

Physical fitness levels and characteristics of volleyball players across different age groups

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Abstract

Physical development and functional abilities undergo considerable changes during early adolescence, particularly among young athletes. This study compared physical growth, fitness levels, and sport-specific technical skills of young volleyball players aged 10–11 and 12–13 years. A cross-sectional comparative study was performed with 60 volleyball players divided into two age groups (n = 30 each). Assessments included anthropometric measurements, physical fitness indicators, functional capacities, reaction times, and volleyball-specific skills. Statistical analyses involved descriptive statistics, Student's t-tests, and correlation analysis. Results demonstrated significant age-related improvements in height ($p < 0.01$), body weight ($p < 0.001$), flexibility ($p < 0.001$), right-hand strength ($p < 0.05$), explosive strength tasks ($p = 0.01–0.05$), agility ($p < 0.05$), and aerobic performance ($p = 0.001–0.05$). Reaction time and cognitive–motor abilities showed no statistically significant differences. Correlation analysis revealed strong associations between physical development, fitness parameters, and functional capacities, particularly in the 10–11 age group. In the 12–13-year-olds, relationships between strength, speed, agility, and autonomic functions became stronger and more organized. The findings indicate that motor performance, strength, and agility develop considerably between ages 10 and 13, alongside gradual maturation of cognitive–motor skills. The strengthening correlations between physical development and functional abilities with age reflect neuromuscular and physiological adaptations. Regular volleyball training significantly improves physical development and work capacity in young players. Structured training during early adolescence can improve athletic performance potential by increasing strength, speed, and endurance.

Keywords: volleyball, physical fitness, functional abilities, adolescence, motor development, correlation analysis

Introduction

Early adolescence is a dynamic and critical stage of human development characterized by rapid somatic growth, biological maturation, and considerable neuromuscular, hormonal, and cardiovascular adaptations (Malina et al., 2004; Lloyd & Oliver, 2012; Beunen & Malina, 2008). During this period, the interaction between natural growth processes and external factors, such as systematic sports training, plays a key role in shaping an individual's long-term physical, motor, and athletic potential. Structural and functional changes in skeletal muscle composition, nervous system efficiency, and metabolic function during this period form the foundation for performance potential in later adolescence and adulthood.

In volleyball—a sport requiring a unique combination of strength, explosive power, speed, agility, reaction time, and fine motor coordination—the timely and progressive development of these physical attributes is essential for mastering technical skills such as spiking, blocking, setting, and rapid court movements. Players must execute repeated high-intensity movements, rapid directional changes, vertical jumps, and accurate ball-handling in fast-paced, dynamic game conditions, making physical preparedness essential for successful performance (Sheppard et al., 2007; Palao et al., 2009).

Systematic, developmentally appropriate training during this sensitive adolescent period can considerably improve neuromuscular efficiency, strengthen the musculoskeletal system, improve functional capacities such as aerobic and anaerobic performance, and facilitate the mastery of complex technical and tactical skills (Bompa & Haff, 2009; Lloyd & Faigenbaum, 2016; Issurin, 2010). Additionally, well-structured and periodized physical training in early adolescence not only results in immediate performance gains but also

contributes to injury prevention, psychological resilience, and long-term athlete development, consistent with contemporary long-term athletic development (LTAD) models (Ford et al., 2011; Côté & Vierimaa, 2014; Fraser-Thomas et al., 2005).

Previous research has consistently shown that regular participation in organized sports during childhood and adolescence has a significant positive impact across multiple developmental areas. These include anthropometric growth, such as increases in height and weight; enhanced cardiovascular efficiency, reflected in improved cardiac output and aerobic capacity; increased muscular strength and endurance; and advancements in psychomotor and cognitive-motor skills (Baquet et al., 2003; Côté et al., 2016; Armstrong & McManus, 2011). Additionally, active involvement in structured sports promotes better neuromuscular coordination, proprioceptive accuracy, and reaction time, all of which contribute to the overall athletic proficiency of young athletes. In volleyball, a sport that relies heavily on explosive movements and rapid neuromuscular responses, targeted training programs have been shown to considerably enhance key physical qualities. These include vertical jump performance, short-distance sprinting speed, agility during complex movement patterns, and accurate ball control—each critical for success in both offensive and defensive aspects of the game (Sheppard et al., 2007; Ziv & Lidor, 2010; Markovic & Mikulic, 2010). By systematically developing these qualities, volleyball training prepares athletes to handle the fast-paced, reactive, and multidirectional aspects of competitive play.

