Int. J. Morphol.,
44(2):526-535, 2026.

Motor Development in Volleyball Players: A Comparative Study of Senior and Junior Bosnian and Herzegovinian National Volleyball Team Members

Desarrollo Motor en Jugadores de Voleibol: Estudio Comparativo de Miembros Senior y Junior de la Selección Nacional de Voleibol de Bosnia y Herzegovina

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PAVLOVIC, R.; KOZINA, Z.; SAVIC, V.; BADAU, D.; RADULOVIC, N. & NIKOLIC, S. Motor development in volleyball players: A comparative study of senior and junior Bosnian and Herzegovinian national volleyball team members. *Int. J. Morphol., 44(2)*:526-535, 2026.

SUMMARY: Motor skills, including explosive lower limb and upper body strength, coordination, flexibility, and endurance, are fundamental for volleyball performance. Evaluating differences between senior and junior players allows optimization of training programs and targeted development of specific motor abilities. This study aimed to examine differences in motor skills between senior and junior male volleyball players from the Bosnia and Herzegovina national team. A total of 29 healthy male volleyball players participated, divided into seniors (n=13; Body Height=194.77 ± 7.01 cm; Body Weight=92.92 ± 7.02 kg) and juniors (n=16; Body Height=197.06±4.65 cm; Body Weight = 83.19±5.15 kg). Motor abilities were assessed using standardized tests: block and spike jump height, standing long jump, dominant and non-dominant handgrip strength, 3 kg medicine ball throw, hand tapping, sit and reach flexibility, and sit-to-stand trunk endurance. Descriptive statistics (mean ±SD, coefficient of variation, skewness, kurtosis) were calculated, and independent t-tests with Levene's test for equality of variances were used to compare groups. Significance was set at $p < 0.05$; $p < 0.01$. Senior players outperformed juniors in explosive lower limb and upper body strength: standing long jump (269.00 ± 19.38 cm *vs*. 253.50 ± 15.34 cm; t = 2.406, p = 0.028), dominant handgrip (52.62 ± 7.63 kg *vs*. 40.75 ± 8.26 kg; t = 3.979, p < 0.001), non-dominant handgrip (42.15 ± 5.00 kg *vs*. 31.88 ± 6.83 kg; t = 4.524, p < 0.001), and 3 kg medicine ball throw (10.17 ± 0.76 m *vs*. 8.22 ± 0.73 m; t = 7.033, p <?0.001). Differences in block jump height, spike jump height, hand coordination, flexibility, and trunk endurance were not statistically significant, although juniors showed higher variability in flexibility and handgrip strength. Senior volleyball players demonstrate superior explosive strength and upper body power, while juniors exhibit greater heterogeneity in motor skills. These findings highlight the necessity for individualized and targeted training programs for younger athletes to optimize motor development and reduce intra-group variability.

KEY WORDS: Motor skills; Explosive strength; Handgrip strength; Coordination; Flexibility; Endurance.

INTRODUCTION

Volleyball is a popular team sport with clear FIVB rules, played indoors or outdoors. Volleyball points involve high-intensity activities such as jumps, multidirectional movements, spikes, blocks, and steps, while intervals between points include low-intensity activities, such as walking and standing (Marques *et al*., 2009; Holmberg, 2013; Kerksick *et al*., 2018). It is an acyclic, highly dynamic, and highly specific sport that requires the simultaneous application of a wide range of technical, tactical, and motor skills (Kozina *et al*., 2023; Bachtiar, *et al*., 2024; Pradana, *et al*., 2024). Its complexity is reflected in the need for rapid decision-making, precise execution of movements, and high coordination of team activities with six players on the court (Pavlovic´ & Zotova, 2024; Sobko *et al*., 2024). The nature

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Received: 2025-10-30 Accepted: 2026-02-07

of the game and the physiological demands it imposes make achieving a high level of fitness essential, combined with technical, tactical, and psychological skills (Pradhan, 2017; Greco *et al*., 2019).

Research shows that volleyball players require a high level of motor skills, i.e., speed, agility, explosive power, strength, aerobic endurance, and flexibility (Oldenburg 2015; Rey *et al*., 2016), which define key determinants of sporting performance. Explosive power enables efficient execution of jumps and strikes, coordination contributes to technical precision and movement stability, while flexibility and endurance ensure continuity of play and injury prevention (Duncan *et al*., 2006; Gabbett & Georgieff, 2007). Particular emphasis is placed on lower-body muscular strength, as players perform a large number of vertical jumps, which are crucial for skills such as spikes, blocks, jump-sets, and jump-serves (Kenny & Gregory, 2006; Newton *et al*., 2006; Hedrick, 2007; Ziv & Lidor, 2010). Some studies indicate that dynamic stretching significantly improves kinetic variables of volleyball players' vertical jumps (Palaniappan *et al*., 2013; Kruse *et al*., 2015; Gulati *et al*., 2021), while others report no similar effects (Little & Williams, 2006; Walsh, 2017). In addition to strength and flexibility, volleyball requires a high level of reaction time and acceleration speed, as players must react very quickly to a fast-moving ball, while the relatively small court limits reaching maximum speed (Johnson *et al*., 2010).

