

Article

Associations Between Jump Performance, Speed, and COD Abilities in Young Elite Volleyball Players

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Abstract

This study examined the relationships between lower-body power, linear speed, and change of direction (COD) speed in young elite volleyball players. A sample of participants ($N = 36$) consisting of elite male volleyball players (age: 15.44 ± 2.02 years; height: 180.83 ± 10.08 cm; weight: 70.38 ± 10.97 kg) was measured in jump performance, speed, and COD abilities. Jump performance was assessed via squat jump (SJ), countermovement jump (CMJ), and CMJ with arm swing (CMJA), while speed and COD abilities were measured using 5 m, 10 m, and 15 m sprints, and the t -test, 9-6-3-6-9, and 505 agility tests, respectively. Pearson's correlation analysis revealed powerful positive correlations among jump tests (e.g., CMJ and SJ: $r = 0.955$, $p < 0.001$), indicating a shared underlying construct identified as explosive power. Jump performance showed moderate to strong negative correlations with sprint times (e.g., CMJA and 10 m sprint: $r = -0.675$, $p < 0.001$) and COD times (e.g., CMJ and t -test: $r = -0.618$, $p < 0.001$), suggesting that greater power enhances acceleration and agility. Sprint and COD tests were strongly interrelated (e.g., 10 m sprint and t -test: $r = 0.719$, $p < 0.001$), highlighting their interdependence. These findings underscore the significant role of lower-body power in volleyball-specific movements, such as rapid sprints and directional changes. Practically, enhancing jump performance through targeted training could improve speed and COD abilities, aiding coaches in player selection and conditioning. Further research is needed to explore these relationships across diverse populations and over time.

Keywords: volleyball; lower-body power; jump performance; speed; change of direction speed; young athletes; correlation



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1. Introduction

Volleyball demands a high level of physical conditioning, technical precision, and tactical intelligence [1]. Volleyball players need to be capable of quick changes of direction (COD), explosive jumps, rapid accelerations, and precise hits and blocks [2]. Their performance is heavily influenced by their ability to generate power during both jumping

and sprinting movements. As such, key factors like acceleration, COD speed, and strong lower-body power, particularly in maximum effort jumps, are crucial for success. Athletes who excel in these areas are more likely to perform at a high level and achieve success [3].

Motor skills such as explosive jumps, speed, and COD speed can be defined as latent motor structures responsible for an infinite number of manifestations that can be measured [4]. Vertical jumps are one of the key factors for success in activities that require the maximal exertion of muscular force in a short period of time [5]. Various types of jumps are used to assess jumping power using different measurement devices [6]. The analysis of COD as a motor skill indicates that successful execution of COD requires interaction with other motor abilities such as strength, which is important for acceleration and deceleration, and coordination, which plays a role in direction changes and movement technique. This detailed analysis highlights the complexity and intricacy of COD as a motor skill [7].

When selecting exercises in the training process, the size of the volleyball court should also be taken into consideration. A player can reach their final position from the starting point in just a few steps, so it is clear that the ability to make quick and explosive starts, stops, and changes in direction is of great importance. Additionally, the ability to transition from horizontal to vertical movement is also crucial. Although speed itself is not decisive in volleyball, the ability to accelerate is essential [8].

The speed of acceleration across various distances has previously been associated with improved performance in jump tests within athletic populations [9]. Specifically, several studies have demonstrated a strong relationship between the results of jump tests and enhanced acceleration performance during sprints [10,11]. These findings suggest that improved performance in jump tests may lead to better acceleration results. Pleša et al. [12] concluded that jump height was in moderate correlation with force-velocity in counter-movement jump ($r = 0.45, p < 0.01$) and in moderate to high correlations with force-velocity in sprint ($r = 0.35, p = 0.022$) among young male volleyball players. Currently, there is a lack of research exploring the connection between lower-body power measures and acceleration performance in young elite volleyball players. Although some researchers have shown that the rate of force development (RFD) is an important performance variable [13,14], and while McLellan et al. [15] found that RFD was significantly correlated with vertical jump (VJ) height during the CMJ test ($r = 0.68$), other studies indicate that RFD has a relatively weak relationship with VJ [16,17]. This inconsistency suggests that RFD may not be the sole or direct indicator of jump height and that a comprehensive assessment of explosive strength and jump performance should also consider other factors such as technique, muscular strength, and coordination.

