

Effects of upper-extremity balance asymmetry on service accuracy in young female volleyball players

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Abstract

Introduction. Upper-extremity stability plays an important role in the application of technical skills that require repetitive and precise upper-extremity movements, such as serving in volleyball. Functional asymmetries in the upper extremities can negatively affect motor control and performance by disrupting balance and strength transfer. **Aim of Study.** The research aimed to investigate whether upper-extremity balance asymmetry predicts serve-accuracy performance in young female volleyball players. **Material and Methods.** A total of 31 female athletes, aged 14 to 18 years with at least two years of licensed sports experience, participated in the study. Upper-extremity balance asymmetries were assessed using the Upper Quarter Y Balance Test (UQYBT) in the medial, inferolateral, superolateral, and composite directions. Serve-accuracy performance was measured based on scores obtained from 10 serves targeting predefined target zones. Data were analyzed using descriptive statistics and multiple linear regression analysis. **Results.** The findings showed that among the four asymmetry variables, only composite asymmetry significantly predicted serve-accuracy performance ($p = 0.002$) and explained 35.7% of the variance in the model ($R^2 = 0.357$). Direction asymmetry measurements (medial, superolateral, inferolateral) did not show a significant relationship with serve performance. **Conclusions.** The findings suggest that upper-extremity composite balance asymmetry is a functional factor influencing serve accuracy in young volleyball players. Moreover, higher composite asymmetry values, particularly those within the upper range of the sample distribution, may be associated with reduced motor control and movement accuracy.

KEYWORDS: balance, motor control, asymmetry, service accuracy, UQYBT.

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Introduction

The consistency of technical performance in athletes depends on strength capacity and balance, motor control, proprioception, and bilateral symmetry. In sports that involve frequent overhead movements, such as serving, blocking, and spiking, upper-extremity stability is crucial for accurate, repeatable execution of these skills [1-3]. The effective functioning of the upper extremity, both in terms of movement production and accuracy, directly influences the quality of technical skills. One key factor affecting upper-extremity stability is functional asymmetry. While the human body naturally exhibits some lateral differences, higher levels of asymmetry may disrupt balance, force transfer, and movement continuity [4, 5]. Previous findings suggest that asymmetry values derived from upper-extremity balance tests may reflect functionally meaningful deficits rather than normal lateral variation [6]. Recent evidence suggests that upper-quarter balance performance is influenced by

intrinsic factors, such as age and sex, as well as by sport-specific demands, highlighting the importance of evaluating functional asymmetry within homogeneous athlete groups [7]. Structural or functional differences between dominant and non-dominant sides may affect force distribution and the precision of technical execution [4, 5]. Over time, these imbalances can result in asymmetric loading of the musculoskeletal system, thereby increasing the risk of injury [1, 8].

Identifying asymmetries between extremities is essential for planning preventive training and technical interventions. Functional performance tests are among the primary tools used for this purpose. The Upper Quarter Y Balance Test (UQYBT) is a widely used test for assessing upper-extremity stability and bilateral balance in athletes, with proven applicability in both clinical and field settings [7, 9, 10]. In young female overhead athletes, the UQYBT has been used alongside upper-body field performance tests, and differences in balance performance have been reported between sports such as volleyball and handball, reflecting the sport-specific demands placed on the upper extremity [11]. Normative reference values for the UQYBT have been established for youth athletes aged 10–17 years, supporting its suitability for evaluating upper-extremity balance and asymmetry in adolescent populations [12]. The composite scores and asymmetry values provided by this test offer significant insights into an athlete's functional balance level [13, 14].

Proprioceptive control of the shoulder complex has been shown to contribute to upper-extremity functional performance, with active joint-position sense significantly associated with YBT-UQ reach distances and composite scores in volleyball players [15]. Data obtained from applying the UQYBT to athletes can be associated with both balance and performance levels. Research has shown that this upper-extremity-specific test is related to technical skills, and significant asymmetries may cause various deviations in technical performance [7, 16]. In adolescent overhead athletes, specific asymmetry patterns identified through the UQYBT have also been linked to unfavorable functional outcomes, highlighting the potential relevance of composite asymmetry measures [6]. In technically complex movements, such as serving, imbalances in the upper extremity may disrupt the movement chain [17, 18]. This can affect not only accuracy but also technical repeatability and endurance. Furthermore, prolonged imbalances may result in micro-level tissue stress and a decline in performance consistency [19, 20]. Previous research has indicated that training

can mitigate functional imbalances, and appropriate exercise programs can reduce bilateral differences [1, 17]. Therefore, regular assessments and individualized interventions may help programs effectively support performance. Supporting this view, structured warm-up interventions have been shown to improve upper-extremity dynamic balance and stability in female volleyball players, indicating that balance-related asymmetries are modifiable through targeted training [21]. In addition, shoulder-focused injury-prevention programs have been reported to enhance upper-quarter dynamic stability, as measured by the UQYBT, in young volleyball players, further supporting the functional relevance of upper-extremity balance assessments [22].

