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Kinetic and Kinematic Characteristics of Setting Motions in Female Volleyball Players

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Abstract: While being an integral part of both the offensive and defensive segments of the game, the biomechanical parameters of setting motions remain understudied in the scientific literature. Thus, the purpose of the present study was to examine differences in kinetic and kinematic characteristics between: (a) three types of setting motions (i.e., front, middle, back); (b) two types of setting approaches (i.e., stationary, step-in); and (c) proficient (PRO) and non-proficient (N-PRO) volleyball players. Twenty recreationally active females performed five stationary and five step-in setting approaches to Zone 4–2 in a randomized order. Uni-dimensional force plate sampling at 1000 Hz and high-definition camera recording at 30 fps were used to obtain kinetic and kinematic variables of interest. The total number of setting attempts performed by each subject was 30, accounting for a grand total of 600 attempts. PRO setters had less knee flexion, shoulder flexion, and ankle dorsiflexion at the initial concentric phase of the volleyball setting motion when compared to the N-PRO setters. Moreover, significantly greater peak concentric and landing forces, impulse, rate of force development, and vertical jump height were observed for PRO setters compared to N-PRO setters, while no significant differences were found between different setting targets and approaches.

Keywords: biomechanics; female; team sports; force; overhead pass; coaching; performance

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1. Introduction

Volleyball is one of the most popular international sports in which two teams of six players are required to make quick decisions contingent upon the opponent's strategic plan of attack. It is a fast-paced game organized into the attack and defense phases [1,2]. The attack phase consists of the reception, setting, attack, and attack coverage, while the defense phase consists of blocking, defense, setting, counter-attack, and counter-attack coverage [1,2]. By being present in both phases, the setting motion represents the essential part of the offensive and defensive segments of the game. It is one of the fundamental volleyball-specific skills defined as the second contact carried out by a specialized player called the setter [3,4]. Setters are required to have good on-court awareness since they make the majority of the tactical decisions during the game. Moreover, their primary responsibility is to organize the offensive play in order to put the attacker in the best position to score a point and ultimately help the team to secure the winning game outcome [3,4].

Every point in a volleyball game starts with a serve and is followed by a reception of a ball (i.e., receive) [5]. Despite not being a skill that directly translates into a scoring opportunity, an excellent receive allows the setter to efficiently organize a game and make it more challenging for the opposing team to predict the offensive play. González-Silva et al. [2] found that reception efficacy, setting technique, and tempo of the set were significant predictors of the setting performance in both male and female athletes competing in the Under-16 Spanish championship. In a follow-up study examining games played in the men's world volleyball championship, the same group of authors found that reception efficacy was positively associated with successful setting performance, unlike variables related to the serve criteria which demonstrated negligible contribution (e.g., the role of the server, type of serve, serve zone) [6]. In addition, Palao et al. [7] found that winning teams utilized a jump-set more frequently and efficiently than losing teams, which subsequently resulted in a better side-out success and an improved offensive performance by leaving the attackers with one or no blockers [7]. Moreover, these findings confirmed that the setter's ability to utilize a jump-set motion was highly dependent on the success of the first offensive contact [7].

Another factor contributing to the quality of the setting motion and game outcome is the player's choice of a setting zone. Tsavdaroglou et al. [8] showed that both male and female setters performed the majority of their setting attempts to Zone 4 (i.e., front), 39.5% and 38.6%, respectively. Male setters chose Zone 3 (i.e., middle) and Zone 2 (i.e., back) as their second and third choice, while females preferred setting to Zone 2 over Zone 3 [8]. In a similar investigation, Oikonomopoulou et al. [9] observed that Zone 4 in a 3rd tempo (i.e., slow set) was a preferable target for junior female setters, regardless of the reception origin as another variable related to optimal setting performance. Moreover, it is interesting to note that the performance of setters in offensive plays tended to be more predictable in junior than in the elite level of competition [9].

Although being one of the essential volleyball-specific skills, there is a lack of scientific literature focused on examining the kinetic and kinematic characteristics of setting motions. The majority of volleyball research studied the biomechanical parameters of attacking and blocking motions [10–12]. To our knowledge, only one study has aimed to assess the kinematic characteristics of different types of setting motions and found greater angular displacement of the head, trunk, and shoulder during the back setting motion when compared to the front setting motion [13].