The diversity of methods and measurement instruments highlights the complexity of volleyball performance; however, this variety also makes it difficult to directly compare the effectiveness of different interventions [18,19]. Change of direction (COD) parameters, which assess movement efficiency by contrasting agility and linear speed, represent a relatively new concept in evaluating young athletes' motor abilities, yet their application in volleyball remains insufficiently explored [20–22]. This observation underscores the importance of gaining a deeper understanding of the interrelationships among fundamental motor skills.

The volleyball literature highlights several gaps in understanding the relationships between fundamental motor skills in young elite players, emphasizing the need for this study. From a physical capacity perspective, key factors for successful volleyball performance include vertical jumping, explosive acceleration, and changes of direction [2,23]. These abilities constitute an important component of the training process, where they are continuously monitored and systematically developed to enhance players' physical preparedness. Previous research has mostly examined strength and speed relationships

separately. For example, studies have shown that effective change of direction (COD) performance requires well-developed lower-limb strength and explosiveness [24]. Adequate leg strength is thought to enable athletes to rapidly change direction; however, the extent to which this applies to young volleyball players remains unclear.

The complex interrelationships among jump performance, speed, and COD ability have not been sufficiently explored in an integrated manner [12]. Moreover, the unique characteristics of young elite players have not been adequately addressed in the existing literature. Therefore, the aim of this study was to examine the relationships between lower-body explosive power, assessed via jump tests, and linear and COD speed in young elite volleyball players. Understanding the interaction of specific physical capacities in young volleyball athletes can help coaches make better decisions regarding player position assignments. Furthermore, a more comprehensive understanding of the interrelationships among fundamental motor skills may assist in optimizing training strategies tailored to young volleyball players. Based on existing evidence, the hypothesis of this study is that explosive leg power is correlated with both speed and COD ability in young elite volleyball players. This study will contribute to the existing literature on the association of these parameters, with an emphasis on the innovative aspect concerning data from the youth elite volleyball population.

2. Methods

2.1. Participants

To determine the required sample size, we performed an a priori calculation using the G*Power v3.1 program (Bonn, Germany, Bonn FRG, University of Bonn, Department of Psychology). Based on G*Power ($1 - \beta > 0.8$; effect size = 0.3; $\alpha = 0.05$) the required sample size was 35. In total, this cross-sectional observational study included 36 elite young male volleyball players (age: 15.44 ± 2.02 years; height: 180.83 ± 10.08 cm; weight: 70.38 ± 10.97 kg) from a first-league club competing at the highest level for their age group in Serbia. The criteria for inclusion in the study were young male volleyball players with a training age of ≥ 5 years, and without a recent injury (>12 months) or any illness at that moment. The measurements were conducted during the preparatory period, at a stage when the athletes were involved in an intensive and structured training process. Before the assessment, they were thoroughly briefed—both in writing and verbally—on the study's procedures, potential risks and benefits, and their right to withdraw at any stage. Written consent for voluntary participation was obtained from both the players and their legal guardians. The selected athletes had a minimum of five years of volleyball experience, had engaged in general training at least four times per week over the past year, were currently training for more than seven hours weekly, and had no pre-existing medical conditions that could affect their participation. The protocol was approved by the Ethics Committee of the University of Niš (protocol code 04-1769/2, date of approval: 18 October 2024).