The development of motor skills in volleyball players depends on multiple factors, including genetic predisposition, age, training experience, biological maturity, as well as the quality and structure of the training process (Putra *et al*., 2024; Pradana *et al*., 2024; Bachtiar *et al*., 2024; Pavlovic´ & Zotova, 2024; Sobko *et al*., 2024). During early sports specialization, juniors undergo a phase of intensive development of basic motor skills, while at the senior level these skills are further refined through specific, high-intensity, and individualized training (Toselli & Campa, 2018). Older players generally have greater muscle mass, better neuromuscular coordination, and a more stable level of motor efficiency, allowing them a higher degree of movement control and faster execution of technical elements of the game (Singh & Singh, 2021). The transition from junior to senior competition represents a critical period in an athlete's development, as it is when differentiation occurs in physical abilities, motor readiness, and psychophysiological stability. Although juniors are expected to have high motivation and potential for improvement, greater intra-group variability in motor test results is often observed, which may result from various factors — from individual differences in the pace of biological maturation, through variations in training load, to technical-tactical priorities in the sports development process (Gangey & Kerketta, 2016; Khanna & Koley, 2020; Nagorna *et al*., 2023; Hrynchenko *et al*., 2025). Comparative studies analyzing differences between juniors and seniors within the same sports system or national team provide valuable insights into the continuity of motor development and the effectiveness of training programs. Such research allows coaches and sports experts to identify specific areas requiring additional development, as well as to optimize the training process according to age and individual characteristics of athletes (Aouadi *et al*., 2012; Caia *et al*., 2016). Especially in volleyball, where each phase of the game requires specific motor qualities, analyzing differences between age groups has practical importance for long-term planning of athlete development and the formation of a sustainable national team selection.

The aim of this study is to analyze and compare the motor skills of senior and junior male volleyball players of the Bosnia and Herzegovina national team. Special emphasis is placed on explosive lower limb power, upper body strength, coordination, flexibility, and endurance. By analyzing differences between these groups, the study seeks to identify how age, training experience, and the degree of physiological maturity affect the development of volleyball-specific motor skills.

The research hypotheses are formulated as follows:

H1: There are statistically significant differences in the level of development of motor skills between juniors and seniors of the Bosnia and Herzegovina volleyball team.
H2: Seniors will show a higher level of explosive power and coordination compared to juniors, as a result of longer training experience and physiological maturity.
H3: Differences in flexibility and endurance between the groups will be less pronounced, indicating the importance of individual characteristics and training structure.

MATERIAL AND METHOD

Participants

The sample of respondents included 29 male volleyball players from the national team of BIH divided into a subsample of seniors (n=13; body height = 194.77 ± 7.01 cm; body mass = 92.92 ± 7.02 kg) and a subsample of juniors (n= 16, body height = 197.06±4.65 cm; body weight = 83.19±5.15 kg). All study participants were healthy and physically fit, with no history of injuries in the last six months. Before the commencement of this study, every participant received a comprehensive overview of the study's

specifics and outcomes assessment methods, and they provided signed consent forms as evidence of their agreement to participate. The Council of the University of East Sarajevo approved this study under approval number 01-C-396-XXXVIII/10, dated November 25, 2010 and the study was conducted per the Declarations of Helsinki (2010). The study followed the STROBE guideline while conducting the study procedures, as explained in Figure 1.

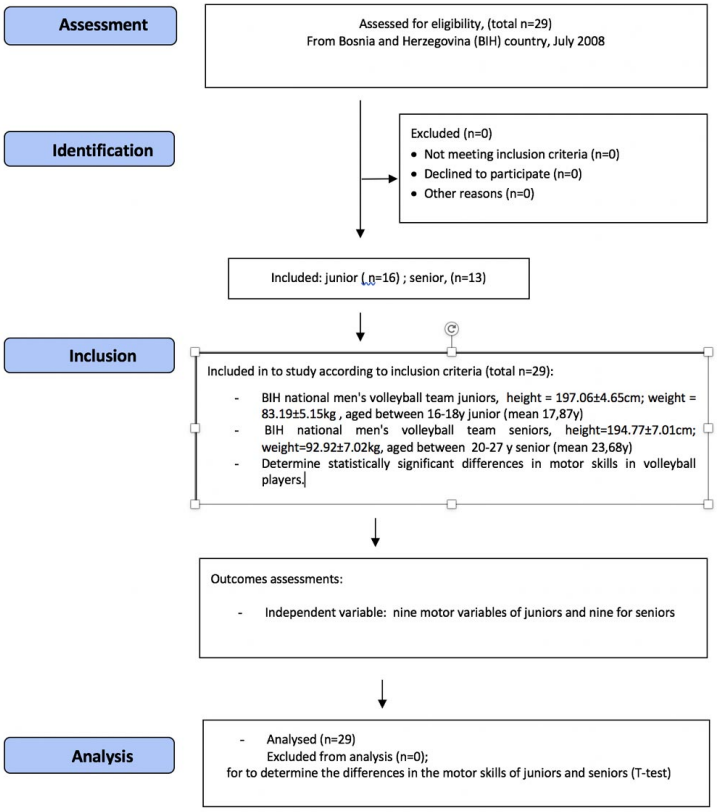

Fig. 1. A STROBE flow chart shows participants' assessment, identification, inclusion and data analysis.