Aim of Study

This study examines the effect of upper-extremity asymmetry on serving accuracy in female volleyball players. In this context, the relationship between functional balance capacity and technical skills will be evaluated, and the effects of asymmetries on sport-specific outcomes will be examined holistically.

Material and Methods

Research model

This study employed a descriptive and predictive quantitative design. Descriptive statistics were used to summarize the data, and multiple linear regression analysis was conducted to examine the predictive effect of upper-extremity asymmetry on service accuracy [23]. Participants were selected using a convenience sampling design based on availability and eligibility criteria.

Participants

Female athletes aged 14–18 who had played volleyball for at least two years participated in the study voluntarily. The data were collected from licensed female volleyball players recruited from local developmental-level clubs. According to the Participant Classification Framework [24], our participants were classified as Tier 2 (trained/developmental) based on their regular, organized training and competitive participation. Participants were recruited from local volleyball clubs competing at the regional youth level. According to the sample size analysis conducted using the G*Power 3.1 program, the minimum sample size was calculated to be 23 for a moderate effect size ($f^2 = 0.35$), a 5% significance level ($\alpha = 0.05$), and an 80% test power ($1 - \beta = 0.80$).

in the multiple linear regression analysis. However, to prevent potential data loss and increase the study's statistical power, 31 female volleyball players were included. Participants were provided with detailed information about the purpose, process, and potential risks of the research, and participation was entirely voluntary. For individuals of legal age, parental consent and written approval were obtained in accordance with the relevant ethical guidelines. Exclusion criteria for the study included upper-extremity injury within the last 6 months, active pain complaints, or a diagnosis of a musculoskeletal, nervous, or cardiovascular system condition. Information about the participants is presented in Table 1.

Table 1. Descriptive statistics for the participants' demographic and physical characteristics

Variable	n	Min.	Max.	$\bar{X}$	SD
Age (years)	31	14.00	18.00	16.16	1.75
Training age (years)	31	2.00	6.00	3.87	1.09
Body weight (kg)	31	47.00	70.00	58.94	7.08
Height (m)	31	1.60	1.87	1.70	0.07
Body mass index (kg/m ²)	31	16.26	23.74	20.42	1.58

Note: $\bar{X}$ – mean; SD – standard deviation; Min. – minimum; Max. – maximum; n – number of participants; BMI – body weight / (Height²)

According to Table 1, the mean age of the participants was 16.16 ± 1.75 years, and the mean training age (years of structured volleyball training) was 3.87 ± 1.09 years. The mean body weight was 58.94 ± 7.08 kg, the mean height was 1.70 ± 0.07 m, and the body mass index (BMI) was 20.42 ± 1.58 kg/m².

Data collection tools

In this study, the data were collected using the personal information form, the Upper Quarter Y Balance Test, and the service accuracy test.

Personal information form

Personal information form was prepared by the researcher to collect participants' demographic and

athletic characteristics, including age, height, body weight, and years of sports experience.

Y-balance test

The Upper Quarter Y Balance Test (UQYBT) was used to evaluate upper-extremity functional balance capacity. The UQYBT is a valid and reliable test designed to assess the dynamic stability of the upper extremity in a closed kinetic chain position [25]. This test is an effective screening tool for identifying side-to-side differences in balance and control, especially in athletes [26]. In this test, participants reach in three directions (medial, inferolateral, and superolateral) using their dominant and non-dominant arms. While standing on a fixed platform, the participant extends the free arm in each direction as far as possible. Each reach distance is normalized based on arm length. Arm length is measured in a supine position from the seventh cervical vertebra (C7) to the tip of the middle finger [7, 25].

