et al. (2015) and explained to the participants prior to beginning. After a signal from the administers, the participant will begin with cone A and move forward to cone B, then shuffle to the right of the cone to cone C, then back to cone A. After coming back to cone A, the participant will move forward to cone D, then circle back to cone B. Then the participants will shuffle from cone B to the right to cone E. As fast as they can, the participants will then finish by returning to cone A. Two trials were conducted and recorded in seconds, with 30 seconds rest between trials and 1-minute between performing the SAT and SET tests (Figure 1).

The final field test is the speed and endurance test (SET). The test administrator will measure a 5m x 6m square then place the starting cone A in the middle of the first horizontal 6m line. Cones B, C, and D are placed 1m apart on the right side of the 5m line. Cones E, F, and G are placed on the opposite 5m line. The test was explained to the participants prior to beginning. The participants will start at cone A, then shuffle from cone B back to cone A, then proceed to each cone and back to cone A. The two trials were recorded and the average was calculated. Two trials will be conducted and the two trials are recorded in seconds, rest period was 30 seconds between trials (Figure 2). Both tests were to be performed as fast as the athlete could to the best of their ability. The speed and agility test measured the athletes' speed and ability to change direction accurately from cone to cone. The speed and endurance test measured their speed in seconds to move from each cone while maintaining

Table 1.

Team Norms for each Specific Assessment

Field-Tests	Mean (SD)
Dominant Limb	Right
Height in Block Position (two hands) (cm)	132.67 ± 6.50
Height in Spike Position (dominant Limb) (cm)	135.13 ± 6.86
Wingspan (cm)	159.43 ± 8.09
Hand Grip Average (kg)	27.12 ± 9.22

Best Med Ball Pass (cm)	367.37 ± 33.50
Best Med Ball Pass(sec)	0.88 ± 0.15
Power (Watts)	125.22 ± 27.26
Best SAT (seconds)	12.33 ± 1.24
Best SET (seconds)	28.51 ± 4.77

Statistical Analysis

All statistical tests were carried out by IBM SPSS Statistics Version 24 statistical analysis program with the level of significance measurement set at ($p<0.05$*, $p<0.01$**). All descriptive statistics were used according to the study objectives. A Pearson correlated coefficient analysis was used to examine the relationships between the field tests and anthropometric measurements.

Results

According to the Pearson correlation coefficient test, there were significant correlations between the athletes height and spike position ($r = 0.853$*, $p = 0.031$). Other significant correlations found were between handgrip and Watts from the chest pass test ($r = 0.913$*, $p = 0.011$), blocking position and the speed and agility test ($r = 0.888$*, $p = 0.044$), and blocking position and the speed and endurance test ($r = 0.93$*, $p = 0.022$). The strongest correlation was shown between speed and agility and the speed and endurance tests ($r = 0.964$**, $p = 0.008$).

Discussion

The aim of the present study was to identify correlations between sport specific field-based tests and anthropometric measurements. Anthropometric measurements and non-laboratory field tests specific to sitting volleyball can be useful for the coaching staff to determine which player is best suited for a specific position and the athletes' overall performance on the court. The main findings from the present study were significant correlations with the athletes' height and spike position, hand grip strength and chest pass power, blocking position and speed and agility, blocking position and speed and endurance, as well as a correlation between the speed and agility and speed and endurance tests. The present study observed a positive correlation with time and person. Thus, this meant that the slower the time in the speed and endurance trails correlated to the taller the individual.

Non-Performance Observations

The pretest survey showed on average, the participants train for 5.4 days/week with an additional average of total hours spent training was equal to 14.4 hours/week. The athletes' amputation type varied from upper extremity amputation to lower extremity amputation or specific limitations. Five out of the six participants indicated that they participate in some sort of exercise outside of practice. The average years of playing competitive volleyball between the participants for the present study is 10.5 years. The present studies average years of playing experience is similar to Molik, Kosmol, & Skucas (2008) who observed an average of 11.8 and 12.9 years of training for sitting volleyball per player for the Poland and Lithuania teams, respectively. While training and experience are important for growth and success on the court, it is suggested that athletes with large amounts of experience have an advantage on the court based upon their understanding and knowledge of the sport.