Research Design

Instruments and Measurements

The motor abilities of volleyball players were assessed using standardized and widely accepted instruments and tests in the field of sports science. Standard metric instruments adapted to laboratory conditions were employed. Hand grip strength (HGS) was measured using the isometric dynamometry method with a digital dynamometer CAMRY EH101 (USA), while other measurements were conducted using reliable and validated volleyball-specific motor tests. Specific motor tests for volleyball players were applied, which have previously demonstrated their validity and reliability (Stockbrugger *et al*., 2001; Sattler *et al*., 2012; Muñoz-Bermejo *et al*., 2021; Abe *et al*., 2024).

1.Explosive lower limb strength was evaluated through:

- Block jump height (cm);
- Spike jump height (cm);
- Standing long jump (cm) providing a quantitative assessment of jumping ability.

2. Upper body strength was assessed using

- Dominant hand grip strength (kg);
- Non-dominant hand grip strength (kg);
- 3 kg medicine ball throw (m) reflecting muscle strength and coordination of the upper limbs.

3. Movement frequency speed:

- Hand tapping test (iterations)

4. Flexibility:

- Sit-and-reach test (cm).

5. Trunk endurance:

- Sit-to-stand test (iterations)

All participants were tested under controlled laboratory conditions during a single testing session. Prior to testing, participants completed a standardized 10–15 minutes warm-up to minimize the risk of injury and ensure maximal performance. All tests were performed according to established protocols, with each test repeated 2–3 times, and the best measured value recorded as the final result. A rest period of 30–60 seconds was provided between repetitions to allow full recovery and minimize fatigue, while rest intervals of 2–3 minutes were applied between different tests depending on the intensity of the preceding activity, ensuring measurement validity and minimizing fatigue effects.

Statistical Analysis

Descriptive statistics, including mean, standard deviation (SD), coefficient of variation (CV%), skewness, and kurtosis, were calculated for all measured variables to summarize the motor abilities of both senior and junior players. The Kolmogorov–Smirnov (K-S) test was applied to assess the normality of data distribution. Independent samples t-tests were conducted to compare motor skill differences between senior and junior players. Levene's test was used to assess the homogeneity of variances. Statistical significance was set at $p < 0.05$, and highly significant differences were considered at $p < 0.01$. Confidence intervals (95% CI) were reported for mean differences. In addition to

significance testing, Cohen's d effect sizes were calculated to quantify the magnitude of differences between groups (***). The interpretation of effect sizes was based on the following thresholds (Cohen, 1988): small effect: d =0.2; medium effect: d = 0.5; large effect: d ≥ 0.8. Also presented are the differences between means (Mean1 - Mean2).

RESULTS

Descriptive analysis of volleyball players' motor skills shows clear differences between the senior and junior groups, both in mean values and in result variability (Table I). Seniors achieved an average block jump height of 309.00± 10.93 cm, while juniors reached 307.50 ± 5.83 cm; variability among seniors (CV = 3.54 %) was slightly higher than among juniors (CV = 1.90 %), although the results in both groups were approximately symmetrical (skew. –0.94 and –0.16), suggesting that seniors have slightly greater strength and technical efficiency, whereas juniors are more homogeneous. Similarly, spike jump height was 328.38 ± 11.25 cm for seniors and 325.06 ± 6.41 cm for juniors; juniors showed positive skew. (0.89), whereas the distribution among seniors was slightly negatively skew. (–0.79), and variability was lower for juniors (CV = 1.97 %) than for seniors (CV = 3.43 %), indicating greater heterogeneity among seniors in this test. The standing long jump averaged 269.00 ± 19.38 cm for seniors and 253.50 ± 15.34 cm for juniors; the positive skew. in juniors (1.54) and high kurt. (3.46) suggest the presence of a few exceptionally high scores, while the rest were below average, indicating heterogeneity in lower limb explosive strength among younger players. Seniors also demonstrated significantly greater upper body strength: dominant handgrip strength was 52.62 ± 7.63 kg for seniors and 40.75 ± 8.26 kg for juniors, while non-dominant handgrip strength was 42.15 ± 5.00 kg for seniors and 31.88 ± 6.83 kg for juniors; variability was much higher among juniors (CV > 20 %), and skew. and kurt. indicate the presence of individual extreme values, likely due to differences in training history and hand dominance. The 3 kg medicine ball throw averaged 10.17 ± 0.76 m for seniors and 8.22 ± 0.73 m for juniors, with relatively low variability (CV < 9 %), while the hand tapping test showed 51.54 ± 4.37 iterations for seniors and 48.88 ± 4.16 for juniors, with similar variability (CV ≈ 8.5 %), indicating faster hand coordination among older players. Flexibility, measured by the sit and reach test, was slightly higher in juniors (31.88 ± 6.73 cm) than in seniors (30.85 ± 3.56 cm), but with significantly higher variability (CV = 21.12 % *vs.* 11.53 %), indicating heterogeneity among younger players, whereas seniors were more homogeneous. Trunk endurance, assessed by the sit-to-stand test, was 26.23 ± 3.47 iterations for seniors and 24.00 ± 2.71 for juniors, with greater variability in seniors (13.22 % *vs.* 11.28 %), and the distribution of results was approximately normal.