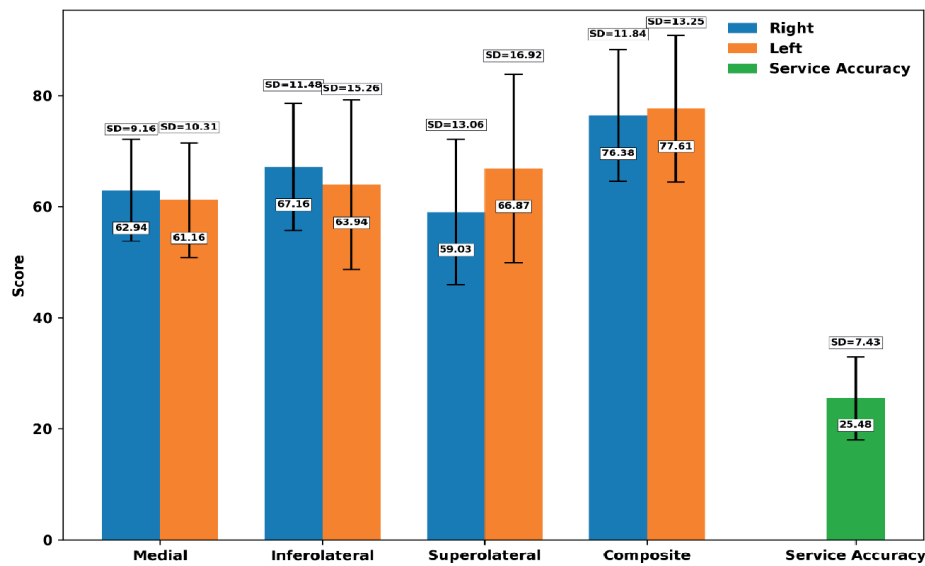
Composite score: $(\text{Medial} + \text{Inferolateral} + \text{Superolateral}) / (3 \times \text{Arm Length}) \times 100$

Asymmetry index: $(\text{Dominant Arm} - \text{Non-dominant Arm})$.

According to recent literature, asymmetry values greater than 7.75 cm indicate a potential risk of injury [4, 25]. The obtained data were evaluated to assess overall composite performance and bilateral balance differences. Descriptive statistics for Upper Quarter Y Balance scores and service accuracy variables are presented in Figure 1.

Service accuracy test

Service accuracy performance was measured to assess participants' technical skill. Each participant was asked to perform 10 consecutive serves from any preferred position within the service zone, aiming at predefined target areas. Each serve was scored based on the zone it landed in, and the total score of all serves represented the individual's service performance. The maximum possible score was 70 points, calculated from ten serves directed at zones assigned to different point values, under both resting and post-exercise conditions [27].



Note: Balance scores are expressed in centimeters (cm), composite balance scores in percentage (%), and service accuracy scores in points.

Figure 1. Descriptive Statistics for Upper Quarter Y Balance Scores and Service Accuracy Variables

Research procedure

The research process was carried out in three separate sessions, with an equal number of participants in each. The order of application was standardized for all participants. First, the personal information form was completed, followed by the UQYBT, and finally the service accuracy test. Before all assessments, a general warm-up protocol consisting of 5 minutes of low-intensity running and 5 minutes of dynamic upper-extremity stretching was performed. Participants were randomly assigned to testing to minimize the risk of systematic error due to the sequence of applications. According to the literature, fatigue may negatively affect UQYBT performance [28]. Therefore, the test order was arranged with the balance test conducted first, followed by the technical performance assessment. Additionally, all measurements were conducted within the same time frame (15:00-17:00), and environmental conditions were kept constant to minimize the influence of external factors.