Therefore, to obtain additional insight into the biomechanical parameters of setting motions and bridge a gap in the scientific literature, the purpose of the present study was to examine differences in kinetic and kinematic characteristics between: (a) three types of setting motions (i.e., front, middle, back); (b) two types of setting approaches (i.e., stationary, step-in); and (c) proficient and non-proficient volleyball setters.

2. Materials and Methods

2.1. Participants

Twenty recreationally active females ($\bar{x} \pm$ SD; height = 173.4 $\pm$ 9.0 cm; body mass = 71.6 $\pm$ 11.9 kg; age = 21.3 $\pm$ 1.5 years; playing experience = 9.7 $\pm$ 2.4 years) with $\geq$5 years of previous volleyball playing experience (e.g., high school, collegiate, professional) participated in the present investigation. The exclusion criteria involved current and/or previous musculoskeletal injuries that may constrain full joint ranges of motion and ultimately impair the setting performance. All testing procedures performed in the present study were approved by the University's Institutional Review Board and all participants signed an informed consent document.

2.2. Procedures

Upon arrival at the laboratory, participants were asked to perform a standardized warm-up procedure consisting of five minutes of dynamic stretching exercises (e.g., high knee pulls, quad stretch, lateral knee lunge, high knees, volleyball shuffle, karaoke) and 5–10 practice setting attempts to a previously self-selected target. Following the completion of the warm-up procedures, each subject performed five repetitions of stationary (i.e., no steps prior to the jump set motion) and five repetitions of step-in setting approaches (i.e., left-right step-in lateral approach) to each of the three targets: Zone 4 (i.e., front); Zone 3 (i.e., middle); and Zone 2 (i.e., back). The total number of setting attempts performed by each subject was 30, accounting for a grand total of 600 setting attempts across all participants. The order of targets for setting attempts was randomly assigned for each participant. In addition, each setting attempt was separated by 30 s of rest and each setting approach was separated by two minutes of rest to assure adequate recovery and eliminate any possible influence of fatigue.

To obtain kinetic variables of interest, participants were asked to stand on a uni-dimensional force plate (Roughdeck, Rice Lake Weighing Systems, Rice Lake, WI, USA) with a data acquisition system (BioPac MP 150, Goleta, CA, USA) sampling at 1000 Hz while performing each of the previously mentioned setting motions. The setting net (Bownet Volleyball Set Net, Bownet Sports, CA, USA; 130 × 31 cm) was positioned at each of the setting zones at 2.64 m (i.e., average attack height for female college athletes) and the volleyball net was positioned at a standardized female net height of 2.24 m. A high-definition video camera (PowerShot SX530, Canon Inc., Tokyo, Japan) sampling at 30 fps, positioned 10 m away perpendicular to the subject's plane of motion, was used to capture each setting attempt and video analysis software (Kinovea, Version 0.8.27) was used to analyze the kinematic parameters of interest [14,15]. Throughout the entire investigation, a research assistant was present to count missed and/or made setting attempts (e.g., inside or outside of the target zone or the setting hoop) and assist with tossing the volleyball to the subject. A detailed representation of the study setup is presented in Figure 1. Additionally, participants were classified as either proficient (PRO; making ≥60% of the setting attempts; n = 10) or non-proficient (N-PRO; making <60% of the setting attempts; n = 10) based on the feedback from a panel of experts composed of collegiate and professional volleyball coaches and players with an extensive amount of experience.

