

Article

Body Composition and Upper- and Lower-Limb Physical Performance in Youth Female Volleyball Players: Evidence from U13 and U15

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Abstract

Objective: This study examined the associations between body composition and physical performance in U13 and U15 volleyball players. **Methods:** A total of 67 female athletes participated, distributed into U13 ($n = 35$) and U15 ($n = 32$) categories. Body weight, body fat percentage, skeletal muscle mass (SMM), and body mass index (BMI) were assessed, along with maximal handgrip strength (HGS), Abalakov jump (ABK), and standing long jump (SLJ). Spearman's rho correlations were calculated by category, with 95% bootstrap confidence intervals based on 5000 resamples and Benjamini–Hochberg adjustment for 24 comparisons. **Results:** In U13, SMM was associated with HGS ($r_s = 0.750$; $q < 0.001$), body fat percentage with ABK jump ($r_s = -0.496$; $q = 0.020$), body weight with handgrip strength ($r_s = 0.430$; $q = 0.043$), and body mass index with ABK jump ($r_s = -0.425$; $q = 0.043$). In U15, SMM was associated with HGS ($r_s = 0.705$; $q < 0.001$), while body fat percentage was associated with ABK jump ($r_s = -0.437$; $q = 0.043$) and standing long jump ($r_s = -0.446$; $q = 0.043$). **Conclusions:** These associations were specific to the variable, test, and age category analyzed and should be considered exploratory. Given the cross-sectional design and sample characteristics, the findings do not support causal inference, individualized training prescriptions, or conclusions that specific body composition profiles optimize physical performance. Longitudinal studies are needed to confirm these findings.



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Keywords: body composition; volleyball players; youth female; physical performance

1. Introduction

Volleyball is a high-intensity intermittent sport that combines explosive actions such as jumps, fast movements, and powerful spikes, interspersed with brief periods of rest [1]. Players can perform up to 200 jumps and between 30 and 50 attacks per match, highlighting the importance of developing strength and power in both the lower and upper limbs [2].

The most widely used tool to evaluate lower-limb performance is the vertical jump, which is particularly valuable for estimating the efficiency of the stretch–shortening cycle and explosive power (Ben Ayed et al., 2020; Grigoletto et al., 2023) [3,4]. Several tests have been designed to assess this ability, and its association with muscle strength has been documented [5,6]. However, there is limited evidence regarding its capacity to discriminate between performance levels in volleyball players aged 12 to 16 years, which could hinder motor development and athletic training during this critical stage [7].

On the other hand, the standing long jump (SLJ) allows for the assessment of antero-posterior explosive strength and is considered a functional test for the lower limbs [8]. This motor task involves coordination between the lower and upper extremities [9–11]. Its association with body adiposity has been used as an indicator of changes in body composition (BC) during growth [12,13], and it has been validated as a muscular fitness test in both active and sedentary populations [14,15]. The relationship between the SLJ and variables of physical performance and BC has been highlighted by [16], who found a significant association between SLJ and speed in female field hockey players. Additionally, a statistically negative association was identified between SLJ values without impulse and body height, as well as BC, in young volleyball players [17].

Regarding upper-limb strength, HGS has been consolidated as a robust indicator of overall muscular capacity due to its low cost, ease of measurement, and strong association with other physical abilities, regardless of sex or age [18]. Moreover, it is recognized for its diagnostic value in assessing musculoskeletal health in young athletes [19].

The assessment of BC, including body fat percentage (%BF) and skeletal muscle mass (SMM), may provide relevant information when examining physical performance during growth (Yeargin et al., 2018) [20]. Anthropometric assessment is commonly used to characterize athletes' morphology and monitor growth, nutritional status, and changes in BC during childhood and adolescence [21,22]. In young volleyball players, previous studies have reported associations between BC indicators and jump performance [17], as well as inverse associations between adiposity-related indicators and several physical and physiological variables [23]. Accordingly, the joint assessment of BC and upper- and lower-limb strength may contribute to a more comprehensive characterization of physical performance in young athletes [24].

Formative volleyball requires high levels of explosive strength in both the lower and upper limbs to perform key actions such as jumps, spikes, and blocks [3]. Although studies have analyzed the association between muscle strength and BC in elite athletes, [25–27] evidence in young female players from formative categories remains limited. Previous research has reported associations between SMM, %BF, jump performance, and muscular strength [28,29]. However, evidence in young female volleyball players from formative categories remains limited, particularly in Chile. This knowledge gap supports the need to examine the relationships between BC indicators and physical performance in this population. This knowledge gap makes it difficult to establish reference parameters and justifies the need to investigate muscle strength alongside BC indicators in young Chilean volleyball players. Such information may contribute to the descriptive characterization of young female volleyball players and support the formulation of hypotheses for future research [30].

