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Positional Comparison of Jump Performance in NCAA Division I Female Volleyball Athletes

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ABSTRACT

Background: The vertical jump task is a critical component of success in volleyball. Each position on the court has its own physical demands and has differing levels of vertical jump task demands. Objective: Thus, the objective of this investigation was to compare vertical jump performance between the two positional groups using the countermovement jump (CMJ) and squat jump (SJ). **Methods:** Using an observational cross-sectional study design, nineteen NCAA Division I female volleyball athletes participated in this investigation. Participants first performed three CMJ trials followed by 3 SJ trials on a force platform. Jump height, peak and mean net propulsive forces, and time to take off were calculated for both the CMJ and SJ. Reactive strength index modified and propulsive duration were additionally calculated for the CMJ and average RFD for the SJ. Independent sample t-tests were performed comparing positional groups on each variable of interest with Hedges g effect sizes additionally calculated. **Results:** No statistically significant differences ($p < 0.05$) were found between any of the variables of interest in the CMJ though moderate effect sizes were seen in jump height ($g = 0.78$). No statistically significant differences were present in the SJ though moderate effect sizes were seen in RFD ($g = 0.65$), mean propulsive force ($g = 0.79$) and peak propulsive force ($g = 0.66$). **Discussion:** As the vertical jump task is a critical task for high-level performance in both positions, and the no differences seen between groups, training programs should be designed to improve jump performance with special attention to the individual athletes' needs rather than the specifics of the playing position.

Key words: Female Athletes, Volleyball, Collegiate Athletes, Vertical Jump, Team Sports

INTRODUCTION

Volleyball is a game that emphasizes having a strong ability to jump as it is a critical component of the technical skills of hitting and blocking (Marques, Van Den Tillaar, Vescovi, & González-Badillo, 2008). As with many sports, each position on the court has a skill set that is important to being successful (Marques, Van Den Tillaar, Gabbett, Reis, & González-Badillo, 2009; Nikolaidis, Afonso, Buśko, et al., 2015; Sattler, Hadžic, Dervišević, & Markovic, 2015). Volleyball is no different and previous investigations have examined anthropometrics, strength, and power differences across a variety of positional groups and skill levels (Marques et al., 2009; Nikolaidis, Afonso, Buśko, et al., 2015; Sattler et al., 2015; Schaal, Ransdell, Simonson, & Gao, 2013).

When specifically investigating vertical jumping anthropometrics and physical performance abilities in volleyball athletes, an individual's performance is an important factor in separating competition levels (Sattler et al., 2015; Sattler, Sekulic, Hadzic, Uljevic, & Dervisevic, 2012). This holds when looking at positional differences. Liberos are statistically smaller in stature than other positions in female volleyball athletes, while outside hitters and middle blockers have demonstrated greater strength than setters and liberos (Malousaris et al., 2008; Marques et al., 2009) In a sample of male volleyball athletes differences in both upper and lower body strength levels where seen between positional groups. (Marques et al., 2009). However, when the same approach is taken across examining positional differences groups, conflicting evidence has been reported concerning vertical jump performance (Marques et al., 2009; Sattler et al., 2015; Schaal et al., 2013). Marques et al. (2009) found there to be no statistically significant positional differences in CMJ height though a nearly 5 cm difference was reported between the highest and lowest positional group. in a sample of professional male volleyball athletes. However, they did see nearly 5 cm differences between opposite hitters and setters. In a much larger sample of male and female international volleyball athletes, positional differences were detected between receivers and setters in the male sample while no differences were seen in the female during both the CMJ and squat jump (SJ) tasks (Sattler et al., 2015). Similar findings were reported in a sample of female volleyball athletes from the pooled Division I collegiate and high school levels, with no differences seen between three positional groups (hitters, setters, and defense) positional groups.(Schaal et al., 2013). Within a sample of youth female volleyball athletes, no dif-