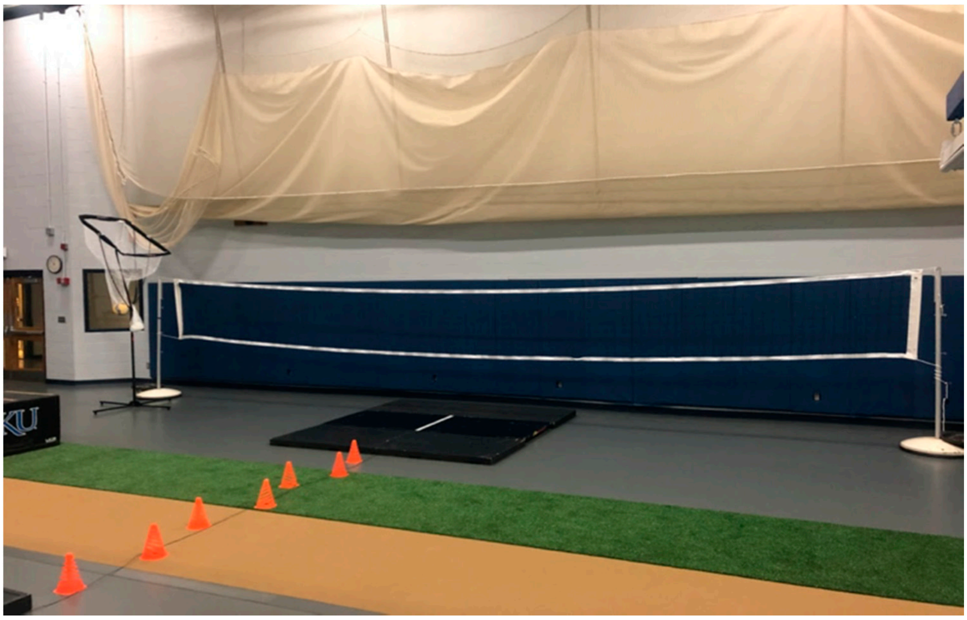

Figure 1. The experimental setup.

2.3. Variables

Kinetic variables of interest derived from ground reaction force curves investigated in the present study were *peak concentric force* (PCF; greatest force observed during the concentric portion of the setting jump), *peak landing force* (PLF; greatest force observed during the landing portion of the setting jump), *impulse* (IMP; area under the force-time curve greater than participant's body weight), *rate of force development* (RFD; slope from the timepoint when force curve crosses participants body weight until the greatest concentric force), and *vertical jump height* (VJH; derived from the flight time; VJH = $(t^2 \cdot g)/8$, g = 9.81 $m \cdot s^{-2}$, t = flight time) [16,17]. See Figure 2.

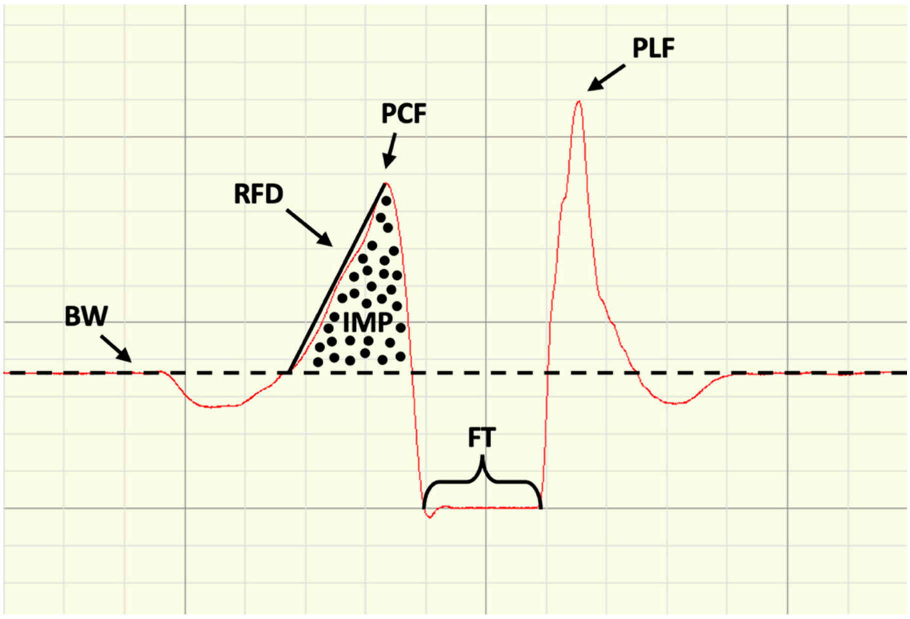

Figure 2. Graphical representation of kinetic variables examined in the present study. PCF = peak concentric force; PLF = peak landing force; RFD = rate of force development; BW = body weight; IMP = impulse; FT = flight time.

