

The effect of combined core training intervention on ball throwing velocity and jump performance in competitive young female handball players

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Abstract

Background and Study Aim Handball is a dynamic team sport that requires a combination of technical, tactical, and physical abilities. Among the key physical components, throwing velocity and vertical jump performance are essential for successful gameplay. These skills rely not only on upper and lower limb strength but also on core muscle function. The aim of this study is to investigate the impact of a combined core training intervention on ball throwing velocity and vertical jump performance in young competitive female handball players.

Material and Methods A total of 28 young female handball players ($\bar{x} = 17.21 \pm 0.74$ years, 169 ± 5 cm body height, 62.07 ± 7.43 kg body weight) participated in the study. They were divided into an experimental group (EG = 14) and a control group (CG = 14). Both groups underwent a pretest to assess ball throwing velocity and vertical jump performance. After the initial measurements, the CG followed a standard training regimen. The EG completed an intervention program comprising six combined core exercises, performed three times per week for eight weeks. The same measurements were repeated after the program. A 2x2 repeated measures ANOVA was used to determine differences between EG and CG. The main effects of time (pretest and posttest), group, and the time*group interaction were evaluated.

Results No changes were observed in the ball throwing velocity or jump performance of the CG between pretest and posttest. However, significant improvements were found in the EG for both ball throwing velocity and vertical jump performance ($F = 47.467$, $p < .001$, $\eta^2 = .646$).

Conclusions Designing core training programs in a sport-specific manner plays a significant role in developing athletes who require both general and specialized training.

Keywords: handball, core training, ball throwing velocity, vertical jumping

Introduction

Handball is a high-intensity team sport that demands well-developed physical, technical, and tactical abilities to achieve optimal performance. Among the physical requirements, the ability to execute powerful throws and high vertical jumps is critical for success in both offensive and defensive actions. These motor skills are influenced by multiple physiological factors, including the strength and coordination of the core muscles, which serve as a vital link between the upper and lower body during dynamic movements.

Handball is one of the most popular team sports, requiring a wide variety of movements, such as jumps, accelerations, changes of direction, and passes, which are the most frequently performed actions [1, 2]. In addition to technical and tactical skills, anthropometric characteristics and physical performance play a crucial role in success [3, 4].

Handball players must extensively use both their upper and lower extremities during the game. The lower extremities are heavily involved in movements like running, jumping, and leaping, while the upper extremities are essential for force- and skill-demanding actions such as shooting, catching, pushing, blocking, and goal shooting [5].

The jump shot is the most frequently employed shooting technique in team handball, accounting for 73–75% of all shots in a competitive game [6]. To counter these shots, two common defensive strategies are used: blocking the ball and collaborating with the goalkeeper to reduce the opponent's success rate. Both strategies require defenders to perform vertical jumps. Therefore, vertical jumps are a critical element in both offensive and defensive technical-tactical actions.

Numerous studies have reported that optimizing force production and transmission through good core stability enhances vertical jump performance and reduces the risk of sport-related injuries [7, 8]. However, a study by Prieske et al. [9] on a

group of soccer players found that core strength training interventions led to statistically significant improvements in sprint times and kicking performance, but not in jump height.

One of the key performance factors in handball is shooting performance, as the winning team is always the one that scores the most goals [10]. Players aim to increase their scoring opportunities by attempting as many shots as possible, most of which are overhead throws [11]. Over the course of a season, each handball player performs at least 48,000 throwing actions, with shot speeds reaching up to 130 km/h [12]. The overhead throw is a complex, full-body movement that requires precise coordination of body segments. It also demands mobility, as well as the stability, strength, and power of the pelvis, spine, and core muscles [13, 14]. A review of the literature reveals the use of various core training designs aimed at improving spinal stabilization. One controlled study on spinal stabilization training reported that interventions consisting of static core exercises led to slight improvements in throwing velocity [15], while another study found contradictory results [16].