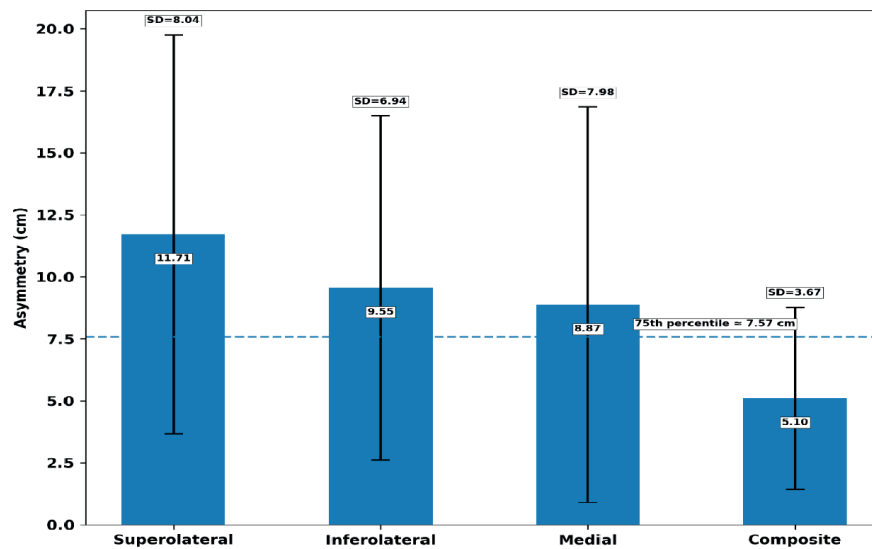
Data analysis

The data were analyzed using SPSS 25.0. The normality of the distribution was assessed using the Shapiro-Wilk test, and all variables were found to be normally distributed ($p > 0.05$). Descriptive statistics, including mean, standard deviation, minimum, and maximum values, were calculated and presented in Upper-extremity balance performance and asymmetry levels were analyzed across reach directions. In the descriptive graphs, $\pm$ SD error bars were used.

Multiple linear regression was conducted to examine relationships among variables. Service accuracy score was the dependent variable, and the composite, medial, superolateral, and inferolateral asymmetry values were included as independent variables. The significance level was set at $p < 0.05$. The model's explanatory power was evaluated using R-squared (R^2) and adjusted R-squared (R^2_{adj}) values. Prior to conducting the multiple linear regression analysis, the assumptions of linearity, normality of residuals, homoscedasticity, and absence of multicollinearity were examined. Visual inspection of residual plots and Q-Q plots indicated no major violations. Variance inflation factor (VIF) values were below accepted thresholds, indicating no multicollinearity. Effect size was calculated using Cohen's f^2 ($f^2 = R^2 / [1 - R^2]$). According to Cohen's benchmarks (0.02 = small, 0.15 = medium, 0.35 = large), the observed effect size ($f^2 = 0.56$) indicates a large effect.

Ethical approval

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained Ethics Committee Name: Scientific Research and Publication Ethics Committee of Erzurum Technical University Project/approval ID: Meeting No: 06, Decision No: 11 Date of approval: April 21, 2025. Written consent was obtained from the legal guardians of participants under 18, and informed consent was obtained from all other participants.



Note: Asymmetry values are expressed in centimeters (cm) (Asymmetry = Dominant Arm – Non-dominant Arm). The dashed line indicates the 75th-percentile cut-off value.

Figure 2. Descriptive Statistics for Upper Extremity Asymmetry Variables

Results

According to the data presented in Figure 1, the mean medial score for the right upper extremity was 62.94 ± 9.16 , the mean inferolateral score was 67.16 ± 11.48 , the mean superolateral score was 59.03 ± 13.06 , and the mean composite score was 76.38 ± 11.84 . For the left upper extremity, the mean medial score was 61.16 ± 10.31 , the mean inferolateral score was 63.94 ± 15.26 , the mean superolateral score was 66.87 ± 16.92 , and the mean composite score was 77.61 ± 13.25 . The

participants' mean service accuracy score was also 25.48 ± 7.43 .

Figure 2 shows that the highest mean asymmetry was observed in the superolateral asymmetry measurement, with a value of 11.71 ± 8.04 . Inferolateral asymmetry followed this at 9.55 ± 6.94 , medial asymmetry at 8.87 ± 7.98 , and composite asymmetry with the lowest mean value of 5.10 ± 3.67 . Composite asymmetry values ranged from 0.40 to 13.75 cm. To describe the upper range of composite asymmetry within the sample, the 75th percentile was approximated as the Z-score of the standard normal distribution ($Z = 0.674$), corresponding to mean + $0.674 \times SD$, yielding a value of approximately 7.5–8.0 cm.

As shown in Table 2, the multiple linear regression analysis revealed that only composite asymmetry significantly predicted service accuracy ($B = -1.345$, $p = 0.002$; $\beta = -0.601$). The overall model was statistically significant ($F_{(4,26)} = 3.612$, $p = 0.018$), explaining 35.7% of the variance ($R^2 = 0.357$; Adjusted $R^2 = 0.258$). Higher composite asymmetry values were associated with lower service accuracy, whereas the medial, superolateral, and inferolateral asymmetries did not show significant effects ($p > 0.05$). In the regression analysis, the statistical significance of individual predictors was evaluated using regression coefficients and p-values, while the overall model fit was assessed using the F-statistic; therefore, separate t-values were not reported.