Kinematic variables examined at the initial concentric phase of the setting motion (i.e., preparatory phase) were *knee angle* (KA; internal angle between the thigh and the shank: knee joint center; greater trochanter; and lateral malleolus), *hip angle* (HA; internal angle between the torso and the thigh: greater trochanter; knee joint center; and acromion), *ankle angle* (AA; relative angle between the shank and the ground: lateral malleolus; knee joint center; and line parallel to the ground), *shoulder angle* (SAC; relative angle between the upper arm and torso: acromion; greater trochanter; and olecranon). Kinematic variables assessed at the point of the setter's initial contact with the ball were *shoulder angle* (SAB; relative angle between the upper arm and torso: acromion; greater trochanter; and olecranon) and *volleyball height* (BH; perpendicular distance between the center of the volleyball and the ground divided by the subject's height). See Figure 3.

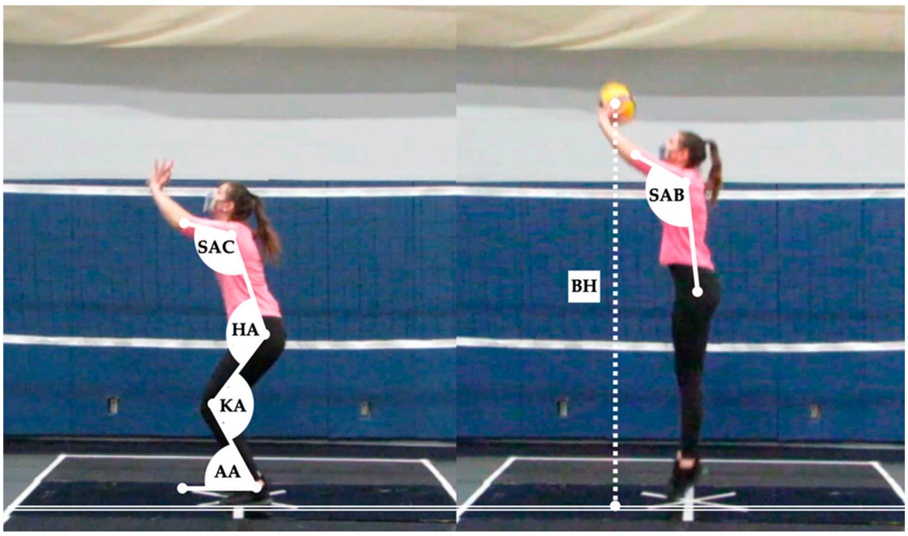

Figure 3. Graphical representation of kinematic variables examined in the present study. SAC = shoulder angle at the initial concentric phase of setting motion; HA = hip angle; KA = knee angle; AA = ankle angle; SAB = shoulder angle at the initial contact with the ball; BH = ball height.

2.4. Statistical Analysis

Descriptive statistics, means and standard deviations ($\bar{x} \pm SD$), were calculated for each dependent variable. The same researcher carried out an analysis of kinetic and kinematic variables examined in the present study, with intraobserver variability of 2.84%. The Shapiro–Wilk test corroborated that the assumption of normality was not violated. A MANOVA was used to examine the main effects and interaction effects between different types of setting approaches (i.e., stationary, step-in), setting motions (i.e., front, middle, back), and proficiency level (i.e., PRO, N-PRO). Follow-up ANOVAs with Bonferroni adjustments were used when significant main effects were observed. Statistical significance was set a priori to $p < 0.05$. All statistical analyses were performed in the SPSS statistical software (Version 27.0; IBM Corp., Armonk, NY, USA).

3. Results

Descriptive statistics for all dependent variables examined in the present study are presented in Table 1. The MANOVA revealed a non-significant interaction effect between setting approach, setting target, and proficiency level ($F_{[22,196]} = 0.304$, $p = 0.999$, $\Lambda = 0.935$, $\eta_p^2 = 0.033$). Moreover, no significant interaction effects were observed between setting approach and proficiency level ($F_{[11,98]} = 0.885$, $p = 0.558$, $\Lambda = 0.910$, $\eta_p^2 = 0.090$), setting target and proficiency level ($F_{[22,196]} = 0.382$, $p = 0.995$, $\Lambda = 0.919$, $\eta_p^2 = 0.041$), and setting target and setting approach ($F_{[22,196]} = 0.617$, $p = 0.909$, $\Lambda = 0.875$, $\eta_p^2 = 0.065$).