Anthropometrics and Field Based Testing

The present study observed a taller position when the athlete was in their spike position. During a block position the athletes' keep their bottom on the floor with their elbows extended and their fingers spread to cover more surface area of the ball, but in the spike position the non-dominant arm reaches backwards like a bow-and-arrow to create more torque used to hit the ball at the height of the ball's position. The Pearson analysis test showed a significant correlation between height and spike position ($r = 0.853^*$, $p = 0.031$). Spike position had a higher correlation based on the seated position of the players, as they were extended with one hip lifted higher than the other therefore one's height can positively or negatively impact a higher spiking position. The present findings contrast Molik et al. (2008), who did not find a significant correlation between athlete's overall height and the range of reach in the sitting position. The authors attributed the lack of correlations due to athletes' limited range of motion in their upper limb joints, additional reasons possibly attributing to dissimilar correlations could be related to sample size of ($n = 21$) participants from Molik et al. (2008) compared to the present study ($n = 6$). While overall height of the present studies athletes attributed to an athletic position (spike), additional findings suggest that blocking position is strongly correlated with the SAT and SET. Interestingly, the present study had a positive correlation with blocking height and SAT. Thus, the greater one's blocking position, the slower their SAT times are.

Marszalek et al. (2015) saw significant negative correlations with block position and the SAT ($r = -0.505$, $p \leq 0.004$). While the present study differs with block position and SAT compared to Jeoung (2017), they found no significant relationships between spike and block position on speed and agility. Jeoung (2017) found that blocking position and speed and endurance was a negative correlation ($r = -0.32$, $p < 0.01$). This study reported that speed and endurance factors played a part in overall defense and receiving skills, whereas Marszalek et al. (2015) found speed and endurance had no effect on overall performance of volleyball skills. Although there was a negative correlation, the current study found a positive correlation, which meant that there was an inverse relationship between person and time. There are many factors that could have yielded a negative correlation for Marszalek et al. (2015) based on the demographics and sample size of their study. The sample size was 20 Polish sitting volleyball players, which included males and females (*n*=12 males, 8 females) with an average age of 35.5 and 30.5 years, respectively. The current study only had female participants with an average age of 25.5 years. The 2015 study did not provide height from the blocking position, but measured the athletes three times with the accuracy within 0.5cm and recorded the average. This study also performed a 30-second anaerobic test on an arm crank ergometer, then participated in six field tests, and concluded with anthropometric measurements such as height in the blocking and spike position, as well as lateral arm reach. Jeoung (2017) also reported negative correlations between blocking and SAT. The participants of this study were 45 sitting volleyball players from the Korean National volleyball game from 2016-2017 with an average age of 42.5 years old, they did not disclose if the athletes were male or female. These differences could aid in the different correlations found in these studies compared to the present study.

An interesting finding for the present study is the strong correlation with the SAT and SET tests ($r = 0.964$). As described in the methods section, the SAT and SET tests are both multi-directional tests. While the aim of each test (agility and aerobic endurance specific) may have direct application with sport, the present investigation observed no differences between the two, thus, the potential reason for significant correlations between both tests could technically be tied back to multi-direction demands of the sport of sitting volleyball, however, future research is warranted to elaborate on what specific mechanisms (central or peripheral) may attribute to similarities with outcomes.

Lastly, the present study observed a significant correlation between handgrip and power. This correlation was also observed in an article by Molik et al. (2013), with handgrip and the chest pass test, as well as the 20m sprint with wheelchair basketball athletes. While the present study focused on a separate population compared to Molik et al. (2013) (sitting volleyball vs. wheelchair basketball), it is plausible that ballistic based movements may be tied back to overall strength levels. However, further research is needed to accurately assess sport specific field-based tests and anthropometric measurements in sitting volleyball athletes.