It was hypothesized that greater SMM would be positively associated with HGS and jump performance, whereas higher body fat percentage and body mass index (BMI) would be negatively associated with performance in jump tests. A positive association between body weight and HGS was also expected. These relationships were analyzed separately in the under-13 (U13) and under-15 (U15) categories. Therefore, the objective of this study was to determine the association between body composition characteristics and upper- and lower-limb strength in formative-stage female volleyball players according to their category.

In this regard, the novelty of this study is that it specifically analyzes female players in the U13 and U15 categories in Chile and provides context-specific descriptive information on this group, which is scarcely explored in the international literature.

2. Methods

2.1. Study Design

This was a cross-sectional observational study with non-probabilistic territorial convenience sampling of correlational design, aimed at describing and examining the association between body composition (BC) characteristics and Abalakov jump (ABK), SLJ, and HGS in volleyball players. Participants were recruited prior to the start of the 2025 competition season. Evaluations were conducted in a single morning session starting at 9:00 a.m. The independent variables included height (cm) and BC characteristics: body weight (kg), SMM (kg), and %BF. Subsequently, dependent strength variables were assessed, including ABK (cm), SLJ (cm), and HGS (kg).

2.2. Participants

The sample included 67 female volleyball players from the Los Lagos Region, Chile, with 35 players in the U13 category and 32 in the U15 category. The participants had a mean age of 13.5 ± 1.1 years, a mean height of 156.6 ± 6.3 cm, a mean body weight of 55.8 ± 11.0 kg, a mean %BF of $29.5 \pm 7.9\%$, and a mean SMM of 21.2 ± 3.5 kg. All players belonged to clubs competing in a federated league in the Los Lagos Region and were voluntarily recruited for this study (Figure 1). Consequently, the sample cannot be considered representative of the general population of young volleyball players. Participants were recruited through direct visits to the training sessions of clubs competing in the Los Lagos Regional Volleyball League. The principal investigator contacted and invited all clubs participating in the league. During these visits, the research team presented the study to the players and their parents or legal guardians. The study objectives, assessment protocol, voluntary nature of participation, and confidentiality procedures were explained. At the meeting, parents or legal guardians who agreed to their daughters' participation provided written informed consent, while the players provided assent. All consent and assent procedures were completed before data collection.

2.3. Inclusion and Exclusion Criteria

To be included in this study, participants had to meet the following criteria: (a) be under 15 years of age, (b) belong to a club affiliated with the Los Lagos Volleyball Association, (c) have trained at least twice per week during the past six months, (d) have parental or guardian authorization, (e) present no musculoskeletal injuries, and (f) attend at least 80% of their club training sessions. Exclusion criteria included taking medications that could alter BC and having acute injuries or pain at the time of evaluation.

All players received prior information about the study objectives. Participation was voluntary, following the signing of assent and informed consent forms by parents or legal guardians, as appropriate. The study was conducted in accordance with the principles of the Declaration of Helsinki and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies and was approved by the Ethics Committee of the Department of Physical Activity Sciences, Universidad de Los Lagos (Code: 1-3-2025).

2.4. Procedures

Measurements were conducted on Saturday, 5 April 2025, starting at 9:00 a.m. All participants were instructed to arrive fasting and without having trained during the pre-

vious 48 h. Two weeks prior, they completed a familiarization session with the strength testing protocols to reduce the learning effect of the procedures. All standardized tests were performed indoors, supervised by the principal investigator, and administered by two assistants specialized in sport and health sciences, who were blinded to the participants at the time of measurement.