Table 2. Results of the regression analysis

Model	independent variable	B	Std. error	β	t	p
1	Constant	31.500	4.004	—	7.867	<0.001
	Composite asymmetry	-1.345	0.388	-0.601	-3.469	0.002*
	Medial asymmetry	0.105	0.214	0.102	0.491	0.627
	Superolateral asymmetry	-0.035	0.201	-0.034	-0.175	0.863
	Inferolateral asymmetry	0.070	0.205	0.060	0.343	0.735

Note: B – unstandardized regression coefficient; R^2 – coefficient of determination; Std. error – standard error; β – standardized regression coefficient ($R = 0.598$, $R^2 = 0.357$, Adjusted $R^2 = 0.258$, Std. error = 7.06, $F_{(4,26)} = 3.612$, $p = 0.018$). Symmetry values are expressed in centimeters (cm). Service accuracy is reported in points; * $p < 0.05$

Discussion

This study aimed to investigate the impact of upper-extremity balance asymmetry on service accuracy in female volleyball players aged 14 to 18 years. The findings showed that the highest mean asymmetry was observed in the superolateral direction; however, multiple linear regression analysis revealed that only the composite asymmetry score was significantly associated with service accuracy. These findings suggest that, within the present sample of young female volleyball players, overall balance symmetry may be more closely associated with service accuracy than direction-specific asymmetry measures. Compared with similar studies in the existing literature, the findings offer insight into the importance of symmetry and its relationship with performance, particularly in upper-extremity activities prone to asymmetric loading. From a practical perspective, coaches may consider monitoring composite upper-extremity balance asymmetry during regular functional assessments of young volleyball players. However, such assessments should be interpreted cautiously and in conjunction with technical, physical, and training-related factors rather than as a standalone performance indicator. It should be noted that composite upper-extremity balance asymmetry is proposed as a performance-monitoring parameter rather than a standalone tool for injury-risk screening. It is important to note that the cross-sectional design of the present study precludes any causal interpretation of the observed associations. Although composite upper-extremity asymmetry emerged as a significant predictor of service accuracy, the findings should be interpreted as indicative of a relationship rather than a cause–effect mechanism. The observed associations reflect concurrent functional characteristics within the sample and do not allow conclusions regarding whether balance asymmetry directly leads to changes in service performance or vice versa.

One of the study's findings is that only the composite asymmetry score had a significant predictive effect on service accuracy. This indicates that although directional asymmetry measurements (medial, superior, and inferior) did not show a significant relationship individually, the overall level of asymmetry was more predictive of service performance. The study that confirmed the reliability of the UQYBT also emphasized that the composite score represents general balance symmetry and may be related to performance [25]. Similarly, the relationship between composite asymmetry levels in the upper extremity and athletic performance parameters has been reported, with higher asymmetry levels associated

with potential negative effects on performance [4]. This result is consistent with our study, which found that only the composite asymmetry score was significantly associated with service accuracy. In a similar study, UQYBT performance was reported to be associated with asymmetric movement patterns and considered a potential indicator of musculoskeletal injury risk and its negative impact on sports performance [29]. This observation aligns with previous research suggesting that composite asymmetry may be linked to both functional performance and injury-related outcomes. In a separate study, it was also noted that asymmetry may not always result in performance loss and, in some cases, can be a form of sport-specific adaptation [5]. On the other hand, differences in composite scores may vary by sport, which may explain some inconsistencies [14]. Accordingly, this study's findings suggest that composite balance symmetry may be a significant functional factor influencing service accuracy in young volleyball players. However, the absence of a comparison with more skilled or elite volleyball players limits the extent to which these findings can be generalized across different performance levels. In this context, higher composite asymmetry values observed within the upper range of the sample distribution were descriptively associated with lower service accuracy scores; however, this observation should be interpreted as a distribution-based finding rather than a definitive performance threshold. Interpretation should remain cautious, as the sample included only Tier 2 (trained/developmental) female players, and the absence of male athletes limits broader inference. From a theoretical perspective, composite asymmetry may reflect integrated neuromuscular coordination and proprioceptive control across multiple movement planes rather than isolated directional balance deficits. Motor control frameworks emphasize that accurate overhead performance relies on coordinated intersegmental control and effective sensorimotor integration [30]. Supporting this view, disruptions in intermuscular coordination have been shown to compromise upper-extremity movement precision across different task conditions [31]. Additionally, experimental evidence indicates that proprioceptive disturbances can influence composite Upper Quarter Y Balance Test scores, highlighting the sensitivity of composite measures to fluctuations in neuromuscular control relevant to performance accuracy [32]. This finding suggests that service accuracy may depend on integrated upper-extremity control rather than on isolated directional stability, as composite asymmetry reflects cumulative neuromuscular coordination and proprioceptive