Limitations of this study include the location of testing within the University of Central Oklahoma Wellness Center, which could produce outside factors interfering with testing. These factors could include bystanders or other individuals visiting the gymnasium floor while conducting the tests. Another limitation of this study is that of the participants and the willingness to provide maximal effort and full participation of the tests being performed. This study was conducted during the Covid-19 Pandemic, which was a direct impact on participation rates, and overall accessibility to the athletes. Some of the athletes who were able to participate in the study were considered residential athletes, which refers to them living in the area and having the ability to practice within their set schedule. There were athletes who moved closer to the practice site to optimize practice time before the upcoming season.

The present study highlighted the need for further research to develop a battery of field-based tests that could be used to assess physical fitness and athletes' skills on the court. One of the main limitations of the present study was the number of participants. We were not in contact with the athletes themselves, only the Women's National team coach. The coach then relayed the information to the athletes that we would be conducting tests, but not when we were coming officially. Communication during further studies could improve the rate of participation.

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Figures

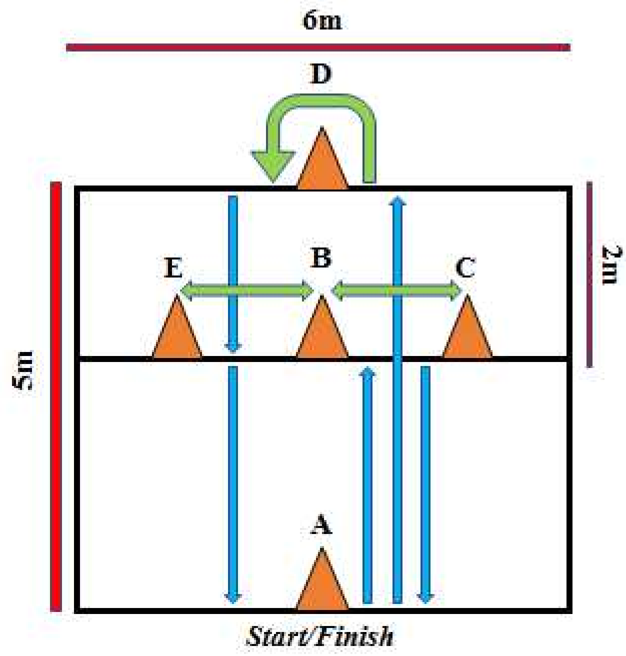

Figure 1. *Speed and Agility test*

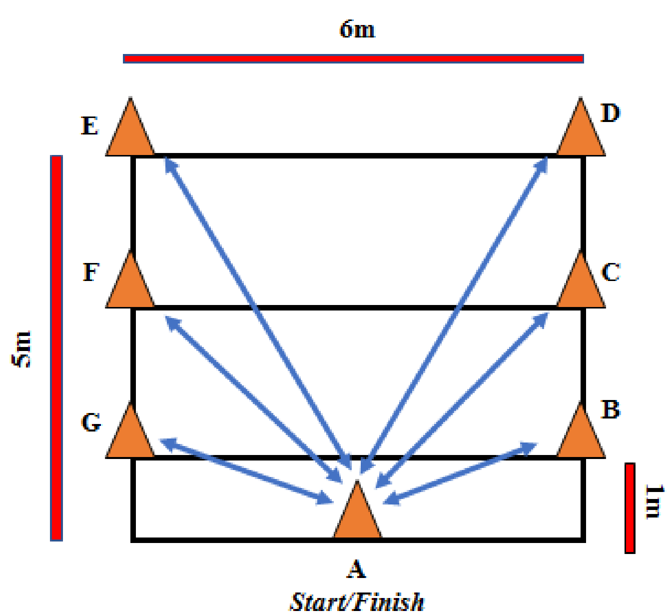

Figure 2. *Speed and Endurance test*

Appendix A – Informed Consent Form

Research Project Title:

Correlations Between Anthropometric Measurements and Sport Specific Field-based Tests in Sitting Volleyball

Researchers:

Mary Springfield, B.S.

