Journal Sport Area
http://journal.uir.ac.id/index.php/JSP
Vol. 11. No. 2. August, (2026)

Kinaesthetic perception and spike performance in volleyball: A correlational analysis

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Received 25 September 2025; Accepted 18 May 2026; Published 15 June 2026
Ed 2026; *11*(2): 179-188

ABSTRACT

Background: Despite extensive research on biomechanical determinants of spike performance, evidence linking perceptual–kinaesthetic abilities to sport-specific execution remains limited. **Objectives:** This study examined the relationship between kinaesthetic perception and spike performance in volleyball. **Methods:** A correlational design was used with 40 male physical education students (non-elite players). Kinaesthetic perception was assessed using the Kinaesthetic Obstacle Test (KOT), and spike performance was evaluated through an on-court accuracy test. Pearson's correlation was applied. **Results:** A significant positive relationship was found between kinaesthetic perception and spike performance ($r = 0.614$, $p < 0.05$). The coefficient of determination ($r^2 = 0.377$) indicates that kinaesthetic perception accounts for 37.7% of the variance in performance. **Conclusion:** Kinaesthetic perception is meaningfully related to spike performance, supporting its role in perceptual-motor integration during complex open skills. However, performance is multifactorial, and findings are limited to a non-elite sample. Future studies should incorporate additional physical and perceptual variables and employ designs that allow stronger inference.

Keywords: Kinesthetic perception; spike performance; volleyball; proprioception; sensorimotor integration

https://doi.org/10.25299/sportarea.2026.vol11(2).25010

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How to Cite: Lardika, R. A., Tulyakul, S., Sulastio, A., & Rusmanto (2026). Kinesthetic perception and spike performance in volleyball: A correlational analysis. *Journal Sport Area*, *11*(2), 179-188. https://doi.org/10.25299/sportarea.2026.vol11(2).25010

Authors' Contribution: a – Study Design; b – Data Collection; c – Statistical Analysis; d – Manuscript Preparation; e – Funds Collection

INTRODUCTION

The volleyball spike is a complex, open skill movement requiring precise spatiotemporal coordination, rapid force production, and accurate perceptual motor integration (De Waelle et al., 2021; Faß et al., 2020; Formenti et al., 2019). Unlike closed skills performed in stable environments, the spike demands real-time adaptation to a moving ball, opponent block positioning, and court spatial awareness (De Blasiis et al., 2025; Pavlov & Buzhinskiy, 2019; Pereira et al., 2015). Despite its importance as a primary attacking technique, successful spike execution remains challenging due to the need for precise timing, coordination, and adaptation to dynamic environmental conditions (Height et al., 2020; Pavlov & Buzhinskiy, 2019). Accuracy in anticipating the arrival of the ball greatly influences the stages of performing a smash, as it determines the effectiveness of approach, jump, and ball contact phases (Grosso et al., 2024; Marszałek et al., 2018; Nasuka et al., 2020; Pavlov & Buzhinskiy, 2019). This can only be achieved by players who are able to perform anticipatory movements in response to external stimuli, characteristic of open motor skills (De Blasiis et al., 2025; Holfelder et al., 2020).

In this study, kinaesthetic perception is operationalised as the ability to perceive, interpret, and mentally simulate body position and movement without visual feedback, encompassing both proprioceptive awareness and kinaesthetic motor imagery (KMI) (Filgueiras et al., 2018; Peters et al., 2025; Zapała et al., 2023). This construct reflects internal modelling of movement dynamics, which is essential for planning and adjusting complex motor actions such as the volleyball spike. Kinaesthetic perception has been shown to correlate with motor learning rates (r = 0.52-0.68) in upper limb positioning tasks (Giblin et al., 2015), and with performance in sports requiring closed - loop control, such as gymnastics and shooting (Baiano et al., 2023; Ridderinkhof & Brass, 2015). However, its role in interceptive open skills, where visual input is simultaneously available, remains less understood.