Functional and physiological markers such as maximal oxygen consumption (VO_2max) and resting heart rate are key indicators for assessing physiological adaptations to training in young athletes (Rowland, 2005; Bar-Or & Rowland, 2004). Higher VO_2max values indicate superior development of the aerobic energy system, essential for maintaining performance during extended rallies and tournaments, while a lower resting heart rate reflects improved cardiovascular efficiency and autonomic control—both characteristic of a well-conditioned young athlete. Despite these insights, there is still a lack of comprehensive research that simultaneously explores the structural relationships between physical development, fitness, autonomic functions, cognitive-motor abilities, and volleyball-specific technical skills across different stages of early adolescence. Understanding these interconnections is essential for creating training programs that are developmentally appropriate and effectively optimize both physical and technical-tactical development in young athletes (Vaeyens et al., 2008; Ford et al., 2011; Balyi & Hamilton, 2004).

The purpose of this study was to perform a cross-sectional comparative analysis of volleyball players aged 10–11 and 12–13 years. Specifically, we assessed differences in anthropometric measurements, physical fitness indicators, functional capacities, autonomic functions, and volleyball-specific technical skills between the two groups. Additionally, we examined the correlation patterns between these variables in each age group to better understand the evolving structure of physical preparedness during early adolescence. We hypothesized that the older players would exhibit superior physical and functional attributes, along with stronger and more interconnected relationships between developmental and performance metrics, reflecting biological maturation and training adaptations.

Materials and methods

Participants

The study included 60 young volleyball players divided into two age groups: 10–11 years old ($n = 30$) and 12–13 years old ($n = 30$). All participants were actively engaged in volleyball training and attended regular sessions under the supervision of qualified coaches. Inclusion criteria stipulated that participants had no known medical conditions or injuries that could impact their performance.

Study Design

A cross-sectional comparative study design was used to evaluate physical development, motor abilities, physical performance capacity, autonomic functions, and volleyball-specific technical skills in young players from two age groups. Data were collected at the start of the competitive season.

Measurements

Anthropometric and Physical Fitness Indicators

Physical development was assessed by measuring body length (cm), body weight (kg), and vital lung capacity (ml). Physical fitness indicators included flexibility (forward bend test, cm), muscular strength (handgrip strength of both right and left hands, kg), explosive power (high jump and long jump, cm), ball transfer distance (m), agility (fir tree-shaped run, s), short sprint speed (9 m sprint, s), and speed endurance (6 × 5 m shuttle run, s).

Functional and Physiological Measurements

Functional capacities were assessed using the following measures:

Physical working capacity at a heart rate of 130 bpm (PWC130) (kg·m/min),

Maximum oxygen consumption (VO_2max) (l/min and ml/min/kg),

Breath-holding time during inhalation and exhalation (s),

Resting heart rate (beats per minute),

Vital lung capacity (ml).

Reaction Time and Special–Technical Skills

Cognitive–motor abilities were assessed by:

Simple action–reaction time (s),

Reaction to a moving object (number of successful reactions).

Special–technical skills were evaluated using volleyball-specific tasks:

"6–3" Test: Passing the ball from zone 6 to zone 3 and receiving,

"3–4" Test: Making a second pass from zone 3 to zone 4,

"1–6–5" Test: Setting the ball into play across zones 1, 6, and 5.

Statistical Analysis

The collected data were analyzed using descriptive statistics (mean $\pm$ standard deviation) and coefficients of variation (V%). Differences between groups were evaluated with the Student's t-test for independent samples. Statistical significance was set at $p < 0.05$, $p < 0.01$, and $p < 0.001$, based on the strength of the observed differences.