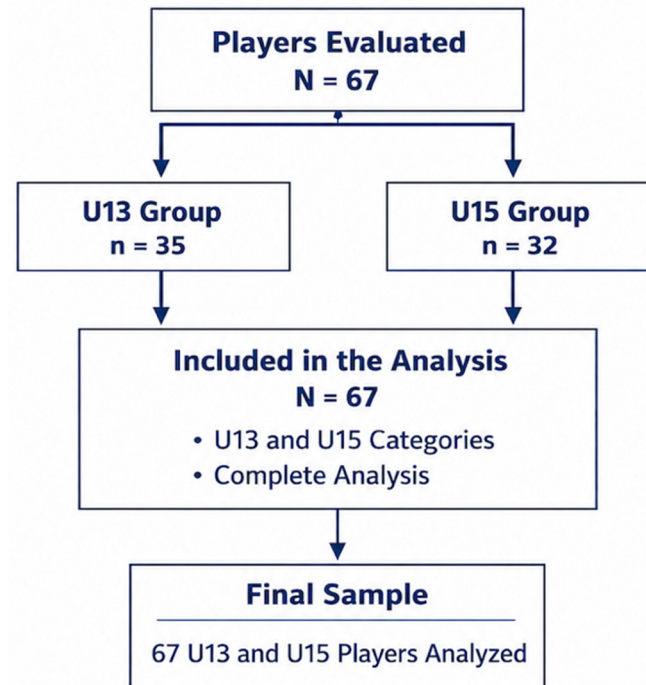


Figure 1. Flow diagram showing participant eligibility and their progression through the different phases of the study.

Regarding attire, participants were asked to wear a T-shirt, leggings, and sports shoes. First, age, height, and BC were assessed. Prior to testing, participants were instructed to (i) rest adequately the night before, sleeping at least 8 h; (ii) avoid consuming stimulant beverages before measurements; (iii) drink approximately 2 L of water the day before; and (iv) not alter their usual dietary habits. During strength evaluations, participants were instructed beforehand to exert maximal effort in all tests.

Before the physical performance tests, participants completed a 15 min volleyball-specific warm-up consisting of joint mobility exercises, light jogging, dynamic stretching, and 30 s of dynamic jumps. The tests were then administered in the following order: ABK, HGS, and SLJ without a run-up. For each test, the best of three attempts was recorded. Rest intervals of 3 to 5 min were provided between tests to reduce fatigue risk [31].

2.5. Instruments

Anthropometric Measurements: Height was measured once using a Seca 225 stadiometer (Seca, Hamburg, Germany), with a precision of 0.1 cm. Participants stood upright with their feet and knees together and their heels, buttocks, and upper back aligned with the stadiometer. The head was positioned in the Frankfurt plane, with the lower margin of the orbit aligned horizontally with the upper margin of the external auditory meatus. Participants were instructed to inhale and maintain an upright posture while the headpiece was lowered onto the vertex. Height was recorded in centimeters [32].

Body weight and BC were assessed once using an InBody 120 bioelectrical impedance analyzer (InBody Co., Seoul, Republic of Korea), calibrated according to the manufacturer's instructions [33]. Participants stood barefoot on the contact plates and held the handles

with their thumbs positioned on the electrodes. They remained upright, still, and silent throughout the assessment. The variables recorded were body weight (kg), %BF, and SMM (kg) [34]. BMI was calculated as body weight in kilograms divided by height in meters squared.

Body Weight (kg): The aim was to determine total body mass. Players were weighed wearing light clothing and without shoes. They stood at the center of the platform in an upright position without movement. BMI was calculated by dividing weight by height squared [32].

Body Composition (BC): BC characteristics were assessed using bioelectrical impedance with an InBody 120 body composition analyzer (InBody Co., Ltd., Seúl, Republic of Korea), calibrated by the manufacturer [33]. Players stood barefoot on the plates, holding the handles with thumbs placed on the electrodes, remaining still and silent during measurement. The indicators obtained were body weight, %BF, and SMM (kg) [34]. None of the female participants attended evaluations during the menstrual phase.

2.6. Physical Tests

HGS Test: The objective of this test was to measure maximal HGS. Grip strength of the right hand was assessed. Players were positioned with the shoulder in adduction and neutral rotation, the elbow at 90°, and the forearm and wrist in a neutral position. The second handle position was used, as it is considered optimal for this measurement. Three attempts were performed with one minute of rest between each, and the best value was recorded in kilograms [35]. A Jamar adjustable-handle dynamometer was used. The unit of measurement was kilograms.

ABK Test: The objective of this test was to measure explosive strength and/or jump capacity. Participants performed a vertical countermovement jump using their arms freely. They stood on the measurement surface with their weight evenly distributed, flexed their knees to 90° while moving their arms backward, and from the squat position executed an explosive push-off with both feet while swinging the arms forward and upward. Landing was performed with both feet simultaneously, maintaining balance. Three attempts were performed, and the highest value was recorded [36]. A Chronojump-Boscosystem contact platform (Barcelona, Spain) with software version 2.3.079 was used, which measures flight time and calculates jump height. This test evaluates muscular and elastic components of the lower limbs.