2.2. Procedures

All athletes were thoroughly briefed on the testing procedure. Each test was conducted indoors, in the team's training hall, during the morning hours (9:00–11:00 a.m.). Before the assessments, the players completed a 20-min warm-up consisting of both general and sport-specific exercises. The warm-up began with 10 min of running, followed by 5 min of stretching, and concluded with a 7-min segment incorporating progressive running, changes of direction, and plyometric drills. The tests were performed in the following sequence: (1) squat jump (SJ), (2) countermovement jump (CMJ), (3) countermovement jump with arm swing (CMJA), (4) 15 m sprint with split times recorded at 5 m and 10 m, (5) T-test, (6) 9-6-3-6-9 sprint (T9-6-3-6-9), and (7) 505 agility test (T505).

These tests were selected because they capture key performance determinants in volleyball: explosive vertical jumping, rapid short-distance acceleration, and frequent multidirectional agility demands. All procedures were carried out by experienced sports scientists to ensure safety and consistency.

2.3. Measurement

Anthropometry: height and body weight measurements were taken with a precision of 0.1 cm using a Martin anthropometer (GPM, Zurich, Switzerland) and 0.1 kg using a calibrated balance scale (Avery Ltd., Model 3306 ABV, Birmingham, UK).

Motor assessment:

Vertical Jumps (SJ, CMJ, CMJA)

Vertical jump performance was assessed through squat jumps (SJ) and countermovement jumps (CMJ, CMJA). In the squat jump (SJ), athletes start in a stationary position with their knees bent at 90 degrees and their hands placed on their waist. Without utilizing their arms, they executed a vertical jump by extending their legs and landed in the same spot. A 3-s pause in the squat position was required before each attempt. The countermovement jump (CMJ) began from a standing position, also with hands on the waist, and involved a quick knee flexion followed by an explosive jump, with athletes landing in the same place. The CMJA followed the same procedure as the CMJ, but this time athletes were allowed to use their arms freely throughout the movement. Each jump type was performed three times, with 30-s rest intervals between attempts. The jumps were measured using an optical sensor system with transmitting and receiving bars (Optojump, Microgate, Bolzano, Italy), and the jump height (in cm) was recorded for each trial. The highest recorded jump for each type was used for analysis. The reliability and validity of these tests have been established in previous research [25].

Sprint Performance (0–15 m Running Speed)

Sprint speed was measured at 5 m, 10 m, and 15 m using infrared timing gates. A 15 m sprint was conducted with photocell gates (Microgate, Polifemo Radio Light, Bolzano, Italy) positioned 0.4 m above the ground, ensuring an accuracy of 0.001 s. The timing system was triggered automatically when the athletes passed the first gate at the starting line, with split times recorded at 5 m and 10 m. Athletes were instructed to complete the 15 m sprint as quickly as possible, starting from a standing position (crouched start, 0.5 m behind the timing lights). Acceleration was determined by measuring the time taken to cover the initial 5 m segment. Each participant completed two trials with at least three minutes of rest between attempts, and the best result was used for analysis. The 15 m sprint test has been previously validated as a measure of linear speed in research by Nimphius et al. [26].

COD ability (T test, 9-6-3-6-9 test, 505 test)

The change of direction was evaluated using the *t*-test and 9-6-3-6-9 test, with 505 tests conducted using a photocell timing system (Witty System, Microgate, Bolzano, Italy).

The *t*-test setup included three cones positioned in a straight line, with each spaced 4.57 m apart. The test began with the athlete sprinting from the starting gate toward the central cone, located 9.14 m away. Upon reaching the cone, the participant tapped its top with their right hand before making a lateral movement to the right to touch the next cone (4.57 m from the center) with the right hand. The athlete then shuffled left to touch the far-left cone, returned to the middle cone with another lateral movement, and finally sprinted back to the starting line, passing through the gate to complete the test. The reliability and validity of this test have been established in previous research [27].

The total distance covered by the players during this test was 21 m. The test began with the athletes sprinting 9 m after the starting signal. Upon reaching the designated line,

they performed a 180-degree turn to either the left or the right. They then ran 3 m to the following line, executed another 180-degree turn, and continued forward for 6 m. After making a third 180-degree turn, they sprinted an additional 3 m before performing the final turn and completing the last 9-m segment to the finish line. The validity and reliability of this test have been confirmed in previous research [28].