Despite extensive research on biomechanical and physical determinants of spike performance (De Blasiis et al., 2022; Height et al., 2020; Pereira et al., 2015), relatively little attention has been given to perceptual–kinaesthetic factors. Existing studies have largely focused on muscle strength (Asaeda et al., 2019; Pereira et al., 2015), jump performance (De Blasiis et al., 2022), and spatiotemporal technique parameters (Pavlov & Buzhinskiy, 2019), with limited empirical investigation into how kinaesthetic perception contributes to spike execution in dynamic sports contexts. Furthermore, while kinaesthetic motor imagery (KMI) has been studied in laboratory settings (Dahm & Rieger, 2023; Filgueiras et al., 2018; Ridderinkhof & Brass, 2015), evidence linking directly measured kinaesthetic perception rather than self-reported imagery ability to actual spike success in ecologically valid on-court conditions remains scarce (Rimbert & Fleck, 2023; Zapała et al., 2023).

To date, no published study has directly examined the relationship between kinaesthetic perception measured through objective locomotor-based tasks and spike performance in volleyball. To address this gap, the present study examines the association between kinaesthetic perception, measured using a standardised Kinaesthetic Obstacle Test (Shibata & Kaneko, 2013), and spike performance among volleyball players. The KOT requires participants to navigate a coned area blindfolded, thus primarily assessing spatial navigation and general locomotor proprioception rather than sport-specific upper limb kinaesthesia (Giblin et al., 2015). Accordingly, it captures proprioceptive components relevant to the approach and jump phases (e.g., foot placement, balance, and body orientation) but does not directly measure arm swing or ball-contact control. This distinction is important for interpreting the study's findings. Specifically, we test the hypothesis that higher kinaesthetic perception is significantly associated with greater spike success.

METHODS

Research Design

This study employed a correlational research design to examine the association between kinaesthetic perception and spike performance in volleyball. A correlational design was used to examine the association between kinaesthetic perception and spike performance, without manipulating variables (Fraenkel et al., 2023). This design is appropriate given the study's objective to identify perceptual-motor factors associated with spike success rather than to infer causality.

Participants

The population comprised 102 male physical education students enrolled in a volleyball course at the University of Riau. Using purposive sampling, 40 participants (mean age = 20.4 ± 1.2 years) were selected based on the following criteria: active participation in volleyball training, no lower extremity injury in the past six months, and full attendance at testing sessions. Only male participants were included to control for sex-related differences in motor performance. Individuals with prior competitive experience at the provincial level or higher were excluded to ensure a non-elite sample. Sample size adequacy was confirmed using a priori power analysis (G*Power 3.1.9.7; r = 0.40, α = 0.05, power = 0.80), indicating a minimum of 38 participants (Faul et al., 2009). The use of a student sample minimised confounding effects associated with prolonged elite training; however, this may limit generalisability to competitive athletes.

Instruments

Two instruments were used: the Kinaesthetic Obstacle Test (KOT) to assess kinaesthetic perception and a standardised spike performance test to evaluate spike accuracy.

Kinaesthetic Obstacle Test (KOT)

The KOT, adapted from Shibata and Kaneko (2013), was used as a proxy measure of kinaesthetic perception related to locomotor proprioception. Participants walked blindfolded through a 10 m × 5 m area with five cones arranged in a non-linear pattern **(Figure 1)**. The score was calculated as: Score = 100 − [(time in seconds) + (errors × 5)], with higher scores indicating better performance. The KOT assesses spatial navigation and whole-body proprioception without visual input rather than sport specific upper limb kinaesthetic control required for arm swing or ball contact (Dahm & Rieger, 2023; Giblin et al., 2015; Rimbert & Fleck, 2023). Therefore, it reflects perceptual motor components relevant to the approach and jump phases (e.g., foot placement, balance, and body orientation), but does not directly capture upper-limb kinaesthetic awareness. This limitation is acknowledged when interpreting the findings. The test has demonstrated acceptable test–retest reliability in young adults (ICC = 0.85) (Giblin et al., 2015).