A statistically significant main effect was noted for both proficiency level ($F_{[11,98]} = 14.323$, $p < 0.001$, $\Lambda = 0.383$, $\eta_p^2 = 0.617$) and setting target ($F_{[22,196]} = 3.114$, $p < 0.001$, $\Lambda = 0.549$, $\eta_p^2 = 0.259$), while no significant main effect was observed for setting approaches ($F_{[11,98]} = 1.778$, $p = 0.068$, $\Lambda = 0.834$, $\eta_p^2 = 0.166$).

PRO setters had significantly greater KA ($p < 0.001$), AA ($p = 0.039$), PCF ($p < 0.001$), PLF ($p < 0.001$), IMP ($p < 0.001$), RFD ($p < 0.001$), and VJH ($p < 0.001$) when compared to the N-PRO setters. However, PRO players demonstrated smaller SAC ($p = 0.029$) than N-PRO. No statistically significant differences were observed for HA ($p = 0.339$), BH ($p = 0.290$), and SAB ($p = 0.087$).

KA was significantly greater for Zone 2 when compared to Zone 3 ($p = 0.004$), while no differences were observed between Zone 4 and Zone 2 ($p = 0.273$) and between Zone 4 and Zone 3 ($p = 0.325$). Significantly greater SAB was observed when setting the ball to Zone 2 when compared to Zone 3 ($p = 0.024$) and Zone 4 ($p < 0.001$). In addition, SAB was significantly greater for Zone 3 when compared to Zone 4 ($p = 0.026$). No significant difference was observed for the remaining dependent variables ($p > 0.05$).

Table 1. Descriptive statistics, mean and standard deviation ($\bar{x} \pm$ SD), for each kinetic and kinematic variable examined in the present investigation. KA = knee angle; HA = hip angle; SAC = shoulder angle at the initial concentric phase of setting motion; AA = ankle angle; BH = ball height; SAB = shoulder angle at the initial contact with the ball; PCF = peak concentric force; PLF = peak landing force; IMP = impulse; RFD = rate of force development; VJH = vertical jump height.

	AA (deg)	KA (deg)	HA (deg)	SAC (deg)
Approach				
Stationary	53.5 ± 5.1	117.3 ± 6.4	143.6 ± 12.2	123.4 ± 25.4
Step-In	55.3 ± 6.3	116.1 ± 5.9	139.5 ± 9.4	120.9 ± 20.6
Target				
Front	53.9 ± 6.0	116.7 ± 6.5	141.4 ± 11.6	121.3 ± 23.2
Middle	55.4 ± 5.9	118.8 ± 4.9	142.7 ± 9.7	118.1 ± 26.1
Back	53.9 ± 5.2	114.6 ± 6.5 $^{\#}$	140.6 ± 11.9	127.1 ± 18.9
Proficiency				
Non-Proficient	53.3 ± 5.7	114.5 ± 6.6	142.5 ± 12.3	126.8 ± 12.5
Proficient	55.5 ± 5.6 *	118.9 ± 4.9 *	140.6 ± 9.6	117.4 ± 29.5 *
	BH (ratio)	**SAB (deg)**	**IMP (N·s)**	**RFD (N·s^{-1})**
Approach				
Stationary	1.3 ± 0.1	144.9 ± 20.1	175.7 ± 42.1	8769.6 ± 4266.1
Step-In	1.3 ± 0.1	140.4 ± 11.6	178.5 ± 40.7	9510.3 ± 5486.9
Target				
Front	1.3 ± 0.1	133.8 ± 9.3	177.2 ± 45.4	9333.1 ± 5649.6
Middle	1.3 ± 0.2	142.6 ± 22.3 †	173.2 ± 44.4	9726.2 ± 4803.8
Back	1.3 ± 0.1	151.5 ± 9.4 $^{\#\dagger}$	181.0 ± 33.7	8360.4 ± 4182.2
Proficiency				
Non-Proficient	1.3 ± 0.1	144.9 ± 13.0	152.8 ± 16.2	6028.9 ± 2684.4
Proficient	1.3 ± 0.1	140.4 ± 19.3	201.5 ± 44.4 *	12,250.9 ± 4657.5 *
	VJH (cm)	**PCF (N)**	**PLF (N)**	
Approach				
Stationary	12.3 ± 5.2	1955.1 ± 391.9	2011.8 ± 427.8	
Step-In	13.9 ± 5.7	1974.2 ± 458.7	2071.1 ± 451.2	
Target				
Front	13.3 ± 5.7	1978.7 ± 459.9	2085.8 ± 506.1	
Middle	12.7 ± 5.7	2003.2 ± 449.6	2019.1 ± 449.0	
Back	13.4 ± 5.3	1912.1 ± 365.6	2019.4 ± 356.1	
Proficiency				
Non-Proficient	10.4 ± 4.1	1697.7 ± 246.3	1781.9 ± 228.5	
Proficient	15.9 ± 5.4 *	2231.6 ± 398.2 *	2300.9 ± 446.3 *	