Research on the effects of spinal stabilization exercises using sling suspension systems on ball-throwing velocity has shown significant effects in one study [17], but no significant effects in another [18]. There is sufficient evidence demonstrating the positive effects of dynamic exercises using medicine balls and/or resistance bands on ball-throwing velocity [19, 20]. The differing results in studies investigating the impact of core training on throwing velocity may be attributed to the diverse sample groups and training designs employed. These include: (1) core training for shoulder stabilization, (2) core training with sling suspension, and (3) plyometric and resistance training with medicine balls.

Analysis of research findings has shown that core training can influence both vertical jump performance and ball-throwing velocity, although the outcomes vary depending on the type and structure of the training interventions. Researchers emphasize that the effectiveness of core training is closely linked to the integration of dynamic, sport-specific movements that reflect actual game demands. Given the complexity of motor skills in handball and the variety of training methods applied, further examination of targeted core training programs remains important for optimizing key performance indicators in young athletes.

The aim of this study is to investigate the impact of a combined core training intervention on ball throwing velocity and vertical jump performance in young competitive female handball players.

Materials and Methods

Participants

A total of 28 licensed female athletes who participated in the Turkish Handball Federation's youth league were randomly recruited from two different teams. The inclusion criteria required that all participants be healthy handball players with at least two years of continuous training experience and regular team participation. Exclusion criteria included a history of musculoskeletal injuries within the last six months, current participation in other training studies, or any known medical condition affecting neuromuscular performance.

These athletes were randomly assigned to the experimental group (EG, $n = 14$) or the control group (CG, $n = 14$) using a computerized random number generator. The required sample size ($n = 28$) had been calculated using G*Power software with a significance level of 0.05, power of 0.80, and an effect size of 1.00. Allocation concealment was ensured through sealed, opaque envelopes prepared by a researcher not involved in the intervention or data analysis.

Ethical approval for the study was obtained from the Ethics Committee of the Institute of Health Sciences at Marmara University. The average age of participants was 17.21 ± 0.74 years (EG: 17.28 ± 0.53 years; CG: 17.14 ± 0.94 years). Participants were informed about the tests and training programs beforehand. For athletes under 18 years old, parental consent was obtained. Participants who were 18 years old provided written consent themselves.

Research Design

This study was conducted as a randomized trial with a true experimental design using a pretest–posttest control group model.

One week before the intervention, all participants underwent pretests to assess throwing ball velocity and vertical jump performance. The experimental group ($n = 14$) participated in an additional 8-week core training program. The sessions lasted 30 minutes and were held three times a week. The control group ($n = 14$) continued with their regular handball training. One week after the 8-week intervention, posttests were conducted to reassess throwing ball velocity and vertical jump performance.

The experimental group performed core training between February and April, with three sessions per week lasting 30 minutes each. The control group continued traditional handball training with the same frequency. After their warm-up, athletes in the experimental group followed a six-exercise core training program. The intervention was designed specifically for handball. It began with floor-based spinal stabilization exercises and progressively included more dynamic, multidirectional

movements using balance and resistance equipment (e.g., medicine balls). Each exercise was followed by a 60-second rest, and a 120-second rest was provided between sets.

The structure of the training protocol reflects a progressive design. It begins with low-complexity, floor-based stabilization exercises and evolves into more demanding, sport-specific tasks. By aligning exercise intensity, directionality, and movement patterns with real handball gameplay actions, the program aims to improve performance transfer and neural adaptations. This approach distinguishes it from previous unidimensional or single-phase core training models.

Participant adherence was recorded throughout the study. No participant missed more than one session, ensuring that all met the inclusion criteria for analysis. The core stability and strength training program are shown in Figure 1.

Participants were provided with detailed guidance on pre- and post-training nutrition. Additionally, they were advised to avoid high-intensity physical activities and to ensure proper rest on training days to optimize recovery and performance.

Before starting the pretests, all participants' height (cm) and body weight (kg) were measured using a Seca-brand scale, and their Body Mass Index (BMI) was calculated. In both the pre- and posttests, vertical jump height was measured using a Microgate Witty model jump mat. To better assess the contribution of the core region to the kinetic

chain during jumping, the test was performed with an arm swing. Participants were instructed to maintain a 90-degree knee angle during the jump. Two trials were conducted, and the best result was recorded. A rest period of approximately 2 minutes was provided between attempts.