The 505 agility test is designed to assess an athlete's ability to decelerate, change direction, and re-accelerate efficiently. The test begins with the player sprinting 10 m, continuing 5 more meters past the turning line before making a sharp 180-degree turn. After turning, the athlete sprints back toward the starting direction, with timing recorded from the 5-m mark before the turn to the finish line. The test is performed for both left and right turns to evaluate agility in both directions. It is widely used in sports requiring rapid directional changes, with proven reliability in assessing agility and acceleration. The validity and reliability of this test have been confirmed in previous research [29].

2.4. Variables

The independent variables in this study can be categorized into three groups: vertical jump performance, linear sprint performance, and change of direction (COD) ability.

A total of three variables were used to evaluate vertical jump performance: squat jump (SJ), countermovement jump (CMJ), and countermovement jump with arm swing (CMJA). These tests reflect explosive lower-body power and the utilization of stretch-shortening cycle mechanisms.

Linear sprint performance was assessed using three split-time sprint measures: 5 m, 10 m, and 15 m sprint times. These parameters primarily reflect acceleration capacity over short distances, which is highly relevant in volleyball-specific movements.

Change of direction ability was measured using three standardized agility tests: the *t*-test (TT), the 9-6-3-6-9 test, and the 505 test. These tests capture the athletes' ability to rapidly decelerate, change direction, and re-accelerate, which are critical components of volleyball performance.

2.5. Methodological Considerations

While the chosen tests are widely validated, they primarily assess isolated aspects of physical performance and do not capture the situational demands of volleyball. Moreover, as a cross-sectional design, the study identifies associations rather than causality. Future longitudinal or intervention-based research is needed to expand on these findings.

2.6. Statistical Analysis

All statistical analyses were conducted using SPSS v. 20 (IBM Corporation, Armonk, NY, USA). Descriptive statistics were computed for all the data. All variables were tested for normality using the Kolmogorov–Smirnov test. Pearson's correlation coefficient was applied to assess the relationships between the variables. The strength of the correlations was interpreted based on the following criteria: <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, almost perfect. A significance level of $p \leq 0.05$ was used for the correlation analysis [30].

3. Results

The arithmetic mean, standard deviation, 95% confidence interval (CI), and Levene's Test for Equality of Variances (F) of motor abilities are presented in Table 1. Additionally, the Kolmogorov–Smirnov test revealed no evidence that the data deviates from a normal distribution. Since the Kolmogorov–Smirnov test confirmed that the data did not deviate significantly from normal distribution, Pearson's correlation was applied to examine the association between motor ability variables.

Table 1. Descriptive statistics for all observed variables.

n = 36	Mean ± SD	95%CI	F	K-S
CMJ (cm)	34.86 ± 6.20	32.81–37.20	0.282	0.913
CMJA (cm)	42.33 ± 7.50	39.74–45.15	0.022	0.971
SJ (cm)	31.30 ± 6.57	29.13–33.76	3.92	0.300
5 m (s)	1.09 ± 0.08	1.06–1.12	1.40	0.489
10 m (s)	1.87 ± 0.13	1.82–1.92	1.53	0.746
15 m (s)	2.59 ± 0.22	2.51–2.67	0.047	0.589
TT (s)	10.52 ± 0.81	10.23–10.82	0.786	0.204
9-6-3-6-9 (s)	8.01 ± 0.68	7.78–8.27	0.119	0.872
505 (s)	3.67 ± 0.39	3.55–3.82	2.49	0.312

CMJ—countermovement jump, CMJA—countermovement jump with arm swing; SJ—squat jump; 5 m—5 m speed test; 10 m—10 m speed test; 15 m—15 m speed test; TT—agility T test; 9-6-3-6-9—agility test; 505—agility test 505.