Correlation analysis was performed to examine relationships between anthropometric characteristics, physical fitness, functional capacities, autonomic functions, and volleyball-specific technical skills. Significant correlations were identified at $p < 0.05$ and $p < 0.01$ levels.

Results

The comparative analysis between 10–11-year-old and 12–13-year-old youths revealed significant developmental differences across multiple physical and motor performance indicators. A statistically significant increase in body length ($p < 0.01$) and a highly significant increase in body weight ($p < 0.001$) were observed with age, reflecting natural growth during this developmental stage. Likewise, flexibility, measured by the forward bend test, showed a significant improvement ($p < 0.001$), indicating an increased range of motion in the older age group.

Table 1. Physical development and fitness indicators of volleyball players at the beginning of the study

Indicators	Age group						t	P
	10–11 years old (n = 30)			12–13 years old (n = 30)				
	$\bar{X}$	σ	V	$\bar{X}$	σ	V		
Body length, cm	133.13	10.36	6.64	137.98	10.32	6.14	2.81	<0.01
Body weight, kg	39.68	3.52	8.87	45.89	3.79	8.26	4.16	<0.001
Forward bend, cm	3.92	0.39	9.95	3.31	0.31	9.37	4.24	<0.001
Right-hand strength, kg	16.84	1.33	7.90	18.31	1.34	7.32	2.70	<0.05
Left-hand strength, kg	15.61	1.38	8.84	16.74	1.37	8.18	2.01	>0.05
Ball transfer distance, m	5.32	0.37	6.95	5.86	0.38	6.48	3.53	<0.01
High jump, cm	21.31	1.87	8.78	23.67	1.96	8.28	3.02	<0.01
Long jump, cm	162.47	12.49	7.69	173.39	12.59	7.26	2.13	<0.05
Fir tree-shaped run, s	28.87	1.63	5.65	27.47	1.41	5.13	2.25	<0.05
9 m run, s	3.01	0.19	6.31	2.87	0.17	5.92	1.90	>0.05
6 × 5 m shuttle run, s	13.51	1.17	8.66	12.54	1.02	8.13	2.16	<0.05
Action–reaction time, s	0.217	0.012	5.53	0.208	0.011	5.29	1.92	>0.05
Reaction to a moving object, hitting and blocking	3.07	0.24	7.82	3.25	0.23	7.08	1.88	>0.05

Right-hand strength demonstrated a statistically significant increase ($p < 0.05$), while left-hand strength improved without reaching statistical significance ($p > 0.05$), indicating a trend toward balanced development but with slight asymmetry in muscular strength acquisition. Performance in explosive strength tasks—such as the ball transfer ($p < 0.01$), high jump ($p < 0.01$), and long jump ($p < 0.05$)—also showed significant improvements, reflecting improved muscle power and coordination with age. Additionally, speed and agility, measured by the fir tree-shaped run ($p < 0.05$) and the 6 $\times$ 5 m shuttle run ($p < 0.05$), significantly improved in the older group, demonstrating better motor control and movement efficiency. However, no significant differences were observed in the 9-m sprint ($p > 0.05$), suggesting that short-distance speed may stabilize earlier than agility. Reaction-related indicators, including action–reaction time and response to a moving object, also showed no statistically significant changes ($p > 0.05$), indicating that these cognitive–motor skills may develop more gradually over a longer timeframe or are less sensitive to age in this limited range.

Overall, the results show that during the transition from ages 10–11 to 12–13, youths experience considerable improvements in anthropometric characteristics, muscle strength (particularly in the dominant hand), power, and agility, while reaction abilities develop more slowly or less noticeably. These findings are

consistent with established developmental models, which highlight that motor performance capacities increase substantially in early adolescence owing to growth, neuromuscular maturation, and training adaptations.

In the studies performed, average values of physical performance, aerobic capacity, and autonomic functions were examined in young volleyball players across two age groups. Parameters assessed included PWC130, maximum oxygen consumption, breath-holding durations (inhalation and exhalation), heart rate, and lung vital capacity (Table 3.2).