Eric Conchola, Ph.D

Purpose:

The purpose of this study is to find correlations between anthropometric parameters and field-based tests within the game of sitting volleyball.

Procedures:

This study is a cross-sectional design. Upon completion of the informed consent/assent document, the athletes will have their height, weight, age, BMI, and anthropometric measurements completed by the researchers. Next, the individuals will complete the assigned survey, following that, the athletes will complete the sports-specific field-based tests. All tests will be conducted in a gymnasium setting (around 29-31 degrees Celsius). The time commitment for this study only requires a morning of tests. These tests will be done while practice is happening.

The four tests being administered are as follows: A handgrip (HG) analysis, seated chest press test (SCP), speed & agility test (SAT), as well as a speed & endurance test (SET) will be completed by the athletes during their testing session. The athletes will begin with their normal warm-up routine with dynamic movements with their partners. Handgrip (HG) strength is measured using a handheld dynamometer. Participant will hold the dynamometer by their side and will squeeze the handgrip as hard as they can for ~5-seconds. Three different trials will be conducted for the participant's dominant hand; an average of the three trials will be recorded in kilograms (kg). The rest period between trials is 30-seconds. Following the strength assessment, a seated chest pass (SCP) test will be performed. A medicine ball is thrown by the athletes in pairs that are positioned 60 cm apart and seated with their legs extended and back against a wall. The athletes will hold the ball with both hands on either side of the ball, centered against the chest with elbows at their sides. Participants will throw the ball to their partner as hard as they can, the distance from the wall to where the ball lands will be recorded in centimeters. Two maximal efforts will be implemented; the best score out of the two trials will be recorded.

The speed and agility test (SAT) is conducted to assess movement on the volleyball court. The protocol for this test is defined by Marszalek et al. (2015) (Figure 1). After a signal from the administers, the participant will begin with cone A and move forward to cone B, then shuffle to the right of the cone to cone C, then back to cone A. After coming back to cone A, the participant will move forward to cone D, then circle back to cone B. Then the participants will shuffle from cone B to the right to cone E. As fast as they can, the participants will then finish by returning to cone A. Two trials are conducted; the best score from the trials is recorded in seconds.

The final field test is the speed and endurance test (SET) (Figure 2). The test administers will measure a 5m x 6m square then place the starting cone A in the middle of the first horizontal 6m line. Cones B, C, and D are placed 1m apart on the right side of the 5m line. Cones E, F, and G are placed on the opposite 5m line. The participants will start at cone A, then shuffle from cone B back to cone A, then proceeding to each cone and back to cone A. Two trials will be conducted and the best score of the two trials are recorded in seconds. Assessing game performance will happen during game play while the athletes are in training camp. The coaches will assess in scoring game performance qualities using a volleyball statistician sheet. And this data will be shared with the researcher. The athletic trainer for the team will be able to access data for future research with the team.

Expected Length of Participation:

The time commitment for this study only requires a morning of tests. These tests will be done while practice is happening.

Potential Benefits:

Potential benefits for the participants include testing their skills on the volleyball court, along with an anaerobic fitness test and other measurements including body mass index (BMI). This study will also examine game performance qualities.

Potential Risks or Discomfort:

With any physical activity there are inherent risks associated within each activity. The participant will be undergoing physical fitness tests, a potential injury or worsening of an injury may occur. There is little to no risks associated with measuring height, weight, and BMI. The participants may withdraw from testing at any time.

Researcher Contact Information:

This study has been reviewed and approved by the University of Central Oklahoma Institutional Review Board (IRB). If you have questions, you may contact Mary Springfield B.S. at Mspringfield@uco.edu or Eric Conchola Ph.D at econchola@uco.edu. The UCO Institutional Review Board can be reached at irb@uco.edu or 405-974-5497.