Using Pearson’s correlation analysis (Table 2), the study revealed a series of significant associations among various performance tests. Taking into account the correlation of explosive strength with speed, the highest correlation was found between the CMJA test and the 10 m sprint test ($r = -0.675$; Table 2; Figure 1). In addition to that, explosive strength tests showed a large correlation with all agility tests, with emphasis on the correlation between CMJA and TT as the highest correlation found ($r = -0.632$; Table 2; Figure 2). Furthermore, when examining the relationship between speed and agility, the highest correlation was observed between the 10 m sprint test and the 9-6-3-6-9 agility test ($r = 0.728$; Table 2; Figure 3).

Table 2. Pearson correlation of the variables of the study.

Variables		CMJA	SJ	5 m	10 m	15 m	TT	9-6-3-6-9	505
CMJ	r	0.921	0.955	−0.534	−0.636	−0.600	−0.618	−0.465	−0.501
	p	0.000 **	0.000 **	0.002 **	0.000 **	0.000 **	0.000 **	0.007 **	0.003 **
CMJA	r		0.902	−0.578	−0.675	−0.636	−0.632	−0.600	−0.578
	p		0.000 **	0.001 **	0.000 **	0.000 **	0.000 **	0.000 **	0.001 **
SJ	r			−0.552	−0.633	−0.587	−0.579	−0.449	−0.450
	p			0.001 **	0.001 **	0.000 **	0.001 **	0.011 *	0.11 *
5 m	r				0.871	0.692	0.514	0.590	0.397
	p				0.000 **	0.000 **	0.003 **	0.000 **	0.024 *
10 m	r					0.833	0.719	0.728	0.515
	p					0.000 **	0.000 **	0.001 **	0.003 **
15 m	r						0.618	0.539	0.525
	p						0.000 **	0.001 **	0.002 **
TT	r							0.798	0.602
	p							0.000 **	0.000 **
9-6-3-6-9	r								0.594
	p								0.001 **

CMJ—countermovement jump, CMJA—countermovement jump with arm swing; SJ—squat jump; 5 m—5 m speed test; 10 m—10 m speed test; 15 m—15 m speed test; TT—agility T test; 9-6-3-6-9—agility test; 505—agility test 505; *—correlation significant at 0.05 level; **—correlation significant at 0.01 level.

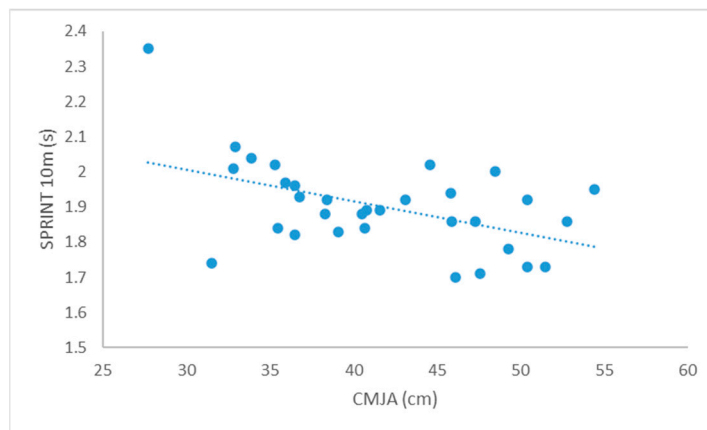


Figure 1. Correlation of explosive strength and speed.

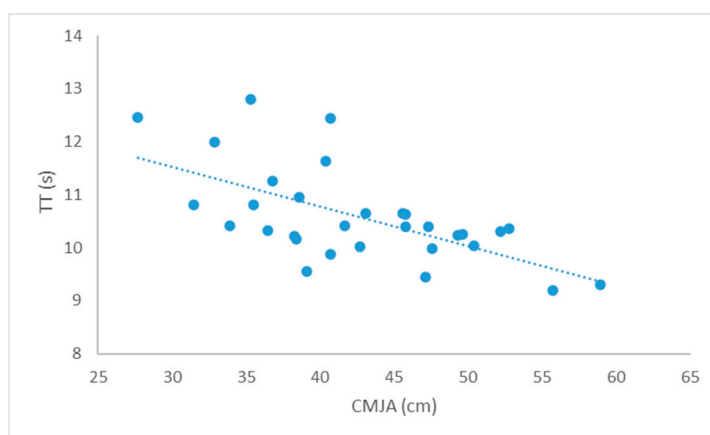


Figure 2. Correlation of explosive strength and agility.