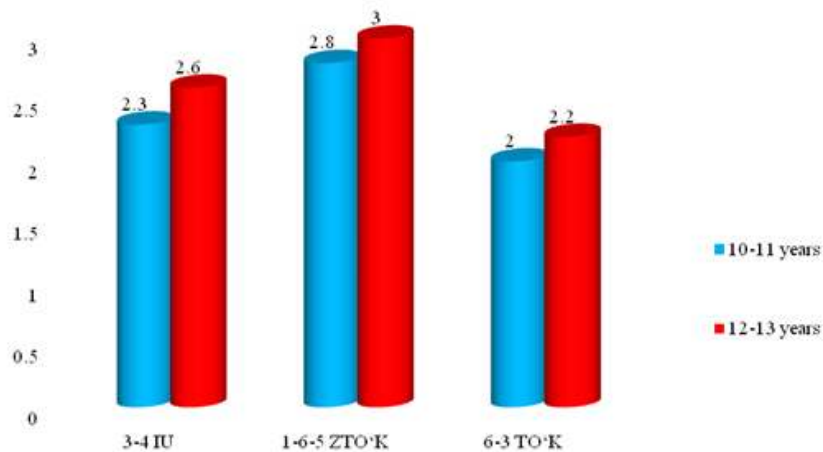
Table 2. Physical performance and autonomic function indicators of volleyball players at the beginning of the study ($\bar{x} \pm \sigma$)

Indicators	Age group						T	P
	10–11 years old (n = 30)			12–13 years old (n = 30)				
	$\bar{X}$	σ	V	$\bar{X}$	σ	V		
PWC130, kg·m/min	483.43	53.02	10.97	587.43	61.34	10.44	4.44	<0.001
PWC130 per weight, ml/min/kg	12.39	1.22	9.85	13.29	1.24	9.33	1.79	>0.05
Maximum oxygen consumption, l/min	2.07	0.24	11.79	2.42	0.27	11.16	3.33	<0.01
Maximum oxygen consumption per weight, ml/min/kg	53.52	5.79	10.82	47.89	4.87	10.17	2.58	<0.05
Breath-holding after inhalation, s	34.29	4.06	11.84	42.39	4.73	11.16	4.50	<0.001
Breath-holding after exhalation, s	22.78	2.89	12.69	24.89	3.02	12.13	1.75	>0.05
Heart rate, beats/min	68.32	6.79	9.94	63.37	5.79	9.14	1.92	>0.05
Lung capacity, ml	2300.1	258.9	10.79	2929	296.8	10.14	4.65	<0.001

The abovementioned indicators, such as those of physical fitness, increase significantly and consistently with age, which agrees with the findings reported in the literature.

Our research shows that the physical activity indicators were slightly higher than those of same-age children who did not regularly participate in sports, as reported in the scientific literature.

Resting heart rate, an indicator of long-term adaptation to sports, was 68.32 ± 4.1 beats/min at ages 10–11, while vital lung capacity at this age reached 2300 ± 163 ml. Additionally, the body's hypoxic tolerance indicators showed rapid improvement with age (Table 3.2). The age-related progression of specialized training in young volleyball players was assessed using specific skill tests: "6–3" – passing the ball from zone 6 to zone 3 and receiving it; "3–4" – passing the second ball from zone 3 to zone 4; and "1–6–5" – putting the ball into play across zones 1, 6, and 5. Figure 3.1 shows the changes in special test results across the two age groups.



("6–3" – passing the ball into play from zone 6 to zone 3 and receiving the ball;

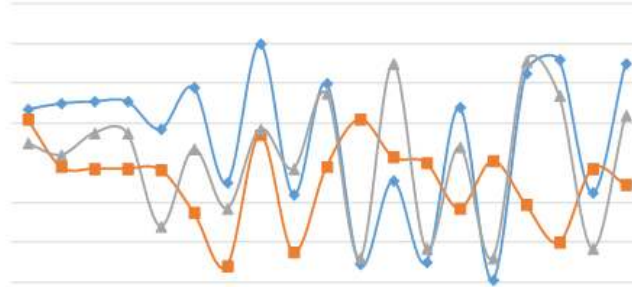
"3–4" – second pass from zone 3 to zone 4;

"1–6–5" – putting the ball into play across zones 1, 6, and 5.)