SLJ (without run-up): The objective of this test was to measure explosive strength of the lower limbs. Players jumped forward with both feet together from the starting line, attempting to reach the greatest possible horizontal distance. Measurement was taken from the starting line to the nearest heel mark upon landing. Three attempts were performed, and the best result was recorded [8]. Instrument: Stanley measuring tape with 0.1 cm precision.

2.7. Data Analysis

Descriptive data for the BC characteristics and strength tests of the players were presented using mean and standard deviation (SD). To determine data distribution, the Shapiro–Wilk normality test was applied, appropriate for samples under 100 participants ($n = 67$). Consequently, non-parametric tests were used in subsequent correlational analyses, specifically Spearman's rho coefficient, between four BC variables—body weight, %BF, SMM, and BMI—and three physical performance variables—ABK, SLJ, and HGS—analyzed separately for U13 ($n = 35$) and U15 ($n = 32$). For each association, 95% bootstrap confidence intervals were obtained through 5000 resamples. Given that 24 tests were conducted, the Benjamini–Hochberg procedure was applied, considering all correlations as a single family.

Statistical significance was set at $q_{BH} < 0.05$. Reported values included r_s , 95% bootstrap CI, unadjusted two-tailed p , and q_{BH} .

No a priori power analysis was performed; a sensitivity analysis indicated that the U13 and U15 sample sizes allowed detection of correlations of approximately $r \geq 0.46$ and $r \geq 0.48$, respectively, with $\alpha = 0.05$ and power = 0.80. Consequently, subgroup analyses were interpreted as exploratory. Given the limited subgroup sample sizes and the absence of direct measures of biological maturation, cumulative training experience, and playing position, no multivariable-adjusted models were performed. Therefore, the observed bivariate associations were not interpreted as estimates of independent effects of BC on physical performance. The magnitude of correlations was interpreted using the thresholds proposed by [37] for sports sciences: <0.1 , trivial; 0.1 – 0.3 , small; 0.3 – 0.5 , moderate; 0.5 – 0.7 , large; 0.7 – 0.9 , very large; and >0.9 , nearly perfect [37]. The adopted level of significance was $p < 0.05$. Statistical analyses were performed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA).

3. Results

Table 1 presents the descriptive characteristics of BC and physical performance of participants in the U13 and U15 categories. In the U13 category ($n = 35$), the mean age was 12.5 ± 0.5 years and the mean height was 154.9 ± 6.4 cm. The mean body weight was 51.4 ± 7.9 kg, mean body fat percentage was $27.9 \pm 7.0\%$, mean SMM was 19.80 ± 2.67 kg, and mean BMI was 21.44 ± 3.04 kg/m². Regarding physical performance, the mean jump height in the ABK test was 25.28 ± 5.06 cm, the mean distance in the SLJ was 158.14 ± 23.75 cm, and HGS averaged 23.59 ± 4.36 kg.

Table 1. Body composition and physical performance characteristics of U13 and U15 players.

Variable	U13 Mean	U13 SD	U15 Mean	U15 SD
Age (years)	12.5	0.5	14.5	0.5
Height (cm)	154.9	6.4	158.5	5.7
Body weight (kg)	51.4	7.9	60.5	12.0
%BF (%)	27.9	7.0	31.2	8.6
SMM (kg)	19.8	2.6	22.7	3.6
BMI (kg/m ²)	21.4	3.0	24.0	4.3
ABK (cm)	25.277	5.056	25.869	5.268
SLJ (cm)	158.143	23.750	159.156	22.302
HGS (kg)	23.594	4.364	27.784	5.102

Note. U13, under 13 ($n = 35$); U15, under 15 ($n = 32$); SD, standard deviation; %BF, body fat percentage; SMM, skeletal muscle mass; BMI, body mass index; ABK, Abalakov vertical jump; SLJ, standing long jump; HGS, handgrip strength.

In the U15 category ($n = 32$), the mean age was 14.5 ± 0.5 years and the mean height was 158.5 ± 5.7 cm. The mean body weight was 60.59 ± 12.09 kg, mean %BF was $31.24 \pm 8.64\%$, mean SMM was 22.7 ± 3.6 kg, and mean BMI was 24.07 ± 4.32 kg/m². In terms of physical performance, the mean jump height in the ABK test was 25.87 ± 5.27 cm, the mean distance in the SLJ was 159.16 ± 22.30 cm, and HGS averaged 27.78 ± 5.10 kg.