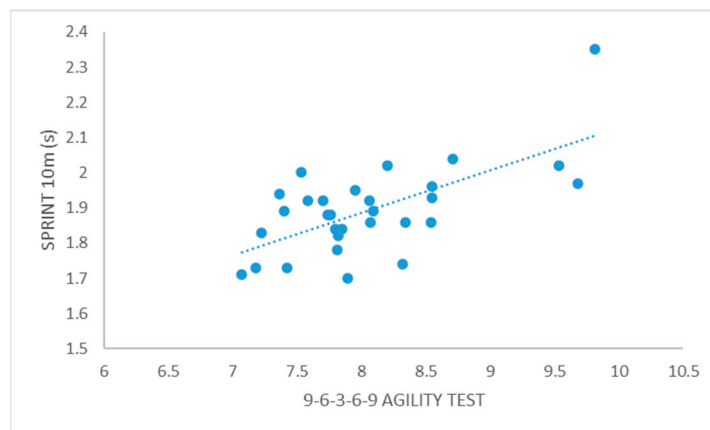


Figure 3. Correlation of speed and agility.

4. Discussion

This study aimed to analyze the relationships between explosive power, speed, and agility performance, as well as the extent to which performance in one domain influences the other. The key findings revealed a clear and consistent correlation between all measured variables. All variables showed small to almost perfect correlations, with statistical significance in every case. Explosive strength tests (CMJ, CMJA, SJ) had almost perfect correlation to each other and also showed small to large negative correlations with sprint times over 5 m, 10 m, and 15 m, as well as with agility test results (*t*-test, 9-6-3-6-9, 505).

These negative correlations mean that higher explosive power is linked to faster sprint times and better agility. Sprint tests were also related to each other and showed moderate to very large positive correlations with agility tests, suggesting that these abilities share similar physical and technical factors. Overall, the results suggest that improving one of these abilities is likely to improve performance in the others as well.

The results of this study highlight significant relationships between jump performance (measured via CMJ, CMJA, and SJ), linear speed (5 m, 10 m, and 15 m sprints), and change of direction (COD) speed (*t*-test, 9-6-3-6-9, and 505 tests) in young elite volleyball players. The almost perfect positive correlations among the jump tests (e.g., CMJ and SJ: $r = 0.955$, $p < 0.001$; CMJ and CMJA: $r = 0.921$, $p < 0.001$) suggest that these measures tap into a shared construct of explosive strength, a critical determinant of volleyball performance. This finding emphasises the importance of maximal force production in short timeframes for jumping activities, which are fundamental to actions such as spiking and blocking in volleyball [5].

The moderate to large negative correlations between jump performance and sprint times (e.g., CMJA and 10 m sprint: $r = -0.675$, $p < 0.001$; SJ and 15 m sprint: $r = -0.587$, $p < 0.001$) indicate that greater explosive strength is associated with faster acceleration and linear speed. This aligns with prior research by Lockie et al. [31], who found a strong link between jump test outcomes and sprint acceleration in athletic populations, and supports Banda et al. [9], who suggested that enhanced jump performance could translate to improved sprint capabilities. In contrast to our findings, Vescovi and McGuigan [32] reported weak associations between CMJ performance and various sprint distances. This can be explained by the fact that jumps involving a countermovement relying on the eccentric-concentric phase of motion [33], whereas short sprints (5–15 m) are more dependent on concentric force production during acceleration [34]. This clarifies the well-documented relationship between SJ and acceleration [35,36], but only partially accounts for the link between countermovement jumps and short-distance acceleration. It suggests that other factors, such as age and training experience, may have influenced the results, given that the participants were young athletes.