Figure 1. Performance levels reflecting the specialized training of young volleyball players across different age groups

As shown in Figure 3.1, younger athletes exhibit stronger interactions. Test results reflecting specialized training improve with age, similar to indicators of physical development, fitness, and work skills. These findings align with existing literature.

To examine age-related differences in the structural organization of physical training, we performed a correlation analysis of key physical, functional, and special–technical training indicators in young volleyball players aged 10–11 and 12–13. The analysis revealed that most indicators in the 10–11 age group demonstrated strong and widespread correlations (Figure 3.2).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
03-Apr	0.27	0.3	0.31	0.31	0.17	0.38	-0.1	0.6	-0.2	0.4	-0.5	-0.1	-0.5	0.28	-0.6	0.45	0.52	-0.2	0.5
01/06/2005	0.22	-0	-0	-0	-0.3	-0.5	0.14	-0.5	-0	0.22	0.03	0	-0.2	0.01	-0.2	-0.4	-0	-0.1	
06-Mar	0.1	0.04	0.15	0.15	-0.3	0.07	-0.2	0.17	-0	0.35	-0.5	0.5	-0.4	0.08	-0.5	0.51	0.34	-0.4	0.24

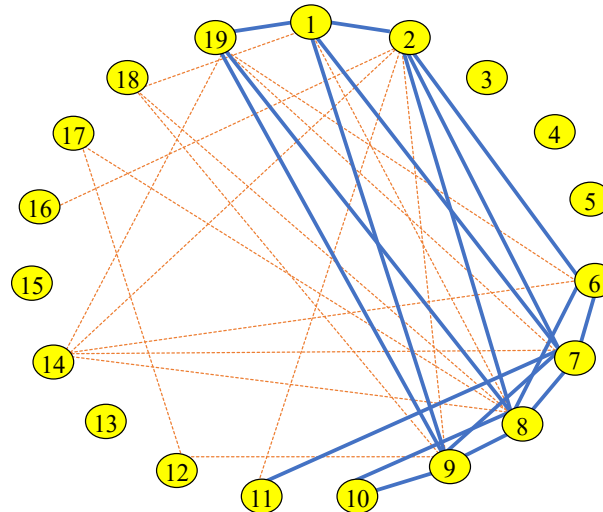
Explanation: 1 – body length, 2 – body weight, 3 – PWC130, 4 – maximum oxygen consumption, 5 – forward bend, 6 – right arm strength, 7 – left arm strength, 8 – passing the ball, 9 – high jump, 10 – long jump, 11 – fir tree-shaped run, 12 – 9 m run, 13 – 6 × 5 m shuttle run, 14 – action–reaction time, 15 – reaction to a moving object, 16 – breath holding during inhalation, 17 – breath holding during exhalation, 18 – heart rate, 19 – lung vital capacity;

_____ – significant correlation, $p < 0.05$ – significant correlation, $p < 0.01$.

Figure 2. Relationship between physical development, work skills, physical fitness, and autonomic functions in 10–11-year-old volleyball players

Physical development indicators—such as body length, body weight, and lung vital capacity—show a significant correlation with numerous indicators of physical–functional and work-related abilities. This aligns with findings from other researchers who reported similar correlations between physical development and functional capabilities in athletes aged 10–12. It appears that the younger the age group, the more interconnected the structure of motor skills.

As shown in Figure 3.3 above, there is a strong correlation between the working capacity of young athletes (PWC130), physical development indicators (body length, weight, and lung vital capacity), movement quality levels ($p < 0.05$), and several measures of the body's autonomic functions. These findings are fully consistent with previous research. A.A. Guzhalsky noted that indicators such as body length, weight, and chest circumference played a significant role in the expression of athletes' movement qualities (Figure 3.3).