Table 2 analyzes the following results: The three physical tests demonstrated good to excellent intra-session reliability. For the ABK, the single-measure intraclass correlation coefficient (ICC) was 0.863, 95% CI [0.804, 0.909], and the average-measure ICC across three trials was 0.950, 95% CI [0.925, 0.968]. For the standing long jump without run-up, the single-measure ICC was 0.895, 95% CI [0.835, 0.934], while the average-measure ICC was 0.962, 95% CI [0.938, 0.977]. Handgrip strength showed the highest concordance values,

with a single-measure ICC of 0.985, 95% CI [0.972, 0.992], and an average-measure ICC of 0.995, 95% CI [0.991, 0.997]. All coefficients were statistically significant, $p < 0.001$.

Table 2. Spearman correlations between body composition and physical performance by age category.

Body Composition	Performance Test	U13 (n = 35)				U15 (n = 32)			
		r_s	95% CI	p	q_{BH}	r_s	95% CI	p	q_{BH}
Body weight	ABK	−0.259	[−0.538, 0.070]	0.133	0.213	−0.302	[−0.611, 0.059]	0.093	0.177
Body weight	SLJ	0.089	[−0.276, 0.419]	0.613	0.653	−0.156	[−0.491, 0.224]	0.394	0.499
Body weight	HGS	0.430	[0.092, 0.682]	0.010	0.043	0.291	[−0.123, 0.627]	0.106	0.181
%BF	ABK	−0.496	[−0.743, −0.165]	0.002	0.020	−0.437	[−0.740, −0.060]	0.012	0.043
%BF	SLJ	−0.366	[−0.639, −0.022]	0.031	0.082	−0.446	[−0.728, −0.064]	0.010	0.043
%BF	HGS	−0.245	[−0.548, 0.097]	0.157	0.235	−0.149	[−0.516, 0.246]	0.416	0.499
SMM	ABK	0.187	[−0.169, 0.494]	0.282	0.398	0.083	[−0.288, 0.430]	0.653	0.653
SMM	SLJ	0.401	[0.040, 0.671]	0.017	0.051	0.374	[0.017, 0.651]	0.035	0.084
SMM	HGS	0.750	[0.534, 0.872]	<0.001	<0.001	0.705	[0.363, 0.904]	<0.001	<0.001
BMI	ABK	−0.425	[−0.677, −0.106]	0.011	0.043	−0.334	[−0.642, 0.025]	0.062	0.135
BMI	SLJ	−0.146	[−0.495, 0.232]	0.404	0.499	−0.299	[−0.623, 0.092]	0.096	0.177
BMI	HGS	0.082	[−0.264, 0.420]	0.638	0.653	0.136	[−0.300, 0.507]	0.457	0.523

Note. ABK, Abalakov vertical jump; SLJ, standing long jump; HGS, handgrip strength; %BF, body fat percentage; SMM, skeletal muscle mass; BMI, body mass index; r_s , Spearman correlation coefficient; CI, confidence interval; q_{BH} , Benjamini–Hochberg-adjusted q value. The 95% CIs were obtained using 5000 bootstrap resamples. The p values are unadjusted and two-tailed. The q_{BH} values treat all 24 correlations as a single family. Bold values identify associations with $q_{BH} < 0.05$. Side-by-side presentation does not constitute a formal comparison of correlations between categories.

In the U13 category, after controlling the false discovery rate using the Benjamini–Hochberg procedure, four statistically significant associations were identified. Body weight was positively related to HGS, with $r_s = 0.430$, 95% bootstrap CI [0.092, 0.682], $p = 0.010$, and $q_{BH} = 0.043$. Likewise, body fat percentage was negatively associated with performance in the ABK jump, with $r_s = -0.496$, $p = 0.002$, and $q_{BH} = 0.020$. SMM showed a strong positive association with HGS ($r_s = 0.750$, 95% bootstrap CI [0.534, 0.872], $p < 0.001$, $q_{BH} < 0.001$). Finally, BMI was negatively related to ABK performance, with $r_s = -0.425$, 95% bootstrap CI [−0.677, −0.106], $p = 0.011$, and $q_{BH} = 0.043$.