Note: * significantly different when compared to non-proficient; # significantly different when compared to the middle target; † significantly different when compared to the front target; ($p < 0.05$).

4. Discussion

Previous research has documented that when preparing to execute a setting motion, setters should flex their knees and dorsiflex the ankles to assure greater stability prior to the jumping movement [18]. In addition, keeping the shoulders and elbows slightly flexed in the front of the body can allow setters to see the path of the ball following the receive [18]. While both PRO and N-PRO setters followed the previously mentioned guidelines, the findings of the present study indicate that PRO setters had less knee flexion, shoulder flexion, and ankle dorsiflexion at the initial concentric phase (i.e., preparatory phase) of the volleyball setting motion when compared to the N-PRO setters. It is apparent that N-PRO setters overemphasized moving into the squatting position alongside keeping their elbows higher above the ground which may have impaired their ability to properly execute a setting motion. This may be attributed to the lack of knowledge of N-PRO setters regarding the proper setting technique as well as the lack of time devoted to practicing this essential volleyball skill. Moreover, these findings may imply that besides instructing setters to flex their knees, dorsiflex the ankles, and flex the shoulders, volleyball coaches should pay close attention to the movement magnitude to assure optimal improvements in setting performance.

When examining the differences in kinematic characteristics between three setting targets (i.e., front, middle, back), the findings of the present study indicate that shoulder flexion at the initial contact with the ball was significantly greater for the back set when compared to the middle and front set. These findings are in agreement with Ridgway and Wilkerson [13] who found greater angular displacement of the head, trunk, and shoulder when comparing front with back setting motions. In addition, the same group of authors found no significant differences in knee flexion between front and back setting targets, which is in line with the results obtained in the present investigation. However, it is interesting to note that significantly less knee flexion was needed when executing middle compared to back setting motions, which may be attributed to the closer proximity of the setting target (i.e., Zone 3 vs. Zone 2). Alongside the importance of lower body kinematic parameters, previous research has shown that movement in the elbow and wrist joints may be of critical importance for properly executed setting motions [19,20]. While not examined in the present investigation, future research should focus on studying the upper body kinematics in a laboratory and/or live game setting, especially with the exponential growth of performance monitoring technologies that allow for non-invasive movement analysis (e.g., markerless motion capture systems) [21–23].

Previous volleyball literature has been primarily focused on studying the biomechanical parameters of volleyball blocking and attacking movements [10,13,24,25]. To our knowledge, this is the first investigation focused on examining the kinetic characteristics between PRO and N-PRO setters, and different setting targets and approaches. Significantly greater peak concentric and landing forces, impulse, rate of force development, and vertical jump height were observed for PRO setters compared to the N-PRO setters, while no significant differences were found between different setting targets and approaches. The peak concentric forces for stationary and step-in setting motions were similar to the ones observed for blocking approaches (e.g., stationary, shuffle, and swing block) [10]. However, peak landing forces were smaller in magnitude for both types of setting motions, which is understandable considering that vertical jump height during blocking motions was approximately two-fold greater [10]. When compared to four-step and step-close attacking approaches, setting motions examined in the present study had lower impulse values [26]. This difference may be attributed to the training status of participants examined in the previously mentioned investigation (i.e., recreationally active individuals vs. collegiate athletes). In addition, due to the majority of lower body injuries occurring as a consequence of improper landing technique combined with high impact forces, further research is warranted to more thoroughly explore potential injury risks associated with the performance of various types of setting motions [4,24,27].