Analysis of differences in motor skills between senior and junior volleyball players shows that seniors generally achieve better results, particularly in tests of explosive strength and upper body strength, while differences in flexibility and coordination were not statistically significant (Table II, Fig. 2). Block jump height was 309.00 ± 10.93 cm for seniors and 307.50 ± 5.83 cm

Table I. Descriptive statistic of motor skills volleyball.

Motor skills	Age	N	Mean ± SD	Range	CV%.	Skew.	Kurt.	K-S
Block jump height (cm)	Seniors	13	309.00±10.93	287.00 - 323.00	3.54	-0.94	0.36	0.196
	Juniors	16	307.50±5.83	295.00 -318.00	1.90	-0.16	0.34	0.090
Spike jump height (cm)	Seniors	13	328.38±11.25	306.00-344.00	3.43	-0.79	-0.09	0.172
	Juniors	16	325.06±6.41	317.00-340.00	1.97	0.89	0.47	0.191
Standing long jump (cm)	Seniors	13	269.00±19.38	237.00-297.00	7.20	0.01	-1.15	0.140
	Juniors	16	253.50±15.34	235.00-297.00	6.05	1.54	3.46	0.211
Dominant HGS (kg)	Seniors	13	52.62±7.63	44.00-66.00	14.51	0.41	-0.89	0.178
	Juniors	16	40.75±8.26	32.00-64.00	20.27	1.43	3.12	0.144
Non-dominant HGS (kg)	Seniors	13	42.15±5.00	36.00-50.00	11.86	0.31	-0.97	0.127
	Juniors	16	31.88±6.83	22.00-46.00	21.43	0.73	-0.02	0.180
Medicine ball throw 3 kg (m)	Seniors	13	10.17±0.76	9.00-11.50	7.45	0.28	-0.91	0.193
	Juniors	16	8.22±0.73	6.80-9.40	8.83	-0.36	-0.35	0.173
Hand tapping test (iter.)	Seniors	13	51.54±4.37	45.00-58.00	8.48	0.12	-1.41	0.176
	Juniors	16	48.88±4.16	44.00-56.00	8.51	0.55	-1.01	0.175
Sit and reach test (cm)	Seniors	13	30.85±3.56	23.00-35.00	11.53	-1.10	0.98	0.209
	Juniors	16	31.88±6.73	23.00-45.00	21.12	0.59	-0.72	0.176
Sit - to - stand test (iter.)	Seniors	13	26.23±3.47	21.00-32.00	13.22	0.35	-0.59	0.141
	Juniors	16	24.00±2.71	20.00-30.00	11.28	0.51	0.36	0.125

Note: Mean:average values; K-S: Kolmogorov-Smirnov test; SD: Standard deviation; CV%: coefficient of variation; Kurt.: Kurtosis; Skew: Skewness; HGS - Hand grip strength.

Table II. Differences in motor skills between volleyball players.

Variables	Age	Mean ± SD	t -value	p (2-sided)	p – Levene	Mean 1 – 2	95% CI		Cohen's d
							Lower	Upper	
Block jump height (cm)	Senior	309.00±10.93	0.473	0.661	0.069	1.50	-5.001	8.001	0.17
	Juniors	307.50±5.83							
Spike jump height (cm)	Senior	328.38±11.25	1.000	0.356	0.045	3.32	-3.492	10.137	0.35
	Juniors	325.06±6.41							
Standing long jump (cm)	Senior	269.00±19.38	2.406	0.028*	0.154	15.50	2.283	28.717	0.86***
	Juniors	253.50±15.34							
Dominant HGS (kg)	Senior	52.62±7.63	3.979	0.000**	0.955	11.86	5.747	17.984	1.50***
	Juniors	40.75±8.26							
Non-dominant HGS (kg)	Senior	42.15±5.00	4.524	0.000**	0.377	10.27	5.618	14.940	1.69***
	Juniors	31.88±6.83							
Medicine ball throw 3 kg (m)	Senior	10.17±0.76	7.033	0.000**	0.600	1.94	1.377	2.511	2.59***
	Juniors	8.22±0.73							
Hand tapping test (iter.)	Senior	51.54±4.37	1.676	0.108	0.653	2.66	-0.597	5.924	0.63
	Juniors	48.88±4.16							
Sit and reach test (cm)	Senior	30.85±3.56	-0.496	0.603	0.019	-1.02	-5.280	3.223	-0.19
	Juniors	31.88±6.73							
Sit - to - stand test (iter.)	Senior	26.23±3.47	1.946	0.071	0.290	2.23	-0.121	4.582	0.71
	Junior	24.00±2.71							