Although in U13, additional associations were observed between %BF and the SLJ ($r_s = -0.366$, $p = 0.031$) and between skeletal muscle mass and the standing long jump ($r_s = 0.401$, $p = 0.017$), these did not retain statistical significance after adjustment for multiple comparisons ($q_{BH} = 0.082$ and $q_{BH} = 0.051$, respectively). The remaining correlations assessed in this category were not statistically significant.

In the U15 category, body fat percentage was negatively associated with ABK performance ($r_s = -0.437$, 95% bootstrap CI [−0.740, −0.060], $p = 0.012$, $q_{BH} = 0.043$) and with the SLJ ($r_s = -0.446$, 95% bootstrap CI [−0.728, −0.064], $p = 0.010$, $q_{BH} = 0.043$). Likewise, SMM was strongly and positively related to HGS ($r_s = 0.705$, 95% bootstrap CI [0.363, 0.904], $p < 0.001$, $q_{BH} < 0.001$). The association between skeletal muscle mass and standing long jump was significant before adjustment ($r_s = 0.374$, 95% bootstrap CI [0.017, 0.651], $p = 0.035$) but did not remain after correction for multiple comparisons ($q_{BH} = 0.084$). The other associations analyzed in this category did not reach statistical significance.

Taken together, the results show that SMM was consistently associated with greater HGS in both categories, whereas higher %BF was linked to lower performance in jump tests, particularly in the ABK. Nevertheless, these associations should be interpreted as statistical relationships rather than causal effects. Moreover, although some coefficients differed descriptively between U13 and U15, no formal test was conducted to compare the magnitude of correlations across categories; therefore, such differences should not be inferred as statistically significant.

4. Discussion

The findings suggest that the relationship between BC and physical performance in young female volleyball players is specific to the body component and motor task evaluated. SMM was primarily related to HGS, whereas adiposity-related indicators were more consistently associated with jump performance. This pattern may reflect the different mechanical and physiological demands of the tests. HGS depends largely on the amount of force-producing tissue and has been recognized as an indicator of general muscular strength in children and adolescents [18,38]. In contrast, jumping requires athletes to accelerate and displace their body mass, meaning that a greater proportion of non-force-producing mass may represent an additional mechanical load [13,23,39]. These findings should be interpreted as exploratory, unadjusted associations. The observed relationships may partly reflect shared variation related to growth, biological maturation, body size, and training experience, rather than independent effects of BC on physical performance. Although the analyses were conducted separately for U13 and U15 players, stratification by age category does not eliminate potential confounding within each group. Biological maturation, cumulative training experience, and playing position were not assessed, and body size was not included as an adjustment variable. Consequently, the present analyses cannot disentangle the contribution of BC from that of these potentially interrelated factors.

The findings are consistent with those reported by [40], who observed that cadet players with greater muscle mass achieved better results in strength and jump tests ($r = 0.60$, $p < 0.05$), and with [18] who demonstrated a significant association between HGS and overall muscular strength in adolescents ($r = 0.73$, $p < 0.01$), validating the use of HGS as a proxy for general muscular development. Similarly, refs. [19,38,41] documented strong associations between HGS and muscle mass in young volleyball players, reinforcing the relevance of this indicator in formative contexts. In addition, [42] confirmed positive and statistically significant correlations between handgrip strength and skeletal muscle mass ($r = 0.73$). In the present study, the magnitude of the correlations between skeletal muscle mass and handgrip strength was large to very large (U13: $r_s = 0.750$, $p < 0.001$, $qBH < 0.001$; U15: $r_s = 0.705$, $p < 0.001$, $qBH < 0.001$), supporting the consistency of the pattern observed in the literature. The association between SMM and HGS may partly reflect shared variation related to growth, biological maturation, body size, and training experience. Because these factors were not controlled for, the present analyses cannot establish whether this association is independent of their influence [43]. Furthermore, [44] found that anthropometric development is significantly associated with manual strength ($r = 0.65$, $p < 0.01$), reinforcing the influence of growth on strength capacity during prepubertal and pubertal stages. Likewise, body fat percentage was negatively associated with performance in the ABK jump ($r_s = -0.496$, 95% bootstrap CI $[-0.743, -0.165]$, $p = 0.002$, $qBH = 0.020$).