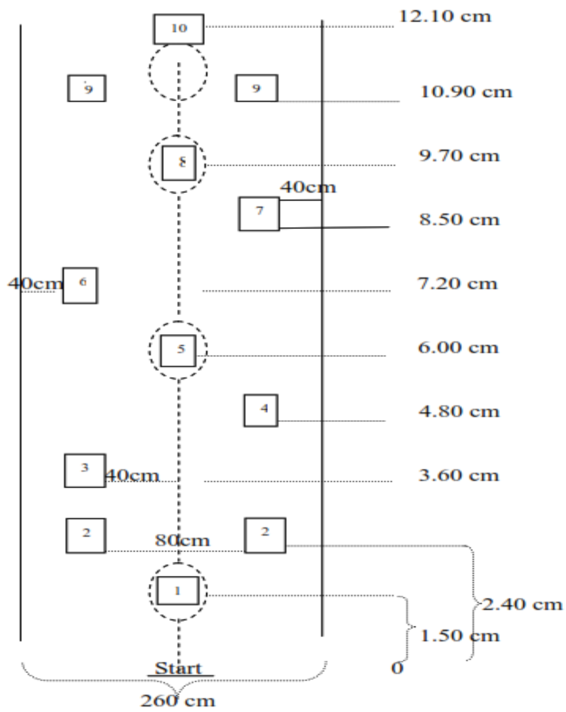

Figure 1. Kinaesthetic Obstacle Test

Spike Performance Test

Spike performance was assessed using a standardised on court accuracy test (Dearing, 2019; Palao & Valadés, 2012). The test was conducted on a regulation volleyball court with predefined scoring zones **(Figure 2)**: Zone 1 (deep corner, 3 points), Zone 2 (mid-court, 2 points), and Zone 3 (cross-court angles, 2 points). Balls landing in-bounds outside these zones scored 1 point, while errors (net, out, or blocked) scored 0. Each participant performed 15 spike attempts against a passive two-person block, and total scores were converted into percentages. The protocol demonstrates ecological validity by replicating key elements of game situations, including a live setter, defensive presence, and temporal constraints. The test has shown acceptable test retest reliability (r = 0.82) (Dearing, 2019; Palao & Valadés, 2012).