While these results may help to bridge the gap in scientific literature by providing better insight into the kinetic and kinematic characteristics of volleyball setting motions, this study is not without limitations. The testing procedures were conducted in a controlled laboratory setting that is not identical to an in-game competitive environment (e.g., no audience and opponents). Moreover, the setting tempo (i.e., speed of the set) was not taken into account when examining setting proficiency. Thus, the impact of these factors on biomechanical variables examined in the present study warrants further investigation as well as how they differ between various competitive levels (e.g., high school, collegiate, and professional).

5. Conclusions

The findings of the present study indicate that PRO setters had less knee flexion, shoulder flexion, and ankle dorsiflexion at the initial concentric phase (i.e., preparatory phase) of the volleyball setting motion when compared to the N-PRO setters. Moreover, significantly greater peak concentric and landing forces, impulse, rate of force development, and vertical jump height were observed for PRO setters compared to the N-PRO setters, while no significant differences were found between different setting targets and approaches. These findings may help strength and conditioning practitioners and sport-specific coaches to develop training regimens that resemble kinetic and kinematic characteristics observed in the present investigation and ultimately help athletes to improve their on-court setting performance.

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Informed Consent Statement: Informed consent was obtained from all participants involved in the present study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Palao, J.M.; Santos, J.A.; Ureña, A. Effect of team level on skill performance in volleyball. *Abbreviated Int. J. Perform. Anal.* **2004**, *4*, 50–60. [CrossRef]
2. González-Silva, J.; Domínguez, A.M.; Fernández-Echeverría, C.; Rabaz, F.C.; Arroyo, M.P.M. Analysis of setting efficacy in young male and female volleyball players. *J. Hum. Kinet.* **2016**, *53*, 189–200. [CrossRef] [PubMed]
3. Buscà, B.; Febrer, J. Temporal fight between the middle blocker and the setter in high level volleyball. *Rev. Int. Med. Cienc. Act. Fis. Deporte* **2012**, *12*, 313–327.
4. Silva, M.; Lacerda, D.; João, P.V. Match analysis of discrimination skills according to the setter attack zone position in high level volleyball. *Int. J. Perform. Anal.* **2013**, *13*, 452–460. [CrossRef]
5. Paulo, A.; Zaal, F.T.; Fonseca, S.; Araújo, D. Predicting volleyball serve reception. *Front. Psychol.* **2016**, *7*, 1694. [CrossRef]
6. González-Silva, J.; Fernández-Echeverría, C.; Conejero, M.; Moreno, M.P. Characteristics of serve, reception and set that determine the setting efficacy in men's volleyball. *Front. Psychol.* **2020**, *11*, 222. [CrossRef] [PubMed]
7. Palao, J.M.; Ahrabi-Fard, I. Effect of jump set usage on side-out phase in women's college volleyball. *J. Sport Hum. Perform.* **2014**, *2*, 1–10.
8. Tsavdaroglou, S.; Sotiropoulos, K.; Barzouka, K. Comparison and assessment of the setting zone choices by elite male and female volleyball setters in relation to opposing block organization. *J. Phys. Educ. Sport* **2018**, *18*, 2147.
9. Oikonomopoulou, A.; Barzouka, K.; Sotiropoulos, K.; Drikos, S.; Noutsos, K. Spatiotemporal analysis of setting per game complex and origin of the ball in junior female volleyball players. *J. Phys. Educ. Sport* **2022**, *22*, 652–660.
10. Cabarkapa, D.; Fry, A.C.; Cabarkapa, D.X.; Rogers, A.C.; Mosier, E.M. Ground reaction forces of commonly sed volleyball blocking approaches. *J. Kinesiol. Exerc. Sci.* **2020**, *89*, 13–20. [CrossRef]
11. Salci, Y.; Kentel, B.B.; Heycan, C.; Akin, S.; Korkusuz, F. Comparison of landing maneuvers between male and female college volleyball players. *Clin. Biomech.* **2004**, *19*, 622–628. [CrossRef] [PubMed]
12. Reeser, J.C.; Fleisig, G.S.; Bolt, B.; Ruan, M. Upper limb biomechanics during the volleyball serve and spike. *Sports Health* **2010**, *2*, 368–374. [CrossRef] [PubMed]
13. Ridgway, M.E.; Wilkerson, J. A kinematic analysis of the front set and back set in volleyball. In Proceedings of the 4 International Symposium on Biomechanics in Sports, Halifax, NS, Canada, 15–19 July 1986.
14. Cabarkapa, D.; Fry, A.C.; Cabarkapa, D.V.; Myers, C.A.; Jones, G.T.; Deane, M.A. Kinetic and kinematic characteristics of proficient and non-proficient 2-point and 3-point basketball shooters. *Sports* **2021**, *10*, 2. [CrossRef]
15. Cabarkapa, D.; Fry, A.C.; Poggio, J.P.; Deane, M.A. Kinematic differences between proficient and non-proficient free throw shooters–video analysis. *J. Appl. Sports Sci.* **2021**, *1*, 12–21. [CrossRef]
16. Cabarkapa, D.V.; Fry, A.C.; Cabarkapa, D.; Parra, M.E.; Hermes, M.J. Impact of accelerometer placement on assessment of vertical jump performance parameters. *J. Phys. Educ. Sport* **2022**, *22*, 1340–1345.
17. Cabarkapa, D.; Fry, A.C.; Hermes, M. Accuracy of an experimental accelerometer for assessing countermovement vertical jump height. *Sports Innov. J.* **2021**, *2*, 45–55. [CrossRef]