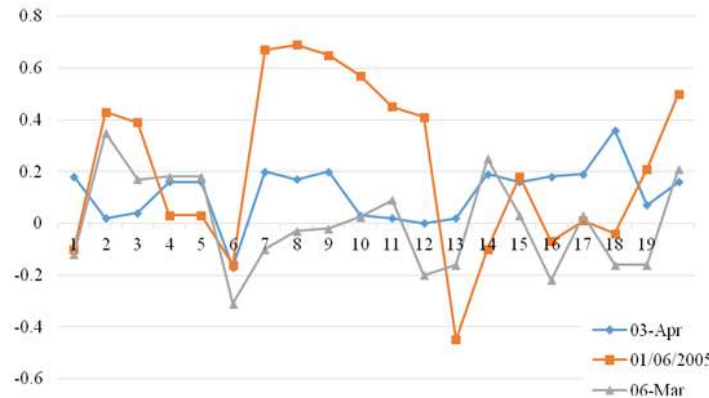


Explanation: 1 – body length, 2 – body weight, 3 – PWC130, 4 – maximum oxygen consumption, 5 – forward bend, 6 – right-hand strength, 7 – left-hand strength, 8 – ball passing, 9 – vertical jump, 10 – long jump, 11 – fir tree-shaped run, 12 – 9 m sprint, 13 – 6 × 5 m shuttle run, 14 – movement reaction time, 15 – reaction to a moving object, 16 – breath holding during inhalation, 17 – breath holding during exhalation, 18 – heart rate, 19 – lung capacity;

_____ – significant correlation, $p < 0.05$ – significant correlation, $p < 0.01$.

Figure 3. Structure of the relationship between physical development, work skills, physical fitness, and autonomic function parameters in 12–13-year-old volleyball players

Strength, speed–strength qualities, agility (measured by the fir tree-shaped run), and speed endurance (6×5 m shuttle run) often show significant correlations with each other and with indicators of autonomic functions. In the second age group (12–13 years), the overall number of significant associations between physical fitness, work capacity, physical development, and autonomic functions increased slightly compared to the younger group. In this age group, correlations between physical development and strength and speed–strength qualities were statistically significant. Additionally, the relationships between strength, speed–strength qualities, and speed measures were further strengthened. The number and strength of correlations between movement test results and autonomic function indicators remained consistent.



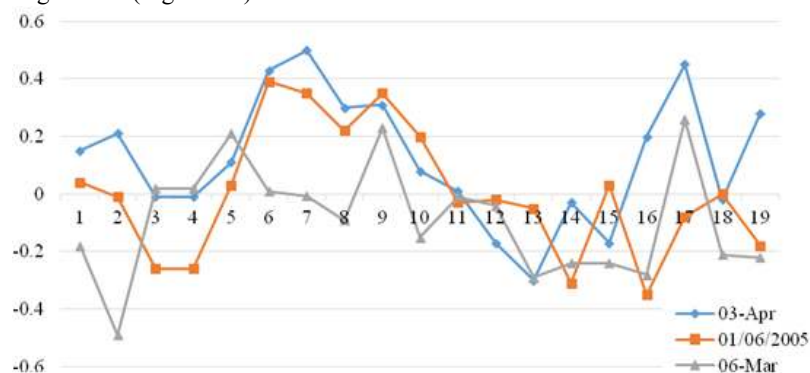
Explanation: Analysis of the correlation between special training indicators in the "6–3," "3–4," and "1–6–5" tests among 10–11-year-old volleyball players and their physical development, work skills, and physical fitness indicators.

Figure 4. Correlation between special and technical training indicators in 10–11-year-old volleyball players

The analysis of correlations between special training indicators from the "6–3," "3–4," and "1–6–5" tests and measures of physical development, physical performance, and physical training in volleyball players from both age groups is presented in Figure 3.4. It was determined that, among 10–11-year-old volleyball players, significant correlations appeared only in a few instances.