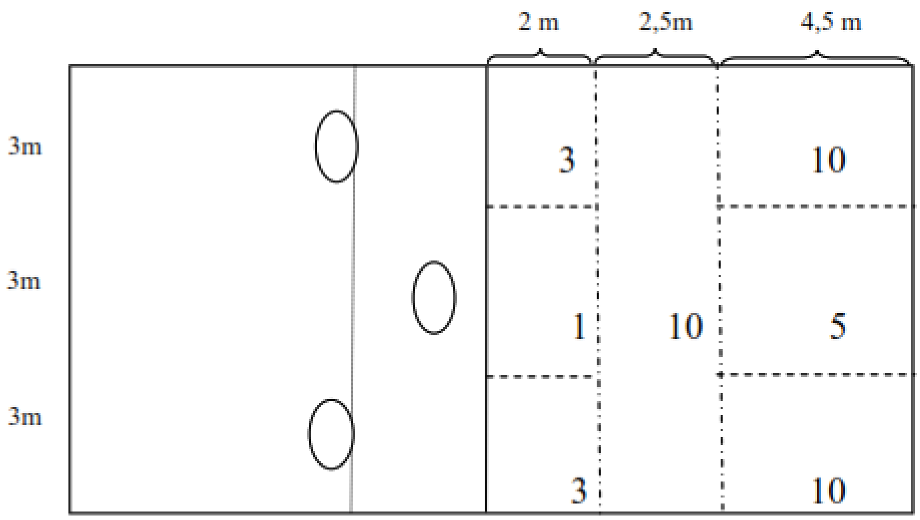

Figure 2. Spike Performance Test

Procedures

Data collection was conducted over two sessions, one week apart, at the University of Riau volleyball court under standardised environmental conditions (08:00 local time). Participants were instructed to refrain from vigorous physical activity for 24 hours prior to testing. For the kinaesthetic perception test, participants were blindfolded and wore noise-cancelling headphones emitting white noise to eliminate visual and auditory cues. After one familiarisation trial with vision, each participant completed three recorded blindfolded trials. Performance was scored using the fastest trial with the fewest errors. For the spike performance test, a consistent feeder delivered high passes to an experienced setter (5 years of competitive experience), who set the ball to the left front position (position 4). Trials were repeated if the set was judged as inaccurate (e.g., too tight, too wide, or off speed), with a 15-second rest interval between attempts. Each participant performed 15 valid spike attempts against a passive two-person block.

Data Analysis

Data were analysed using IBM SPSS Statistics (version 26.0). Assumptions for Pearson's correlation were assessed prior to analysis, including normality (Shapiro–Wilk test), linearity (scatterplot inspection), and absence of outliers (z-scores ± 3.29). Both variables were normally distributed ($p > 0.05$), the relationship was linear, and no univariate outliers were identified. Pearson's product-moment correlation coefficient (r) was used to examine the association between kinaesthetic perception and spike performance ($\alpha = 0.05$, two-tailed). The coefficient of determination (r^2) was calculated to estimate the proportion of variance in spike performance explained by kinaesthetic perception.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki and was approved by the PAIFORI BALI (Number: 003687/PAIFORI BALI/2025).

RESULTS AND DISCUSSION

Results

Assumption Testing

Prior to inferential analysis, the assumptions underlying Pearson's product–moment correlation were examined. Normality was assessed using the Shapiro–Wilk test, while linearity and outliers were evaluated through scatterplot inspection and standardised z-scores. The results indicated that both variables were normally distributed ($p > 0.05$), the relationship between variables was linear, and no univariate outliers exceeded the acceptable threshold (± 3.29). Therefore, the data met the assumptions required for Pearson's correlation analysis.

Descriptive Statistics

Descriptive statistics for kinaesthetic perception and spike performance are presented in **Table 1**. Kinaesthetic perception scores ranged from 62 to 98, with a mean score of 86.4 (SD = 8.7). Spike performance scores ranged from 58 to 94, with a mean score of 82.1 (SD = 9.3). Both variables demonstrated negative skewness, indicating that most participants achieved relatively high scores.

Table 1. Descriptive Statistics and Assumption Testing Results

Variable	Mean ± SD	Range	Skewness	Shapiro–Wilk (W)	p-value	Interpretation
Kinaesthetic perception	86.4 ± 8.7	62-98	-0.87	0.774	0.154	Normal
Spike performance	82.1 ± 9.3	58-94	-0.64	0.924	0.167	Normal

The negative skewness values suggest that participants generally demonstrated relatively high kinaesthetic perception and spike performance abilities. No extreme outliers were identified during preliminary screening.

Correlation Analysis

Table 2 presents the results of the Pearson product–moment correlation analysis between kinaesthetic perception and spike performance. The analysis revealed a statistically significant positive association between kinaesthetic perception and spike performance ($r = 0.614$, $p = 0.001$). Based on Cohen's interpretation criteria, this coefficient indicates a moderate-to-strong correlation. The 95% confidence interval ranged from 0.372 to 0.778, indicating a stable positive relationship between the variables. The coefficient of determination ($r^2 = 0.377$) indicated that kinaesthetic perception accounted for approximately 37.7% of the variance in spike performance, while the remaining 62.3% may be explained by other physical, perceptual, technical, or psychological factors not examined in the present study.

Table 2. Correlation Between Kinaesthetic Perception and Spike Performance

Variables	r	95% CI	r^2	p-value	Interpretation
Kinaesthetic perception – Spike performance	0.614	0.372-0.778	0.377	0.001	Moderate-to-strong positive correlation

The findings indicate that participants with higher kinaesthetic perception scores tended to demonstrate superior spike performance. **Figure 3** illustrates the positive linear relationship between the two variables.