18. Tant, C.L.; Lamack, D.; Greene, B. Sport-specific: A Biomechanical and physiological analysis of the volleyball jump set. *Strength Cond. J.* **1993**, *15*, 25–30. [CrossRef]
19. Maessen, K.M.; Holt, L.E. A cinema/video analysis of setting in volleyball. In Proceedings of the 4 International Symposium on Biomechanics in Sports, Halifax, NS, Canada, 15–19 July 1986.
20. Ozawa, Y.; Uchiyama, S.; Ogawara, K.; Kanosue, K.; Yamada, H. Biomechanical analysis of volleyball overhead pass. *Sports Biomech.* **2019**, *20*, 844–857. [CrossRef]
21. Cabarkapa, D.; Fry, A.C.; Mosier, E.M. Validity of 3-D markerless motion capture system for assessing basketball dunk kinetics—A case study. *Sport J.* **2020**. Available online: http://thesportjournal.org/article/tag/basketball/ (accessed on 1 September 2022).
22. Cabarkapa, D.; Whetstone, J.M.; Patterson, A.M.; Mosier, E.M.; Cabarkapa, D.V.; Fry, A.C. Relationship between health-related physical fitness parameters and functional movement screening scores acquired from a three-dimensional markerless motion capture system. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4551. [CrossRef]
23. Daggett, M.C.; Witte, K.A.; Cabarkapa, D.; Cabarkapa, D.V.; Fry, A.C. Evidence-based data models for return-to-play criteria after anterior cruciate ligament reconstruction. *Healthcare* **2022**, *10*, 929. [CrossRef] [PubMed]
24. Kabacinski, J.; Murawa, M.; Dworak, L.B.; Maczynski, J. Differences in ground reaction forces during landing between volleyball spikes. *Trends Sport Sci.* **2017**, *24*, 87–92.
25. Hughes, G.; Watkins, J.; Owen, N. Differences between the sexes in knee kinetics during landing from volleyball block jumps. *Eur. J. Sport Sci.* **2010**, *10*, 1–11. [CrossRef]
26. Hsieh, C.; Cascarina, S.; Pingatore, J. Kinetic effect of a four-step and step-close approach in a volleyball spike jump for female athletes. In Proceedings of the 28 International Conference on Biomechanics in Sport, Marquette, MI, USA, 19–23 July 2010.
27. Struzik, A.; Pietraszewski, B.; Zawadzki, J. Biomechanical analysis of the jump shot in basketball. *J. Hum. Kinet.* **2014**, *42*, 73. [CrossRef]