Note: *- Significant value, if p<0.05; **-Highly significant value if p<0.01; SD: Standard deviation; Mean 1-2:difference mean; t: T-statistics; 95%CI: Confidence interval; HGS - Hand grip strength; ***Cohen's d (small effect: d = 0.2; medium effect: d = 0.5; large effect: d ≥ 0.8.

for juniors (t = 0.473, p = 0.661, Levene p = 0.069, 95 % CI: –5.001 to 8.001), indicating negligible differences and similar variability between groups. Similarly, spike jump height was 328.38 ± 11.25 cm for seniors and 325.06 ± 6.41 cm for juniors (t = 1.000, p = 0.356, Levene p = 0.045, 95 % CI: –3.492 to 10.137), also without statistical significance. The standing long jump was significantly higher in seniors (269.00 ± 19.38 cm) compared to juniors (253.50 ± 15.34 cm; t = 2.406, p = 0.028, Levene p = 0.154, 95 % CI: 2.283 to 28.717), clearly demonstrating greater lower limb explosive strength in older players. Handgrip strength was significantly higher in seniors for both the dominant hand (52.62 ± 7.63 kg *vs.* 40.75 ± 8.26 kg; t = 3.979, p < 0.001, Levene p = 0.955, 95 % CI: 5.747 to 17.984) and the non-dominant hand (42.15 ± 5.00 kg *vs.* 31.88 ± 6.83 kg; t = 4.524, p < 0.001, Levene p = 0.377, 95 % CI: 5.618 to 14.940), confirming significantly greater upper body strength in seniors. The 3 kg medicine ball throw also revealed highly significant differences between groups: seniors10.17 ± 0.76 m *vs.* juniors 8.22 ± 0.73 m (t = 7.033, p <?0.001, Levene p = 0.600, 95 % CI: 1.377 to 2.511), further supporting superior explosive strength of the trunk and shoulder muscles in older players. The hand tapping test showed 51.54 ± 4.37 iterations for seniors and 48.88 ± 4.16 for juniors (t = 1.676, p = 0.108, Levene p = 0.653, 95 % CI: –0.597 to 5.924), suggesting that hand coordination was not statistically different between groups. Flexibility measured by the sit and reach test was slightly higher in

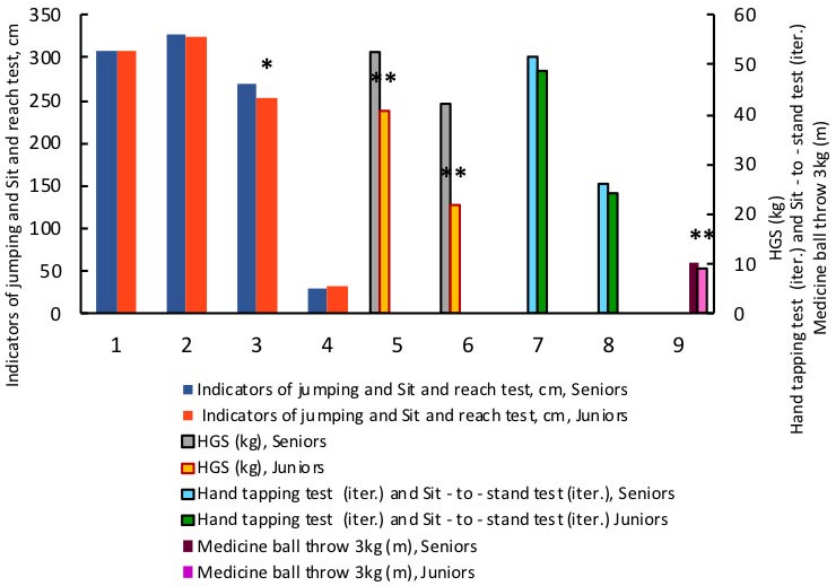

Fig. 2. Indicators of motor skills of senior *vs.* junior volleyball players: 1. Block jump height (cm), Seniors *vs.* Juniors; 2. Spike jump height (cm), Seniors *vs.* Juniors; 3. Standing long jump (cm), Seniors *vs.* Juniors; 4. Sit and reach test (cm), Seniors *vs.* Juniors; 5. Dominant HGS (Hand grip strength) (kg), Seniors *vs.* Juniors; 6.Non-dominant HGS (Hand grip strength) (kg), Seniors *vs.* Juniors; 7. Hand tapping test (iter.), Seniors *vs.* Juniors; 8. Sit - to - stand test (iter.), Seniors *vs.* Juniors