integration across multiple movement planes. Despite these findings, upper-extremity balance was assessed exclusively using a closed kinetic chain test. Volleyball serving, however, is predominantly an open kinetic chain skill that requires sequential intersegmental coordination and high movement velocity. Therefore, the lack of open kinetic chain assessments may have limited the extent to which balance asymmetry findings can be directly extrapolated to serve-specific motor demands. Accordingly, the present findings should be interpreted as reflecting general upper-extremity balance characteristics rather than a direct representation of open-chain, serve-specific motor performance. The present findings are limited to Tier 2 (trained/developmental) female volleyball players aged 14–18 years, which may limit their generalizability to male athletes or higher-performance levels. Therefore, the results should be interpreted within the context of the sampled population.

In the study, the lack of a significant relationship between asymmetry scores in the medial, superior, and inferior directions and service accuracy suggests that directional analyses alone may be insufficient to predict performance variables. This may be explained by individual differences in balance control mechanisms across different directions. It was stated that numerous internal (e.g., strength, mobility) and external (e.g., test environment, experience) factors affect UQYBT scores [7]. Additionally, it was argued that directional balance scores are related to sport-specific movement patterns; therefore, directional asymmetries may not directly impact overall performance [2]. In another study, although the UQYBT provides important information about upper extremity balance through directional and composite scores, it may not be sufficient to explain sport-specific technical skills. This finding aligns with our result that directional scores were not associated with service accuracy [33]. A different study stated that directional asymmetry measurements of the upper extremity can be used to assess mobility and balance, but identifying functional imbalances is more meaningful when all directions are considered together [34]. These findings, indicating that directional asymmetry scores did not serve as statistically significant predictors in our study, suggest that focusing on composite values rather than directional measurements should be prioritized in functional assessments to predict technical skill performance.

The mean service accuracy obtained in the study (25.48 ± 7.43) indicates that the technical accuracy level of young female volleyball players was moderate.

This finding is consistent with the results reported by Lidor et al. in service accuracy tests conducted under both resting and post-exercise conditions [27]. It was particularly shown that hits to high-point target zones, even under fatigue, predicted overall success more accurately. Although no fatigue condition was applied in our study, technical accuracy performance was analyzed with UQYBT asymmetry values. This approach suggests that a complex motor skill, such as serving, cannot be explained solely by balance-related factors. Furthermore, studies by Garrison et al. and Lockie et al. have reported a weak relationship between functional movement competence and sport skill performance, emphasizing that technical skills depend on multidimensional determinants [18, 35]. Therefore, when analyzing service accuracy, it is essential to consider factors such as balance, strength, attention, reaction time, and technical training history.

Conclusions

The findings of the present study suggest that higher composite upper-extremity asymmetry values, particularly those located within the upper range of the sample distribution (approximately 7.5–8.0 cm), may be associated with reduced service accuracy in young female volleyball players. However, this relationship should be interpreted as probabilistic and sample-specific rather than as indicative of a definitive performance threshold. Overall, the results indicate that balanced and symmetrical upper-extremity motor control may play an important role in the sustainability of technical volleyball skills. Several limitations should be considered when interpreting these findings. Due to the cross-sectional design of the study, causal relationships between upper-extremity balance asymmetry and service accuracy cannot be established. Furthermore, the sample consisted exclusively of Tier 2 (trained/developmental) female volleyball players aged 14–18 years, limiting the generalizability of the results to male athletes and higher-performance levels. In addition, upper-extremity function was assessed solely using a closed kinetic chain balance test; therefore, open kinetic chain demands inherent to volleyball-specific skills, such as serving, were not directly evaluated, potentially limiting the sport-specific interpretation of the findings. Future research should employ longitudinal or intervention-based study designs to examine whether targeted upper-extremity training programs can reduce balance asymmetry and improve service accuracy. Moreover, incorporating both closed- and open-chain assessments may help clarify the transferability of balance-related adaptations to sport-specific technical performance.

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Conflict of Interest

The authors declare no conflict of interest.

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