The vertical jump test was conducted after a 15-minute active warm-up, which included 5 minutes of running, 5 minutes of short sprints, and 5 minutes of dynamic stretching and mobility exercises.

The accurate shot velocity test measured the ball's maximum speed (km/h) during a throw using a Sport Radar Gunn (Astro Products, CA) radar gun, positioned 2 meters behind and 1 meter to the right of the athlete. The vertical jump was assessed using the Just Jump System, a contact-based device widely used in sports performance testing. Both instruments have been shown to demonstrate high test-retest reliability (ICC > 0.90) in studies by Butcher et al. [13] and Ozmen et al. [16], and are recognized as valid tools for evaluating explosive lower-limb power and throwing velocity in youth athletes. Additionally, the Sport Radar Gun has been effectively used to assess throwing performance in core training studies involving handball players, as reported by Manchado et al. [15] and Palmer et al. [19].

Participants were instructed to hold a size 2 ball (325 grams, approved by the International Handball Federation) in their dominant hand and perform a standing throw within 3 seconds. They were allowed

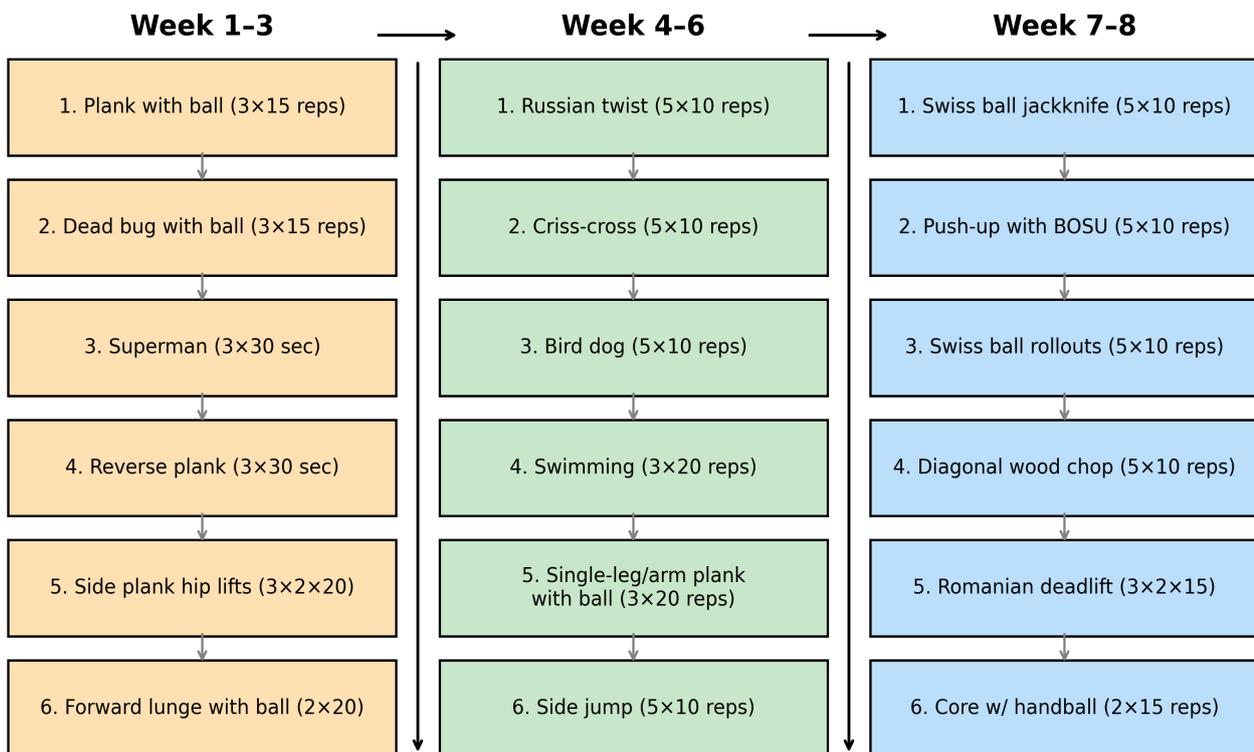


Figure 1. Core training program. Rest intervals: 60 seconds between sets; 120 seconds between exercises.

to take up to three steps from the 9-meter to the 7-meter free-throw line. A 3-minute rest interval was provided between each attempt.