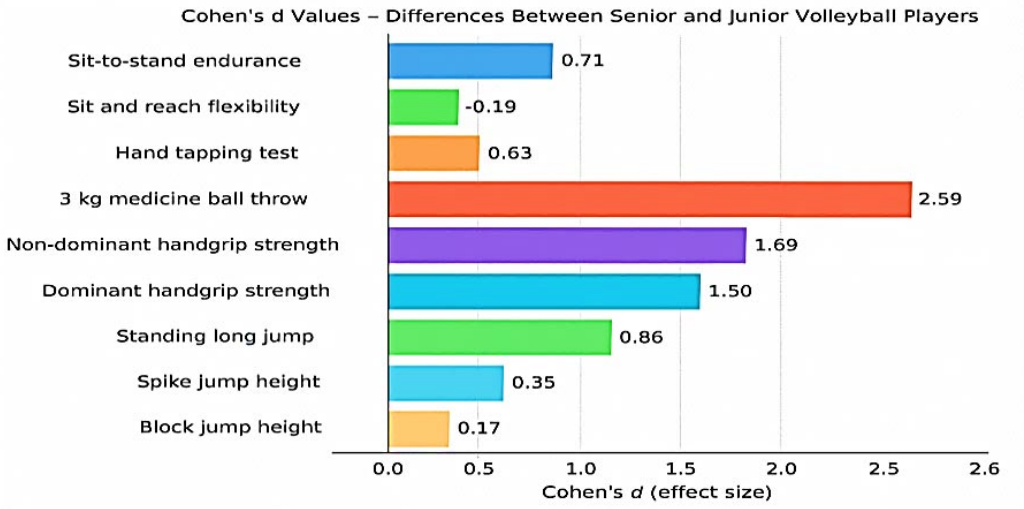

Fig. 3. Cohen's d Effect Sizes: Seniors vs Juniors

juniors (31.88 ± 6.73 cm) than in seniors (30.85 ± 3.56 cm; t = –0.496, p = 0.603, Levene p = 0.019, 95 % CI: –5.280 to 3.223), while trunk endurance measured by the sit-to-stand test was 26.23 ± 3.47 iterations for seniors and 24.00 ± 2.71 for juniors (t = 1.946, p = 0.071, Levene p = 0.290, 95 % CI: –0.121 to 4.582), showing a trend toward better endurance in seniors, but without statistical significance.

Figure 3 shows the differences in motor abilities between senior and junior volleyball players expressed by Cohen's d values, which represent the size of the effect of differences between groups. The biggest difference was observed in throwing a 3 kg medical kit (d = 2.59), which indicates an extremely large effect and significantly better explosive power of the upper body in seniors. Significant differences also exist in hand grip strength, both of the non-dominant hand (d = 1.69) and the dominant hand (d = 1.50), which also shows a high level of strength in more experienced players. Moderate differences were recorded in the sitting-standing endurance test (d = 0.71) and the long jump from a place (d = 0.86), while smaller differences were present in the hand tapping test (d = 0.63) and the height of the jump in the trash (d = 0.35). A minimal difference, almost negligible, was recorded in block (d = 0.17), while the only negative value was observed in flexibility test (d = -0.19), which suggests that juniors were slightly more flexible than seniors. Overall, the results show that seniors have significantly better results in strength and explosiveness tests, while the differences in flexibility and jump height are less pronounced.

Overall, these results confirm that seniors possess higher levels of explosive strength, upper body strength, and general motor fitness, whereas juniors are characterized by greater heterogeneity and variability, especially in flexibility and hand strength. P-values and confidence intervals clearly indicate that statistically significant differences are primarily present in lower limb explosive strength, handgrip strength, and the medicine ball throw, while other tests showed negligible differences. These findings emphasize the need for individualized and targeted training programs for younger volleyball players to develop specific motor abilities and reduce variability within the group.

DISCUSSION

This study aimed to analyze and compare the motor abilities of senior and junior male volleyball players of the Bosnia and Herzegovina national team, focusing on explosive lower limb strength, upper body strength, coordination, flexibility, and endurance. The results show a clear advantage of seniors in the development of explosive and upper body strength, while juniors exhibit greater intra-group variability, particularly in flexibility and handgrip strength.

Senior players achieved better results in the standing long jump, medicine ball throw, and handgrip strength tests, indicating the effects of prolonged and continuous training, as well as the physiological maturity of the musculoskeletal system (Duncan *et al.* 2006; Gabbett & Georgieff, 2007; Singh & Singh, 2021). This is due to natural causes of biological development and is typical not only for volleyball, but also for other sports (Jagiello *et al*., 2015; Ihsan *et al*., 2024; Qadir *et al*., 2024). Explosive lower limb strength is essential for successful execution of vertical jumps, spikes, and blocks, while upper body strength enables effective strikes and stability during contact situations (Kenny & Gregory, 2006; Newton, *et al*., 2006;

Hedrick, 2007; Ziv & Lidor, 2010). These results are consistent with previous research indicating that older and more experienced volleyball players possess higher levels of explosive and functional strength, contributing to more efficient execution of technical elements of the game (Aouadi *et al*., 2012; Caia, 2016).

The absence of statistically significant differences in block and spike jump heights between seniors and juniors suggests that the technical and coordinative aspects of these skills may compensate for differences in raw strength. Timing, precision of movement execution, and neuromuscular coordination are factors that allow juniors to approach senior performance levels, as supported by studies from Hussain *et al*. (2011) and Goranovic´ *et al*. (2022). These observations highlight the complexity of volleyball as an acyclic, dynamic, and highly specific sport, where success depends not only on strength but also on coordination, rapid decision-making, and team synergy (Marques *et al*., 2009; Holmberg, 2013; Kerksick *et al*., 2018).