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ferences were seen in both CMJ and horizontal jump performance (Paz et al., 2017). In contrast to the aforementioned investigations, positional differences have been reported in a sample of female volleyball athletes with outside hitters jumping 3 cm higher than liberos (Nikolaidis, Afonso, Buśko, et al., 2015). Though no statistical differences were reported by Marques et al. (2009) liberos were reported to have a higher vertical jump over outside hitters. Thus, not only have conflicting results been reported between having positional differences in vertical jumping height but differences have also been reported regarding which positional group had the greatest jump heights. Furthermore, there has been no consistent method of defining positional groups. The lack of consistent findings points to the need to further investigate positional differences in female volleyball athletes at all levels of competition. These previous findings have not provided much in the way of rationale as to why or why not positional differences exist.

Vertical jump height can be measured using a variety of different techniques, all of which can provide some level of explanation as to findings of previous investigations into positional differences in volleyball. While the use of force platforms is the gold standard in vertical jump assessment, none of the previously mentioned investigated utilized this technology. While other assessment tools (photoelectric and contact mats) have been validated to force platforms during the vertical jump, a level of error is present (Attia et al., 2017; Glatthorn et al., 2011; Whitmer et al., 2015). The optojump vertical jump assessment system, for example, has been shown to have a systematic basis of approximately 1 cm in comparison to the force platform across three jump modalities (SJ, CMJ, and CMJ with an arm swing) (Glatthorn et al., 2011). Similarly, it has been shown that the use of jump mats that use the flight time to calculate jump height overestimated vertical jump performance. The overestimation is caused by an approximate 100 ms increase in flight time from the jump mat over a force platform (Whitmer et al., 2015). The lack of consistent findings in the positional differences of vertical jump ability may in large part be through methodological differences in the equipment used and under and overestimation of vertical jump performance due to not using gold standard instrumentation. While the CMJ is the most widely used assessment of vertical jumping ability, others jumping tasks have been used to further assess jumping abilities. The SJ is another commonly used task to assess performance in athletic populations and has been utilized when examining volleyball athletes (Borràs, Balius, Drobnic, & Galilea, 2011; González-Ravé, Arija, & Clemente-Suarez, 2011). In the SJ, the countermovement is taken away through hold a semi-squat position for a period of time (typically 3 seconds). At the end of the static hold, individuals are instructed to only positive in the positive direction with no additional countermovement. While large additional countermovements may be detectable by watching the individual perform the task, smaller, more subtle countermovements may go unnoticed when using instrumentation other than a force platform. While the utilization of field-based methodologies such as contact mats and jump and reach devices provide more affordable options to conduct vertical jump testing, the error in the measurement and lack of experimental control that these devices provide limit published findings.

Furthermore, the use of a force platform over other vertical jump measure devices is the ability to look further at the underpinning mechanics that drive performance and have a better understanding of how that performance has been achieved (J. J. McMahon, Suchomel, Lake, & Comfort, 2018). As vertical jump height is determined by one's ability to generate a mechanical impulse (force x time). It is important to examine the variables that create that impulse. Thus, the use of mean propulsive force and propulsive duration as variables of interest is of importance in explaining how a jump was achieved (Bishop et al., 2021). Additional variables such as the reactive strength index modified (jump height/time to take-off) have been shown to be a valid assessment of jumping performance in volleyball athletes, as jump height alone as a variable provides little information as to the efficiency of the performance (Kipp, Kiely, & Geiser, 2016).

While previous literature in identifying positional differences has shown conflicting results in jump performance in female athletes, much of which can be explained by potentially methodological differences. The lack of using gold standard measurement techniques and a more thorough investigation into the mechanisms by that jump performance is obtained warrants further investigation. underpinningsThus, the purpose of this study was to examine the positional differences in vertical jump performance using the countermovement and SJ tasks through the use of established criterion measurement techniques.