Likewise, the negative correlations between jump performance and COD speed (e.g., CMJ and *t*-test: $r = -0.618$, $p < 0.001$; CMJA and 9-6-3-6-9: $r = -0.600$, $p < 0.001$) suggest that superior lower-body power facilitates quicker directional changes. This is consistent with Sheppard et al. [24], who identified explosive strength and power as key contributors to effective COD execution, and Young et al. [7], who highlighted the role of eccentric and concentric strength in deceleration and re-acceleration phases. To perform an effective change of direction, eccentric strength is required to decelerate the body, followed by the development of concentric force to re-accelerate in the new direction [37]. Accordingly, the moderate correlation observed between SJ and the 505 test ($r = -0.450$, $p = 0.10$) is consistent with previous findings. This may also suggest that certain jumping tasks in leg-dominant positions, particularly those involving unilateral turning, are less dependent on the explosive power expressed in the squat jump [38]. One possible explanation could be technical aspects, such as biomechanical adjustments. It is well established that athletes must transition from forward running (deceleration) to backward movement (re-acceleration) during COD tests, which requires a high level of motor abilities that are fundamental to all skills essential for COD performance [39].

The very large positive correlations among sprint and COD tests (e.g., 10 m sprint and *t*-test: $r = 0.719$, $p < 0.001$; *t*-test and 9-6-3-6-9: $r = 0.798$, $p < 0.001$) underscore the interconnectedness of linear speed and agility in volleyball players. This finding is consistent with the study by Little and Williams [40], who reported strong correlations between agility and 10- and 20-m sprint performance. These results are also in agreement with those

of Nimphius et al. [26], who argued that acceleration capacity is a critical underpinning of both linear and multidirectional movements in sports, and corroborates Vescovi and McGuigan [32], who demonstrated that sprint performance over short distances strongly predicts agility outcomes. These results suggest that acceleration and agility share common physiological and biomechanical determinants, particularly over shorter distances. This is especially relevant in volleyball, where short, explosive sprints are frequent due to the limited dimensions of the court [41].

Notably, the moderate correlations between explosive strength and jump height and sprint/COD outcomes (e.g., CMJ and 5 m sprint: $r = -0.534$, $p = 0.002$) are in line with Pleša et al. [12], who reported moderate associations between jump height and force-velocity profiles in sprinting ($r = 0.35$, $p = 0.022$) among young male volleyball players. This suggests that while explosive strength of lower extremities is a significant driver of speed and agility, additional factors such as coordination, technique, or neuromuscular efficiency may also play a role [7,42]. For instance, the arm swing in CMJA likely enhances power output and better correlates with dynamic tasks like the 10 m sprint ($r = -0.675$, $p < 0.001$) compared to SJ, supporting the idea that upper-body contribution influences performance in multifaceted movements [43]. Although some studies did not observe this association, the present findings are based on shorter sprint distances (5–15 m), which primarily reflect acceleration and are more strongly correlated with an athlete's explosive power, particularly CMJ performance. Moreover, all agility tests in this study involved changes of direction requiring both acceleration and deceleration, with running distances ranging from 3 to 9 m before braking and directional shifts occurred. This further highlights the substantial contribution of lower-body explosive strength. Collectively, these results underscore the complex nature of the relationship between physical performance tests [44].

These interrelationships between jumping, sprinting, and COD performance are understandable, as all these movement patterns primarily rely on the activation of lower limb musculature. Furthermore, both jumps and sprints require the generation of maximal muscular force within a very short time frame [5,13]. However, COD performance, in addition to this capacity, also necessitates the integration of other motor abilities such as strength, which is essential for both acceleration and deceleration, and coordination, which plays a crucial role in efficient movement technique and the ability to rapidly change direction [7]. Taken together, this highlights the multidimensional nature of COD ability, which is not only dependent on explosive power but also on the synergistic contribution of various neuromuscular and technical factors. In short, the mechanisms underlying these results lie in the fact that explosive lower-limb strength enables rapid generation of maximal force, thereby enhancing jumping, acceleration, and the execution of change of direction [5], while muscle coordination and movement technique allow precise control of that force in various directions. Efficient motor unit recruitment and the synchronization of eccentric and concentric contractions further integrate jumping, sprinting, and agility [45] while shared energy systems for short-term maximal efforts facilitate the transfer of power between these abilities, explaining why improvement in one is likely to lead to enhancements in the others. It should also be noted that this study did not examine other factors such as differences in running technique, level of biological maturation, and length of training experience which may also have influenced the results.