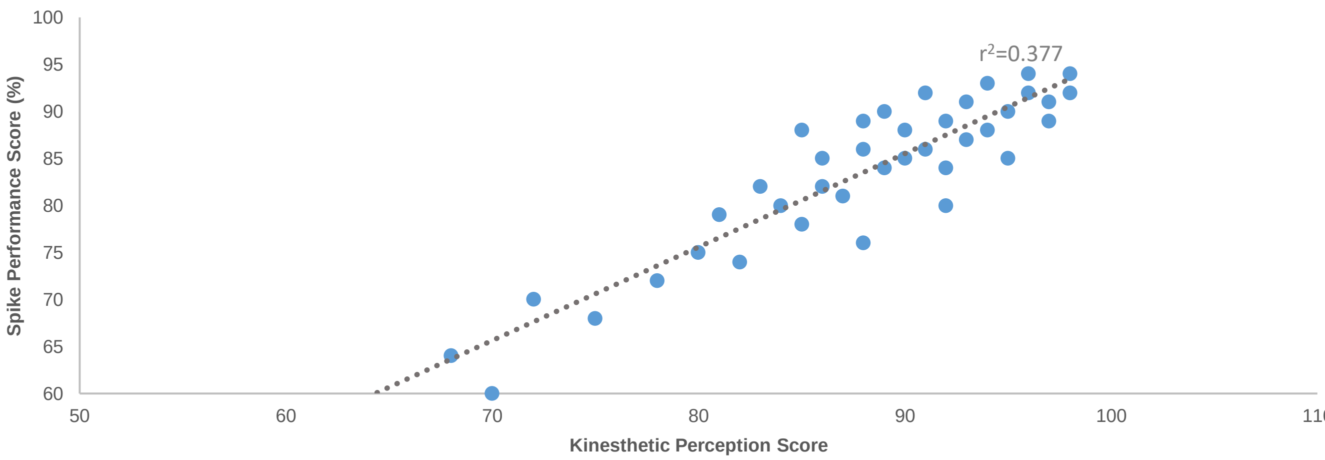

Figure 3. Scatterplot of Kinaesthetic Perception Scores and Spike Performance, Showing a Significant Positive Linear Relationship ($r = 0.614$, $p < 0.05$)

Overall, the results support the proposed hypothesis that kinesthetic perception is significantly associated with volleyball spike performance among non-elite physical education students.

Discussion

This study found a significant moderate-to-strong positive correlation between kinaesthetic perception and volleyball spike performance ($r = 0.614$, 95% CI [0.372, 0.778], $p < 0.05$). The coefficient of determination ($r^2 = 0.377$) indicates that kinaesthetic perception accounts for approximately 38% of the variance in spike success, leaving 62% unexplained.

Why does kinaesthetic perception relate to spike performance? The volleyball spike consists of three temporally distinct phases: the approach and jump (locomotor phase), the arm swing (ball acceleration phase), and the contact and follow-through (precision phase). Each phase places different demands on perceptual systems. During the approach and jump, the player must maintain body orientation and foot placement while visually tracking a moving ball, a dual-task condition requiring proprioceptive feedback for postural control (De Blasiis et al., 2022). Kinaesthetic perception, specifically the ability to simulate and adjust body position without continuous visual monitoring, enables the player to maintain optimal joint angles and timing during this phase (Filgueiras et al., 2018; Ridderinkhof & Brass, 2015). In the arm swing phase, kinaesthetic feedback from the shoulder and elbow guides force production and swing plane; errors in joint position sense at this stage directly affect ball trajectory (Zapała et al., 2023). From the perspective of perception-action coupling, the volleyball spike is an open motor skill that requires continuous integration of sensory information to guide movement in real time (Ridderinkhof & Brass, 2015).