The greater variability among juniors in flexibility and handgrip strength may result from individual differences in the pace of biological maturation, somatotype, training history, and motor adaptation abilities (Pradhan, 2017; Khanna & Koley, 2020; Gulati *et al*., 2021). These findings emphasize the need for individualized training in the junior category to reduce intra-group heterogeneity and optimize the development of specific motor abilities (Toselli & Campa, 2018; Kozina *et al*., 2023; Pavlovic´ & Zotova, 2024).

Flexibility, although important for injury prevention (Kozin *et al*., 2021) and range of motion as well as for the recovery of athletes (Kozina *et al*., 2016), appears to have been maintained in both groups through standard training processes, without significant differential development. A similar conclusion applies to hand coordination, which, although not showing statistically significant differences, directly impacts the technical precision and efficiency of strikes and blocks (Oldenburg, 2015; Rey *et al*., 2016).

These findings confirm that the development of motor abilities in volleyball must be integrated with technical and tactical elements of training to achieve optimal game performance. Individualized and targeted training for juniors can accelerate the development of explosive lower limb and upper body strength, which is crucial for the transition to the senior level. Monitoring intra-group variability in handgrip strength and flexibility can help identify players requiring additional intervention, thereby optimizing motor development (Toselli & Campa, 2018).

Furthermore, the results indicate that the development of explosive lower limb and upper body strength directly impacts tactical execution, as greater strength enables more effective spikes, blocks, and faster serves, which are critical for international-level competitiveness (Kenny & Gregory, 2006; Newton *et al*. 2006). Integrating these abilities into continuous training can enhance long-term team efficiency and reduce the risk of injury, highlighting the importance of biomechanically and functionally based conditioning programs (Pradhan, 2017; Greco *et al*., 2019).

In conclusion, the study confirms that explosive lower limb strength and upper body strength are the key differences between seniors and juniors, while flexibility, hand coordination, and trunk strength show smaller differences but greater variability among juniors. These findings emphasize the importance of individualized, targeted training programs for juniors to enhance motor abilities, reduce intra-group heterogeneity, and facilitate the transition to the senior level (Marques *et al*., 2009; Holmberg 2013; Kerksick, *et al*., 2018). This study provides practical guidance for coaches: continuous monitoring of individual progress, adjusting training according to biological maturity and motor abilities, and focusing on integrating explosive strength with technical precision in daily training sessions can significantly contribute to athlete success at the senior level.

Limitations and Future Recommendations

This study has several limitations that should be considered when interpreting the results. First, the relatively small sample size (29 players) may limit the generalizability of the findings to a broader population of volleyball players. Second, the focus on male national team players means the results may not be applicable to junior or senior players in lower leagues, nor to female volleyball players. Third, the cross-sectional design provides only a snapshot at a single time point, preventing the assessment of longitudinal development of motor abilities. Fourth, the standardized tests used do not cover all aspects of volleyball performance, such as tactical or cognitive skills. Finally, individual differences in training history, experience, and previous injuries may have influenced the results. Considering these limitations, future studies should aim to develop individualized training programs for junior players to enhance specific motor abilities and reduce intra-group variability, conduct longitudinal research to track progression from juniors to seniors, include larger and more diverse samples (including female players) to increase generalizability, and integrate motor tests with functional, technical, and tactical assessments to provide a more comprehensive evaluation of players' capabilities.

Practical Implications

1. Individualized Training for Juniors- the results show greater intra-group variability among juniors, particularly in flexibility and handgrip strength. This highlights the need for personalized training programs, where each junior player is approached according to their specific motor abilities, reducing heterogeneity and Focus on Stability and Injury Prevention accelerating the development of key skills.

2. Emphasis on Explosive Strength and Upper Body Power- senior players significantly outperform juniors in lower limb explosive strength (standing long jump) and upper body strength (handgrip, medicine ball throw). Junior training should include targeted exercises for explosive and functional upper body strength, such as plyometric jumps, medicine ball throws, and specific shoulder stability exercises.

3. Integration of Motor and Technical Elements- although differences in block and spike jump heights are not significant, seniors show superior strength. This underlines the importance of integrating motor development with game technique, so juniors learn to optimally transfer strength into specific technical movements.

4. Monitoring and Performance Evaluation-regular testing of key motor abilities (strength, explosiveness, flexibility, coordination) allows coaches to identify weaknesses in a timely manner and adjust training. Monitoring flexibility and handgrip strength, in particular, can help prevent injuries and optimize performance.

5. Gradual Transition from Junior to Senior Level - considering differences in strength and explosiveness, junior programs should be structured to progressively increase load and intensity, facilitating a safe transition to the senior level while maximizing motor development.

6. Focus on stability and injury prevention- heterogeneity in trunk strength and flexibility among juniors indicates the need for programs emphasizing core stabilization, flexibility, and proprioception, reducing injury risk and improving movement efficiency during play.