METHODS

Participants and Study Design

Using an observational cross-sectional study design, 19 female collegiate volleyball athletes were tested as part of the team's athlete monitoring program (age 19.86 ± 0.86 years, height 180.61 ± 3.99 cm, body 69.93 ± 9.73 kg). All participants in this study were a part of one NCAA Division I program. To aid in increasing the sample size for this study individuals included came from two separate competitive seasons with the most recent testing being used in the analysis. As this study was designed to look at positional differences at one level of competition and using a convenient sampling no formal sample size calculation was performed. However, the sample size for this study is similar to those previously reported in terms of participants per group. All testing used in this analysis was from testing sessions before the first match of the season and after the completion of the preseason training. Participants were divided into two groups (outside hitters and middles) (n = 8 vs 11 respectively). Group determination was conducted through the positional assignment on the official team rosters. All participants had taken part in similar organized team training sessions before testing. Participants met all inclusionary criteria of being currently free of any lower extremity injury at the time of testing and having been medically cleared for sports participation by the sports medicine staff and being a part of the official university roster at the time testing occurred. All participants provided informed written consent before the beginning of testing as approved by the University of Southern Mississippi institutional review board.

Procedures

Jump testing protocol

Before testing, participants completed a standardized dynamic lower-body warm-up. The warm-up included 5 submaximal vertical jump trials under testing conditions to ensure participants were comfortable with the testing procedures. Each participant completed three CMJ trials. Each trial was completed with a polyvinyl chloride dowel (<1.0 kg) placed across the shoulders. Individuals were then instructed to jump as high as possible with maintaining contact with the dowel throughout the duration of the movement. After each trial, 30 seconds were given to reposition participants starting stance. Individuals used a self-selected foot position and countermovement depth similar to previous testing protocols. Instructions were then given to jump as high as possible. The use of a "3,2,1, Go" countdown was used (Donahue, Wilson, Williams, Hill, & Garner, 2021; Donahue, Wright, & Victory, 2021).

Participants then completed three SJ trials. Similar procedures to the CMJ were followed (Donahue, Hill, Wilson, Williams, & Garner, 2021; Donahue, Wright, et al., 2021). Again, participants were allowed to self-select their starting depth and foot position with the dowel placed across the shoulders. Instructions were given to hold the static semi-squat start position and jump as high as possible. If a countermovement was visually detected, trials were repeated until three successful trials were recorded.

Data analysis

All testing was performed using a portable force platform (AMTI, Watertown, MA USA). Ground reaction force data collected during trials was sampled at 1000 Hz. Raw vertical ground reaction force data were then exported and analyzed using a customized spreadsheet (Microsoft Excel, Redmond WA USA). The spreadsheet used was modelled using the equations and phase descriptions provided by Chavda et al(Chavda et al., 2018), and used in previous investigations by the investigators in the current study (Chavda et al., 2018; Donahue, Wilson, et al., 2021; Donahue, Wright, et al., 2021). Concerning the variables of interest in the present analysis concentric and eccentric phase determination was identified as the point at which the center of mass velocity reached zero (J. J. McMahon et al., 2018). Reactive strength index modified was calculated as jump height divided by the time to take off (Ebben & Petushek, 2010). Body mass was determined as the mean vertical force during one second of quiet stance. Movement onset was identified as the first point in which vertical force fell below BM – 5SD of the vertical force during the quiet stance. Take-off was identified as the first point at which force fell below 5SD of the flight phase of the jump. Time to take-off was calculated as the time from movement onset to take-off.

Similar data analysis procedures were used in the SJ through the use of a customized spreadsheet.(Donahue, Hill, et al., 2021) The procedures were adjusted for the removal of the unweighting and braking phases of the jump. Additionally, the average rate of force development was calculated during the SJ as the change in force from movement onset to peak force divided by the time to peak force.