This finding aligns with Baiano et al. (2023), who reported that kinaesthetic perception significantly influences open skills requiring real-time adaptation. Similarly, Giblin et al. (2015) found that kinaesthetic sensitivity correlates with motor learning rates ($r = 0.52$-0.68) in upper-limb positioning tasks. The result is also corroborated by research in other sports, which links superior proprioception and motor imagery to enhanced skill execution (Filgueiras et al., 2018). However, direct comparison with previous volleyball studies is limited because most have focused on biomechanical predictors (jump height, arm velocity) rather than perceptual kinaesthetic factors (De Blasiis et al., 2022, 2025; Height et al., 2020; Pereira et al., 2015). Studies have largely focused on muscle strength (Pereira et al., 2015), jump performance (De Blasiis et al., 2025), and spatiotemporal technique parameters (Pavlov & Buzhinskiy, 2019). While kinaesthetic motor imagery (KMI) has been studied in laboratory settings (Filgueiras et al., 2018; Ridderinkhof & Brass, 2015), evidence linking directly measured kinaesthetic perception to actual spike success in ecologically valid on-court conditions remains scarce (Zapała et al., 2023). To date, no published study has directly examined the bivariate association between kinaesthetic perception measured via a blindfolded obstacle navigation task and spike success in volleyball, making this study a preliminary contribution to a largely unexplored area.

The finding that 62% of spike performance variance is not explained by kinaesthetic perception is consistent with prior multivariate studies. These undoubtedly include biomechanical components such as vertical jump height and arm swing velocity (Baritz, 2020; Özgül, 2018), which directly influence the power and angle of the attack. Pereira et al. (2015) reported that vertical jump height alone accounted for 18-22% of spike success variance in adolescent players, while arm swing velocity contributed an additional 12-15%. De Waelle et al. (2021) found that perceptual-cognitive skills (anticipatory timing and visual search behaviour) explained 12-18% of variance independent of physical attributes. Furthermore, psychological factors such as competitive anxiety, focus, and tactical decision-making (e.g., identifying gaps in the block or defence) also play a crucial role in determining the final outcome of an attack (De Waelle et al., 2021; Pashabadi et al., 2011). Pashabadi et al. (2011) showed that psychological factors such as competitive anxiety and attentional focus explain 8-12% of performance variance in volleyball attacking actions. Taken together, these estimates sum to approximately 50-67%, which brackets our observed 38% for kinaesthetic perception. The residual variance (< 5-10%) is likely attributable to measurement error, fatigue, and unmeasured individual differences (e.g., previous sports experience, motivation). Thus, kinaesthetic perception is not the sole or even dominant predictor of spike success. Rather, it operates in concert with physical, perceptual-cognitive, and psychological factors. This multifactorial architecture has implications for how the field models sport performance: additive or interactive? (Formenti et al., 2019).

A critical methodological consideration is the nature of the Kinaesthetic Obstacle Test (KOT). The KOT, adapted from Shibata and Kaneko (2013), was used as a proxy measure of kinaesthetic perception relevant to the locomotor and proprioceptive demands of the volleyball spike approach and jump phases. The KOT primarily assesses spatial navigation and general locomotor proprioception (i.e., awareness of body position in space during ambulation without vision) rather than sport specific upper limb kinaesthetic perception required for arm swing or ball contact (Giblin et al., 2015). Therefore, the KOT captures the proprioceptive component relevant to the approach and jump phases (foot placement, body orientation, and balance) but does not directly measure the kinaesthetic awareness of the hitting arm or fingers. This distinction is important for interpreting the study's findings and may explain why the observed correlation ($r = 0.614$), while significant, was not stronger (e.g., > 0.80). The instrument has demonstrated acceptable test-retest reliability (ICC = 0.85) in young adult populations (Giblin et al., 2015), but construct validity for volleyball spike performance has not been established.