7. Long-Term Planning for National Team Development- the findings emphasize that systematic development of motor abilities in junior players directly impacts the quality of the senior national team. Implementing targeted training programs can contribute to the long-term competitiveness of the national team.

CONCLUSION

The results of this study indicate that senior male volleyball players from the BiH national team exhibit significantly greater explosive lower limb strength, upper body strength, and hand coordination compared to juniors, whereas juniors show higher variability in flexibility and handgrip strength. Statistically significant differences were primarily observed in the standing long jump, handgrip strength, and medicine ball throw, while other tests did not reveal significant differences. These findings emphasize the importance of individualized training programs for junior players to improve motor abilities, reduce group heterogeneity, and facilitate a more effective transition from junior to senior levels. Future research should involve larger samples, longitudinal assessments, and the integration of functional, technical, and tactical evaluations to support a comprehensive understanding of volleyball players' capabilities and long-term athletic development within the national system.

Contribution to Sport Science

This study is the first in Bosnia and Herzegovina to analyze and compare the motor abilities of senior and junior male volleyball players from the national team, providing empirical evidence of differences in explosive lower limb strength, upper body strength, coordination, flexibility, and trunk endurance. The results confirm that senior players exhibit significantly higher explosive and upper body strength, while junior players show greater intra-group variability in motor skills. The research advances the understanding of athletic motor development during the transition from junior to senior levels, highlighting the influence of physiological maturity, training experience, and individual characteristics. The findings support the design of targeted and individualized training programs to optimize the development of key motor abilities and reduce intra-group variability among younger athletes. Furthermore, this study contributes to sport science by demonstrating the reliability of standardized, sport-specific tests in assessing motor abilities, providing a foundation for future research linking physical capacities to volleyball performance and the long-term development of competitive national teams in Bosnia and Herzegovina.

PAVLOVIC, R.; KOZINA, Z.; SAVIC, V.; BADAU, D.; RADULOVIC, N. & NIKOLIC, S. Desarrollo motor en jugadores de voleibol: Estudio comparativo de miembros sénior y júnior de la selección nacional de voleibol de Bosnia y Herzegovina. *Int. J. Morphol., 44(2)*:526-535, 2026.

RESUMEN: Las habilidades motoras, incluyendo la fuerza explosiva de los miembros inferiores y superiores, la coordinación,

la flexibilidad y la resistencia, son fundamentales para el rendimiento en voleibol. Evaluar las diferencias entre jugadores senior y junior permite optimizar los programas de entrenamiento y el desarrollo específico de habilidades motoras concretas. Este estudio examinaó las diferencias en las habilidades motoras entre jugadores senior y junior de voleibol masculino de la selección nacional de Bosnia y Herzegovina. Un total de 29 jugadores de voleibol masculinos sanos participaron, divididos en seniors (n=13; altura corporal = 194,77±7,01cm; peso corporal = 92,92±7,02 kg) y junior (n=16; altura corporal=197,06±4,65 cm; peso corporal=83,19±5,15 kg). Las habilidades motoras se evaluaron mediante pruebas estandarizadas: altura de salto de bloqueo y remate, salto de longitud sin impulso, fuerza de agarre de la mano dominante y no dominante, lanzamiento de balón medicinal de 3 kg, golpeteo de manos, flexibilidad de sentarse y alcanzar, y resistencia del tronco de sentarse a ponerse de pie. Se calcularon estadísticas descriptivas (media±DE, coeficiente de variación, asimetría, curtosis) y se utilizaron pruebas t independientes con la prueba de Levene para la igualdad de varianzas para comparar los grupos. La significación se estableció en $p<0,05$; $p<0,01$. Los jugadores senior superaron a los junior en fuerza explosiva de los miembros inferiores y la parte superior del cuerpo: salto de longitud de pie (269,00±19,38 cm frente a 253,50±15,34 cm; t=2,406, p=0,028), agarre de la mano dominante (52,62±7,63 kg frente a 40,75±8,26 kg; t=3,979, $p<0,001$), agarre de la mano no dominante (42,15±5,00 kg frente a 31,88±6,83 kg; t=4,524, $p<0,001$) y lanzamiento de balón medicinal de 3 kg (10,17±0,76 m frente a 8,22±0,73 m; t=7,033, $p<0,001$). Las diferencias en la altura del salto de bloqueo, la altura del salto de remate, la coordinación de manos, la flexibilidad y la resistencia del tronco no fueron estadísticamente significativas, aunque los junior mostraron mayor variabilidad en flexibilidad y fuerza de agarre. Los jugadores de voleibol senior demuestran una fuerza explosiva y una potencia del tren superior, mientras que los junior exhiben mayor heterogeneidad en las habilidades motrices. Estos hallazgos resaltan la necesidad de programas de entrenamiento individualizados y específicos para los atletas más jóvenes con el fin de optimizar el desarrollo motor y reducir la variabilidad intragrupal.

PALABRAS CLAVE: Habilidades motrices; Fuerza explosiva; Fuerza de agarre; Coordinación; Flexibilidad; Resistencia.

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