To indicate the target area, a 60 × 60 cm iron frame was placed in the upper and lower corners of the goal. Among the three goal-scoring attempts, the shot with the highest recorded speed was used for evaluation.

Statistical Analysis

SPSS 22.0 (SPSS Inc., Chicago, IL) software was used to analyze the data collected in this study and to ensure the reliability of the analysis process. Skewness, kurtosis, and Shapiro–Wilk values were examined to assess normality assumptions, and it was determined that these assumptions were met. For each variable, the mean, standard deviation, percentage change, mean difference, and effect size were calculated. A 2 × 2 repeated measures ANOVA was used to determine the differences between the experimental and control groups. In this analysis, the main effects of time (pretest and posttest), group (experimental and control), and the time × group interaction were evaluated. The partial eta-squared (η^2) values obtained from the two-way ANOVA results were interpreted as follows: $0.01 \leq \eta^2 < 0.06$ indicates a small effect size; $0.06 \leq \eta^2 < 0.14$ indicates a medium effect size; and $\eta^2 \geq 0.14$ indicates a large effect size [21]. No missing data were

observed in this study; therefore, no imputation or listwise deletion techniques were necessary.

Results

Descriptive statistics regarding the age and physical characteristics of the experimental group (EG) and the control group (CG) are presented in Table 1.

There were no significant baseline differences between the groups in terms of age, body weight, height, or BMI. None of the variables recorded at baseline showed statistically significant differences between the groups ($p > .05$).

The pre- and post-performance evaluations (vertical jump and ball throwing velocity) of the experimental group (EG) and the control group (CG) after the eight-week training program are presented in Table 2 and Table 3.

The data presented in Table 2 show that, following the 8-week combined core training intervention, the experimental group (EG) exhibited an 11.2% improvement in vertical jump performance. In contrast, the control group (CG) demonstrated a modest 3.8% increase despite not undergoing any intervention. The results of the 2 × 2 repeated measures ANOVA on vertical jump performance showed a significant difference between the measurements ($F = 47.467, p < .001, \eta^2 = .646$). This finding indicates that the 8-week intervention

Table 1. Characteristics of Participants (EG - n=14; CG - n=14)

Parameter	Group	Mean	Std. Dev	Std. Error
Age (years)	EG	17.29	0.726	0.194
	CG	17.14	0.770	0.206
Height (cm)	EG	168.60	6.10	1.60
	CG	169.80	4.40	1.20
Weight (kg)	EG	62.50	8.272	2.211
	CG	61.64	6.767	1.808
BMI (kg/m ²)	EG	21.94	1.990	0.532
	CG	21.34	1.746	0.467

Note: EG = Experimental Group; CG = Control Group; BMI = Body Mass Index.

Table 2. Pre- and Posttest Results of Vertical Jump – Repeated Measures 2 × 2 ANOVA

Vertical Jump (cm)	ANOVA (Time)				ANOVA (Group)				ANOVA (Time * Group)				Between Groups Difference			
	Group	Mean+SD	Square Mean	F	p	η^2	Square Mean	F	p	η^2	Square Mean	F	p	η^2	p	η^2
Pretest	EG	30.83±2.97														
	CG	26.00±3.96	65.794	47.467	.000	.646	507.004	21.688	.000	.455	19.802	14.286	.001	.355	.001	.528
Posttest	EG	34.19±2.41			*	**			*	**			*	**	*	**
	CG	26.99±4.38														

Note: EG: Experimental Group, CG: Control Group, * $p < .05$, ** large effect size = $\eta^2 \geq .14$.