Explanation of Confidentiality and Privacy:

All information from the participant, such as name, height, weight, age, biological gender, and testing data will not be duplicated or shared. All information will be confidential and completely private. The information provided by the study will remain in a locked file in a location under the discretion of the advisor's (Eric Conchola) office. All study data entered into statistical analyses and publication reports will have no identification to participants. Only mean (average) values will be reported. No individual or group other than the research team and the athletic trainer will be given information, unless specifically requested by the IRB. All primary data sources will be kept in the locked file cabinet located in the advisor's office or under a password protected flash drive. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and well-being of people who participate in research. The informed consent forms will also be kept for a maximum of three years.

Assurance of Voluntary Participation:

Participation in this study is completely voluntary. Individuals have the right to decline participation and may withdraw from the study at any time. The decision to not partake in the study will not be penalized and will result in loss of potential benefits.

Affirmation by the Research Participant:

I hereby voluntarily agree to participate in the research project listed above. I further understand the above explanations and descriptions of the research project. I understand that there is no penalty if I refuse to participate or withdraw my consent at any time during the study. I acknowledge that I am at least 18 years old. I have read and fully understand the informed consent form and I am signing freely and voluntarily. I acknowledge that a copy of the informed consent form has been given to me to keep.

Participant’s Printed Name: ________________________________

Signature: __________________________________ Date: ___________________

Appendix B – Assent Form

Research Project Title:

Effective Sport-Specific Field-Based Tests to Examine Game Performance in Sitting Volleyball

Researchers:

Mary Springfield, B.S.

Eric Conchola, Ph.D

Purpose:

The purpose of this study is to find correlations between anthropometric parameters and field-based tests within the game of sitting volleyball.

Procedures:

This study is a cross-sectional design. Upon completion of the informed consent/assent document, the athletes will have their height, weight, age, and anthropometric measurements completed by the researchers. Next, the individuals will complete the assigned survey, following that, the athletes will complete the sports-specific field-based tests. All tests will be conducted in a gymnasium setting (around 29-31 degrees Celsius). The tests will have to be conducted on two separate days for the men's and women's team, in which tests would be administered at the same time of day. The five tests being administered are as follows: A handgrip (HG) analysis, seated chest press test (SCP), speed & agility test (SAT), as well as a speed & endurance test (SET) will be completed by the athletes during their testing session. The athletes will begin with their normal warm-up routine with dynamic movements with their partners. Handgrip (HG) strength is measured using a handheld dynamometer. Participant will hold the dynamometer by their side and will squeeze the handgrip as hard as they can for ~5-seconds. Three different trials will be conducted for the participant's dominant hand; an average of the three trials will be recorded in kilograms (kg). The rest period between trials is 30-seconds. Following the strength assessment, a seated chest pass (SCP) test will be performed. A medicine ball is thrown by the athletes in pairs that are positioned 60 cm apart and seated with their legs extended and back against a wall. The athletes will hold the ball with both hands on either side of the ball, centered against the chest with elbows at their sides. Participants will throw the ball to their partner as hard as they can, the distance from the wall to where the ball lands will be recorded in centimeters. Two maximal efforts will be implemented; the best score out of the two trials will be recorded.

The speed and agility test (SAT) is conducted to assess movement on the volleyball court. The protocol for this test is defined by Marszalek et al. (2015) (Figure 1). After a signal from the administers, the participant will begin with cone A and move forward to cone B, then shuffle to the right of the cone to cone C, then back to cone A. After coming back to cone A, the participant will move forward to cone D, then circle back to cone B. Then the participants will shuffle from cone B to the right to cone E. As fast as they can, the participants will then finish by returning to cone A. Two trials are conducted; the best score from the trials is recorded in seconds.