This indicator shows a very high, though not statistically significant, correlation with the sprint ($p > 0.05$) and 6×5 m shuttle ($p > 0.05$) test results. The chest cavity exhibits a strong correlation with tidal lung volume (0.362) and breath-holding times during deep inhalation and exhalation (0.265 and 0.428, respectively), although some uncertainty affects these values. The results of the "1–6–5 ball entry" test do not demonstrate a significant correlation; however, this indicator shows some association with the "Abalakov high jump" results and the strength tests of both the right and left hands.

A similar situation was observed in the second age group (12–13 years old). Only a few correlations were found to be significant (Figure 3.4).



Explanation: Analysis of the correlation between special training indicators in the "6–3," "3–4," and "1–6–5" tests and physical development, work skills, and physical fitness indicators in 10–11-year-old volleyball players.

Figure 5. Correlation between special and technical training indicators in 12–13-year-old volleyball players

Although the "6–3" test score did not show a significant correlation, it was observed to have a broader association with speed qualities, speed endurance (fir tree-shaped run, 9-m sprint, 6×5 -m shuttle run), and body size.

Discussion

The study's results indicate that the key components of physical fitness at different ages are characterized by the number and strength of their interconnections. This finding aligns with the research by Lemos et al. on Paralympic athletes. However, Vescovi et al. suggested that body fat percentage estimates obtained via skinfold measurements may be more accurate than those from air displacement plethysmography, regardless of body composition. Lemos et al. reported similar findings for Paralympic Goalball and Swimming athletes (Lemos et al., 2016; Vescovi et al., 2002).

The position of players in the Body Composition Tracking System Pod (BOD POD) chamber during analysis may have a minor impact on the measured parameters (Peeters, 2011). Although our study adhered to the manufacturer's guidelines regarding participant positioning, we carefully monitored all players' positions to minimize any potential effects. Additionally, because our participants had significant lower limb muscle atrophy or amputation, this could influence fat-free mass composition and potentially lead to over- or underestimation of body fat through body density (BD) measurements (Moore et al., 2015). In contrast, some studies have found that different levels of spinal cord injury do not appear to affect body composition, and BD measurements do not differ between individuals with or without spinal cord injury (George et al., 1988). Therefore, the results of the present study cannot be attributed to differences in lesion levels.

When comparing differences and potential biases between ADP and SF methods, it was found that SF tended to overestimate BF% compared to ADP. Similarly, Lemos et al. reported that in Paralympic athletes, SF overestimated BF% (men: 24.22 ± 7.92 ; women: 32.35 ± 6.14) compared to ADP (men: 22.99 ± 7.70 ; women: 30.32 ± 7.29) (Lemos et al., 2016). However, another study showed that SF (using five different equations) underestimated BF% compared to ADP in wheelchair basketball and rugby athletes (Goosey-Tolfrey et al., 2016). Additionally, Vescovi et al. found that BD estimates in female non-disabled college athletes were very similar between SF and ADP methods (Vescovi et al., 2002). The results of our study indicate that skinfold thickness measurement (SF) is a valid method for assessing body composition in elite standing volleyball (SV) players, consistent with the findings of Lemos et al. (2016). We believe it is crucial to prioritize technical and tactical training owing to the strong correlations between physical fitness indicators in 10–11-year-old volleyball players. These correlations impact the peak of physical development, which is mainly formed during general physical training sessions. Therefore, a decline in physical fitness and development levels among young athletes can lead to a weakening in the structure of these interconnections. Physical training is essential in volleyball, where specialized exercises develop movement qualities and incorporate advanced techniques and effective movement tactics. The physical fitness level of volleyball players significantly influences the team's performance in competitions.

Conclusions

It is determined that interconnections gradually weaken as athletes grow older. We believe training should prioritize technical and tactical preparation, especially owing to the strong correlations between physical fitness indicators in 10–11-year-old volleyball players. These correlations influence the peak physical development, which is largely shaped during general physical training sessions. Therefore, a decline in physical fitness and development among young athletes is reflected in a reduced complexity of these interconnections. Compared to athletes in other positions, attackers exhibit significantly higher levels of physical development. Research also shows that they use their speed–strength capabilities more effectively and demonstrate superior strength and speed endurance.

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