A ceiling effect was also observed, with 70% of kinaesthetic perception scores and 52% of spike performance scores falling in the highest range (90-100). This restricted range and negative skew may attenuate the correlation coefficient, as limited variance reduces the potential to detect a stronger association (Fraenkel et al., 2023). These distributional characteristics suggest that the sample was relatively homogeneous in terms of both kinaesthetic perception and spike performance, which may limit the generalisability of the findings and potentially bias the correlation toward underestimation.

From a theoretical perspective, these findings support the perception-action coupling framework by demonstrating that kinaesthetic perception even when measured through a general locomotor task, contributes meaningfully to performance in an interceptive open skill. This suggests that internal body modelling (Ridderinkhof & Brass, 2015) is not merely a laboratory phenomenon but has measurable associations with real-world sport performance. The findings provide an empirical foundation for understanding how kinaesthetic perception integrates with other performance determinants in volleyball.

Several limitations must be acknowledged when interpreting these findings. First and most importantly, the sample consisted entirely of physical education students who were not competitive athletes (no provincial or above competition history). Participants were physical education students, not competitive athletes, and had no national or regional competition history. This fundamentally limits the generalisability of the findings to elite volleyball players, club level athletes, or populations with extensive sport-specific training. The observed correlation may not replicate in populations with different levels of perceptual-motor expertise. Second, the KOT measures locomotor proprioception, not upper-limb kinaesthesis specific to spiking; construct validity for volleyball spike performance has not been established. The KOT was originally developed for general proprioceptive assessment, not sport-specific skills. Third, ceiling effects in both variables restricted variance, potentially attenuating the correlation. A ceiling effect was observed in kinaesthetic perception scores (70% of participants in the 'very good' range), indicating restricted variance that may have attenuated the correlation coefficient. Consequently, the true strength of the association could be higher than reported in a more heterogeneous sample. Fourth, the sample size ($n = 40$) was relatively small, which may affect the stability of the correlation estimate and the precision of the confidence interval. Fifth, the use of an all-male sample limits generalisability to female athletes, as gender differences in proprioceptive accuracy and motor performance have been documented. Sixth, the correlational design precludes any causal inference. This association indicates that individuals with higher kinaesthetic perception tend to demonstrate greater spike success, but no directional or causal inferences can be made.

Future studies should move beyond bivariate correlation to multivariate prediction models that include kinaesthetic perception alongside jump height, arm velocity, and anticipatory timing to clarify whether kinaesthetic perception explains unique variance beyond these factors. Experimental studies using kinaesthetic training interventions (e.g., blindfolded approach drills, proprioceptive feedback reduction, closed-eye drills, or responsive games) are needed to test causality and determine whether kinaesthetic perception training causally improves spike outcomes. Cross-sectional comparisons across expertise levels (novice vs. intermediate vs. elite) would reveal whether the kinaesthetic perception spike relationship changes with skill acquisition, for instance, whether elite players show lower variance (ceiling effects) or different mechanisms (automated vs. controlled processing). Finally, sport specific kinaesthetic measures (e.g., upper-limb joint position replication tasks) should be developed and validated for volleyball. Longitudinal designs could also examine whether changes in kinaesthetic perception precede or follow improvements in spike performance.

CONCLUSION

This study demonstrates a significant positive association between kinaesthetic perception and volleyball spike performance, highlighting the role of perceptual–motor processes in executing complex open skills. Although the correlational design does not permit causal inference, the findings suggest that kinaesthetic perception contributes meaningfully to performance variability. These results extend existing literature by providing empirical evidence linking objective measures of kinaesthetic perception to sport-specific performance in an ecologically valid setting.

ACKNOWLEDGEMENTS

The authors thank the Physical Education students at the University of Riau for their participation. We also acknowledge the support of the Directorate of Research and Community Services (DPPM) under Grant Number [19578/UN19.5.1.3/AL.04/2025].

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

AI DISCLOSURE STATEMENT

The authors used Grammarly solely for language editing and grammatical improvement. No generative AI tools were used to create, analyze, interpret, or write the scientific content of this manuscript.

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