Regarding lower-limb performance, the negative correlations between %BF and ABK (U13: $r_s = -0.496$, $p = 0.002$, $qBH = 0.020$; U15: $r_s = -0.437$, $p = 0.012$, $qBH = 0.043$) indicate an inverse association between adiposity and jump performance, which is consistent with [45], who demonstrated that higher fat levels were associated with lower physical performance in adolescent volleyball players ($r = -0.59$, $p < 0.05$). Similarly, [13] identified a significant inverse association between adiposity and SLJ in Chilean schoolchildren ($r = -0.47$, $p < 0.01$), and [39] reported that adiposity negatively influenced SLJ performance ($r = -0.01$ to -0.25). Taken together, these findings are consistent with an inverse association between %BF and jump performance. However, given the cross-sectional and exploratory nature of the present study, %BF should not be interpreted as an independent or causal determinant of physical performance.

In the U15 category, SMM was moderately correlated with the SLJ ($r_s = 0.374$, $\rho = 0.35$, $qBH = 0.084$), in contrast to the findings of [3], who reported a strong association between the five-jump test and indicators of muscular power ($r = 0.69$, $p < 0.01$). [46] found moderate correlations between lean mass and jump distance ($r = 0.54$, $p < 0.05$) in adolescent soccer players, suggesting that the muscular component is a cross-cutting determinant of performance in explosive actions.

In terms of maturation, the results reinforce the importance of biological growth and neuromuscular development, factors highlighted by [47,48] as influential in strength expression during adolescence. The positive associations between SMM and HGS in both categories may partly reflect shared developmental and body-size-related variation. However, biological maturation was not assessed, and the correlation coefficients were not formally compared between categories. Therefore, these findings do not demonstrate maturational progression or an age-related change in the strength of the association.

Conversely, the lack of significant correlations between BC variables and some jump tests in younger groups could be explained by the multidimensionality of motor performance, where neuromuscular aspects, technical coordination, and mechanical efficiency influence performance as much or more than SMM [49,50]. These variations may also be conditioned by sample size and heterogeneity in the degree of maturation within the same category.

From a practical perspective, the present findings provide context-specific descriptive information on the relationships between BC and physical performance in young female volleyball players. They may help generate research hypotheses, but they do not establish individual training needs, body composition targets, or an optimal profile for performance. In particular, the observed correlations do not demonstrate that changing SMM or %BF would improve HGS or jump performance. Such applications require additional evidence from appropriately designed longitudinal and intervention studies, with consideration of maturation, body size, and training experience. This study presents the following limitations: non-probabilistic convenience sampling, restricted to participants from the Los Lagos Region, limits the generalization of the findings; therefore, they should be considered preliminary and specific to the analyzed context, without being interpreted as normative values. Likewise, the cross-sectional design prevents establishing causal relationships or changes over time, while the reduced size of the subgroups decreases the precision of the estimates. Another important limitation was the absence of biological maturation indicators, since chronological age does not necessarily reflect maturational status, which may have influenced both BC and physical performance. The absence of adjustment for body size, cumulative training experience, and playing position further limits interpretation of the observed associations. Neither bootstrap confidence intervals nor correction for multiple comparisons addresses confounding. Accordingly, the findings are hypothesis-generating and require confirmation in studies that measure these factors and use appropriately specified adjusted analyses. Nevertheless, the study stands out for the use of non-parametric tests, a comprehensive evaluation of physical performance, and the control of measurement reliability through the intraclass correlation coefficient. Future research is recommended to employ longitudinal designs, assess maturational status, incorporate new performance variables, and use larger and more representative samples.

5. Conclusions

In U13 and U15 female volleyball players, SMM was positively and consistently associated with HGS. Likewise, a higher %BF was related to lower performance in the ABK

in both categories and to lower performance in the SLJ only in the U15 category. In U13, specific associations were also observed between body weight and HGS, as well as between BMI and ABK performance; however, these relationships were not reproduced in the U15 group.

Taken together, the results indicate that the associations between BC and physical performance depend both on the body component evaluated and on the performance test and age category. Due to the cross-sectional design of the study, these findings should be interpreted exclusively as associations and do not allow establishing causal relationships, attributing effects to training, or affirming that certain body profiles optimize performance. Longitudinal studies with larger samples are required to confirm these relationships and to assess their stability throughout athletic development.

Nevertheless, these results should be considered preliminary and specific to the analyzed context. They do not constitute normative reference values nor allow for the formulation of general training recommendations. Future research should incorporate longitudinal designs, larger, multicenter, and more representative samples before establishing conclusions applicable to broader populations of young volleyball players.

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