Statistical Analysis

A Shapiro-Wilk test of normality was used on each variable of interest within both groups. Independent sample t-tests were performed on each variable of interest. Statistical significance was determined using an a priori alpha level of $p \leq 0.05$. The between-group effect size was calculated using Hedges *g*. Effect sizes were interpreted using the criteria of small (0.0 – 0.49), moderate (0.5 – 0.79), and large (> 0.8). All statistical analyses were performed using SPSS (v25.0, SPSS Inc., Chicago, IL, USA).

RESULTS

All results are presented as mean ± SD. Group comparisons for the CMJ are presented in Table 1. No statistically significant differences were present between groups for any of the variables of interest in the CMJ. Though statistical significance was not reached, outside hitters, displayed greater jump heights and moderate effect sizes ($p = 0.11$, $g = 0.78$). Group comparisons for the SJ are presented in Table 2. No statistically significant group differences were present. Moderate effect sizes were seen between groups in peak force ($p = 0.17$, $g = 0.66$), mean force ($p = 0.10$, $g = 0.79$), and average rate of force development ($p = 0.17$, $g = 0.65$) with the outside hitters displaying greater values for each variable.

DISCUSSION

The main findings of this investigation support those previously reported (Sattler et al., 2015; Schaal et al., 2013). No differences were seen in jump height during both the CMJ and SJ. While several studies have reported this finding, jump height alone is a variable that requires further investigation (Marques et al., 2009; Nikolaidis, Afonso, & Busko, 2015; Sattler et al., 2015; Schaal et al., 2013). The present investigation examined not only the outcome of jumping performance (jump height) but also variables that determine jump performance (mean concentric force) and also the strategies used to achieve that performance (time to take-off). Thus, the findings that both position groups have similar jump performance is important in the development of training programs.

As previously stated, the results of this investigation support those that have previously been reported concerning vertical jump performance across position groups in volleyball. One important difference between the present study to those previously reported is the use of a force platform in the current study. While the use of photoelectric and contact jump mats have been validated and shown to provide

Table 1. Countermovement Jump Comparisons

	Middle	Outside	*p value*	*g*
Peak Propulsive Force (N)	890.13±185.34	954.03±191.92	0.81	0.38
Mean Propulsive Force (N)	621.14±174.86	642.14±107.36	0.29	0.15
Time to Take-off (ms)	816.98±122.73	827.27±78.15	0.12	0.10
Jump Height (m)	0.29±0.06	0.33±0.04	0.38	0.78
RSIm	0.36±0.09	0.40±0.07	0.43	0.49

RSIm=Reactive Strength Index Modified; *g*=Hedges *g* effect size

Table 2. Squat Jump Comparisons

	Middle	Outside	*p value*	*g*
Peak Propulsive Force (N)	794.22±173.47	962.55±297.76	0.08	0.66
Mean Propulsive Force (N)	393.59±90.44	481.58±122.92	0.32	0.79
Average RFD (n/s)	2004.57±791.18	2801.88±1443.38	0.09	0.65
Time to Take-off (ms)	401.56±72.32	380.23±52.69	0.66	0.35
Jump Height (m)	0.27±0.05	0.28±0.04	0.74	0.33

RFD=rate of force development; *g*=Hedges *g* effect size

reliable data, they have also been shown to have a systematic bias when tested concurrently against the gold standard force platform (Attia et al., 2017; Whitmer et al., 2015). Additionally, the force platform allows for a more robust data set to be acquired to understand jump performance. Though the outcome of this study does not show statistical differences in terms of jump height (though moderate effect sizes were seen), we have a better understanding of the strategies that are used in female volleyball athletes to achieve a given jump height. Sattler et al. (2015) found that CMJ heights were statistically similar in female volleyball athletes whereas differences were found in males when comparing position groups. The finding that positional differences exist in males has conflicting evidence as Marques et al. (2009) found no differences between positions. This conflict within the present literature can be attributed to factors such as testing modalities (photoelectric vs contact mats), competition level, and individual team differences. The findings of the current study and those previously reported may also point to jump strategy differences between men and women that play a role in the ability to create differences between positional groups (J. McMahon, Rej, & Comfort, 2017). As conflicting findings have been found in males but a more consistent finding of no differences between positions has been found at the international and collegiate levels in females (Marques et al., 2009; Sattler et al., 2015; Schaal et al., 2013).