The final field test is the speed and endurance test (SET) (Figure 2). The test administers will measure a 5m x 6m square then place the starting cone A in the middle of the first horizontal 6m line. Cones B, C, and D are placed 1m apart on the right side of the 5m line. Cones E, F, and G are placed on the opposite 5m line. The participants will start at cone A, then shuffle from cone B back to cone A, then proceeding to each cone and back to cone A. Two trials will be conducted and the best score of the two trials are recorded in seconds. Assessing game performance will happen during game play while the athletes are in training camp. The coaches will assess in scoring game performance qualities using a volleyball statistician sheet. And this data will be shared with the researcher. The athletic trainer for the team will be able to access data for future research with the team.

Expected Length of Participation:

The time commitment for this study only requires a morning of tests. These tests will be done while practice is happening.

Potential Benefits:

Potential benefits for the participants include testing their skills on the volleyball court, along with an anaerobic fitness test and other measurements including body mass index (BMI). This study will also examine game performance qualities.

Potential Risks or Discomfort:

With any physical activity there are inherent risks associated within each activity. The participant will be undergoing physical fitness tests, a potential injury or worsening of an injury may occur. There is little to no risks associated with measuring height, weight, and BMI. The participants may withdraw from testing at any time.

Researcher Contact Information:

This study has been reviewed and approved by the University of Central Oklahoma Institutional Review Board (IRB). If you have questions, you may contact Mary Springfield B.S. at Mspringfield@uco.edu or Eric Conchola Ph.D at econchola@uco.edu. The UCO Institutional Review Board can be reached at irb@uco.edu or 405-974-5497.

Explanation of Confidentiality and Privacy:

All information from the participant, such as name, height, weight, age, biological gender, and testing data will not be duplicated or shared. All information will be confidential and completely private. The information provided by the study will remain in a locked file in a location under the discretion of the advisor's (Eric Conchola) office. All study data entered into statistical analyses and publication reports will have no identification to participants. Only mean (average) values will be reported. No individual or group other than the research team and the athletic trainer will be given information, unless specifically requested by the IRB. All primary data sources will be kept in the locked file cabinet located in the advisor's office or under a password protected flash drive. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and well-being of people who participate in research. The informed consent forms will also be kept for a maximum of three years.

Assurance of Voluntary Participation:

Participation in this study is completely voluntary. Individuals have the right to decline participation and may withdraw from the study at any time. The decision to not partake in the study will not be penalized and will result in loss of potential benefits.

Affirmation by the Research Participant:

I hereby voluntarily agree to participate in the research project listed above. I further understand the above explanations and descriptions of the research project. I understand that there is no penalty if I refuse to participate or withdraw my consent at any time during the study. I acknowledge that I am at least 18 years old. I have read and fully understand the informed consent form and I am signing freely and voluntarily. I acknowledge that a copy of the informed consent form has been given to me to keep.

Participant's Printed Name: ________________________________

Signature: ________________________________ Date: __________________

Appendix C – Pretest Survey

Subject #: _________

PRETEST SURVEY

Anthropometric measurements

Height (in) ____________ Weight (kg) ____________

1. Please fill out the days of the week you train and how many hours/minutes during those sessions.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

2. Do you have any existing injuries? If so, please indicate the injury and pain associated.

3. Are you currently involved in any other exercise training programs? Such as resistance training, muscular endurance, balance, or flexibility programs. If yes, how many hours per week are you training?

4. How long have you been playing competitive volleyball?

5. What type of amputation or limitation do you have?

Appendix D – Data Collection Document

Subject #: ________

Height: ________ cm

Weight: _________ kg

Height in the block position (two hands): _______ in

Height in the spike position (one hand elevated): _______ in

Reach of player's arms (middle finger to middle finger): ________ in

Handgrip: Dominant Right or Left

1. ________ kg

2. ________ kg

3. ________ kg

Medicine ball chest pass:

Trial 1: __________ cm

Trial 2: __________ cm

SAT:

Trial 1: __________ seconds

Trial 2: __________ seconds

SET:

Trial 1: __________ seconds

Trial 2: __________ seconds