These findings advocate for the inclusion of plyometric and strength training in volleyball programs to bolster lower-body power, thereby enhancing speed and COD abilities. This may help optimize performance during the volleyball season [46]. Coaches can use jump test results to identify players suited for roles that require explosive movements (e.g., middle blockers) and tailor conditioning to address weaknesses in speed or agility. However, the study's focus on young elite players (mean age: 15.44 ± 2.02 years) implies

that these relationships may shift with maturation or training experience, as noted by Lloyd et al. [47] in their work on youth athletic development. Longitudinal studies could clarify how these physical qualities evolve and whether training interventions amplify their interdependence over time. The study of how jump performance, sprint speed, and change of direction ability relate in young elite volleyball players aligns with modern sports science trends. These trends prioritize comprehensive assessments of key motor skills and sport-specific testing to improve training. Modern athletic preparation demands complex, integrated methods that consider specific goals, athletes' individual traits, and the sport's unique demands, all in line with current advances toward performance dynamization [48–50].

4.1. Practical Implications

Monitoring the current motor performance of young elite volleyball players holds considerable scientific value and direct practical relevance, particularly given the limited amount of research conducted on this specific population. The obtained data may serve as a foundation for comparisons in future studies and can also assist strength and conditioning coaches in profiling young elite volleyball players.

Furthermore, the findings of this study have important practical implications for the training process. The observed correlations indicate that explosive power, speed, and agility should not be regarded as entirely separate motor capacities, but rather as abilities that share common physiological underpinnings. This suggests that improving one of these qualities may also enhance the others, thereby enabling more efficient planning of training programs. Based on this evidence, volleyball coaches are encouraged to apply integrated training methods that simultaneously develop explosiveness, acceleration, and change of direction ability—for example, combining plyometric exercises, short sprints, and agility tasks tailored to the smaller distance characteristic of the volleyball court. This is especially important in volleyball, where players must be capable of rapid changes of direction, explosive jumps, and sudden accelerations.

4.2. Limitations and Future Suggestions

Although the results provide valuable insights into the physical performance of young volleyball players, several limitations should be acknowledged. The primary limitation is the small sample size, which also prevented classification according to playing positions; this should be addressed in future studies. Additionally, all participants were recruited from a single club, reducing sample representativeness and limiting the generalizability of the findings.

For future research, it may be beneficial to include additional change of direction (COD) tests, as well as analyses of COD deficits and unilateral and dynamic strength. This study did not consider differences in lower-limb length or body asymmetries, although these factors may affect speed performance and should be included in subsequent investigations. Furthermore, the relationship between physical qualities and COD performance should be examined across different angles of directional change. Longitudinal studies are also recommended to monitor the development of explosive strength, speed, and agility throughout growth and training. Moreover, incorporating biomechanical analyses and neuromuscular assessments, such as EMG and 3D motion analysis, could further clarify the mechanisms underlying the observed correlations.

5. Conclusions

This study shows that lower-body power, measured by vertical jump performance (CMJ, CMJA, and SJ), is strongly related to both linear speed and change of direction (COD)

speed in young elite volleyball players. The almost perfect positive relationships among jump tests and their moderate to very large negative connections with sprint and agility results highlight the key role of explosive power in volleyball-specific movements. These findings indicate that increasing lower-body power could enhance acceleration and changes in direction, which are essential for success in this fast-paced sport. Coaches can use these insights to improve training plans and player positioning by focusing on exercises that develop power, speed, and agility at the same time. While this study helps fill a gap in understanding these links among young elite volleyball players, further research is needed to see how these connections appear across different age groups, genders, or competition levels, and to investigate how other motor skills influence performance.

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