Though no statistical differences were found between groups in the SJ, several variables did show moderate effect sizes. Sattler et al. (2015) also found no differences in the SJ height between multiple positional groups. However, they did not report any specific effect sizes with their comparisons or group mean data making a direct comparison between studies difficult. When comparing group differences in the current study, jump height did show a moderate effect size in the SJ with outside hitters outperforming middles. As the SJ is a unique task, especially for volleyball athletes that are accustomed to utilizing the stretch-shortening cycle, differences may have been induced through comfort level in performing the task. However, when examining variables that drive the outcome come of jump height, the mean concentric force was greater in the outside group, though not statistically different, moderate effect sizes were present ($g = 0.79$). This demonstrates the moderate effect in jump height may have been related to force-generating attributes rather than the unique task demands. This is a clear demonstration of the need to examine the underlying mechanical variables that drive vertical jump performance. Future investigations examining positional differences should not only examine jump height but also the underlying mechanics.

Though statistical significance differences were not seen between groups, the small sample size (n = 19) and unequal groups (8 vs 11) may have played a large role as moderate to high effect sizes were present for several variables. Though large samples have been used and no differences were found between groups as it relates to SJ height, the use of the force platform provides a greater level of confidence in the findings (Marques et al., 2009; Sattler et al., 2015). Specifically, in the SJ, no additional countermovement must be performed once in the static semi-squat position as this can result in inflated results. When using devices such as contact mats one must visually rely on seeing a countermovement, which is typically rather large. When using a force platform any reduction in the force-time data regardless of the size would be detected and counted as an unsuccessful trial and repeated.

This study is not without its limitations, as mentioned above, data was collected using a small sample of collegiate volleyball athletes, therefore the findings may not be generalizable across all levels of competition. However, the values of jump height in the CMJ from the current study argue with those shown in other NCAA Division I programs (Kipp et al., 2016; Suchomel, Sole, Bailey, Grazer, & Beckham, 2015). Additionally, having uneven groups with our small sample may have limited our ability to detect statistical differences. This is not the first study to have such issues. Marques et al.

(2009) used a sample of one professional male volleyball team to examine similar positional differences within five groups ranging between 4 and 10 participants. Knowing uneven groups would be a potential limitation in this analysis, we felt that excluding one position group (liberos) that had a small sample (n = 4) allowed for a slightly stronger analysis. Furthermore, previous finds that approximately 5cm differences in jump height were not statistically significant, which largely can be attributed to a one-analysis of variance across five uneven groups ranging between 4 and 10 (Marques et al., 2009).

The results of this study provide important data to practitioners working with volleyball athletes and guide future research. Concerning practitioners, training programs should be designed to meet the needs of individuals rather than position-specific training concerning outside hitters and middles. It is of interest that in the SJ that several force-related variables displayed moderate effect sizes, suggesting that the positional demands force generating capabilities when the stretch-shortening cycle is removed as outside hitters had greater values than middles though not statistically significant. Again pointing to the need to train the individual rather than the positional demands as the SJ is a less sport-specific movement than CMJ, thus transfer to on-court performance may be limited. As for future research in the area of positional differences, it should be noted that the CMJ employed during the current investigation removed the arm swing and again may not transfer directly to on-court performance. Thus, using similar methods of criterion instrumentation and investigating the positional differences when using an arm swing.

CONCLUSION

In conclusion, the results of this study show no statistical differences between outside hitters and middle jump performance in the CMJ and SJ tasks. Outside hitters did show higher values when moderate effect sizes were present. This information is important for practitioners as training programs should not differ based on position. Training programs should be designed around the athlete's individual needs rather than position demands.

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