Table 3. Pre- and Posttest Results of Throwing Velocity – Repeated Measures 2 × 2 ANOVA

Vertical Jump (cm)	ANOVA (Time)					ANOVA (Group)					ANOVA (Time *Group)					Between Groups Difference (Posttest)	
	Group	Mean+SD	Square Mean	F	p	η^2	Square Mean	F	p	η^2	Square Mean	F	p	η^2	p	η^2	
Pretest	EG	63.92±5.76	350.00	66.25	.000	.718	216.07	2.096	.06	.075	248.64	47.07	.000*	.644	.005	.270	
	CG	64.21±9.32															
Posttest	EG	73.14±4.62	350.00	66.25	.000	.718	216.07	2.096	.06	.075	248.64	47.07	.000*	.644	.005	.270	
	CG	65.00±8.67															

Note: EG: Experimental Group, CG: Control Group, *p < .05, ** large effect size = $\eta^2 \geq .14$.

program, or the time factor, led to a general improvement in vertical jump performance (11.2%). The effect size ($\eta^2 \geq .14$) reflects a large effect. There was also a significant difference between the groups in terms of overall performance levels (F = 21.688, p < .001, $\eta^2 = .455$). The overall performance of the EG was significantly higher than that of the CG. A significant time × group interaction was observed (F = 14.286, p = .001, $\eta^2 = .355$), suggesting that the changes in measurements differed between the EG and CG. This result confirms that the training effect was more pronounced in the EG. Posttest analysis revealed a statistically significant difference between the groups (p = .001, $\eta^2 = .528$). The posttest mean score for the EG (34.19 ± 2.41) was significantly higher than that of the CG (26.99 ± 4.38).

The data presented in Table 3 show the performance outcomes for ball throwing velocity. Following the 8-week combined core training intervention, the experimental group (EG) demonstrated a 14.7% improvement in overhead ball throwing performance. In contrast, the control group (CG) exhibited a modest 1.6% increase without any intervention. The findings from the 2 × 2 repeated measures ANOVA on throwing velocity revealed a significant difference in measurements (F = 66.251, p < .001, $\eta^2 = .718$). This result suggests that the 8-week intervention program (i.e., the time factor) significantly enhanced overall throwing performance. The effect size ($\eta^2 = .718$) indicates a very large effect. Conversely, no significant difference was found between the groups in terms of overall performance levels (F = 2.096, p = .160, $\eta^2 = .075$). This outcome implies that there were no significant baseline disparities between the EG and CG in overall performance. A significant time × group interaction was observed (F = 47.065, p < .001, $\eta^2 = .644$). This finding indicates that the magnitude of improvement varied between the groups, with the EG showing a more pronounced change in throwing velocity after training. Analysis of the posttest results revealed a statistically significant difference between the EG and CG (p = .005, $\eta^2 = .270$). The posttest mean score of the EG (73.14 ± 4.62) was significantly higher than that of the CG (65.00 ± 8.67).

Discussion

The aim of this study was to investigate the impact of a combined core training intervention on ball throwing velocity and vertical jump performance in young competitive female handball players. The results showed that the experimental group significantly improved both vertical jump height (by 11.2%) and ball throwing velocity (by 14.7%) after the 8-week intervention. In contrast, the control group demonstrated only minimal improvements. Statistical analysis confirmed that these changes were significant, with large effect sizes observed for both performance indicators.

While previous studies have investigated the impact of core training on athletic performance, many have relied on single-phase protocols or generalized exercise regimens lacking sport-specific progression [14, 15, 17]. The current study extends this body of work by implementing a structured, multi-phase intervention that combines foundational stabilization exercises with dynamic drills tailored to the demands of handball, incorporating unstable surfaces and resistance equipment [16, 18, 19]. Moreover, the focus on competitive female handball players aged 16–18 addresses a demographic that remains underrepresented in existing research, which has predominantly examined male or mixed-gender samples [15, 17, 20]. This combination of methodological rigor and population specificity enhances the relevance and potential applicability of the findings within youth female athletic development contexts.

Characteristics of the participants

The female handball players participating in the study had a mean age of 17.21 ± 0.74 years, an average height of 169 ± 5 cm, and a body weight of 62.07 ± 7.43 kg. These physical characteristics are similar to those reported in a recent study on female handball players (19.5 ± 1.4 years, 165 ± 5 cm, 61.7 ± 9.3 kg) [22]. In another study conducted across four Asian countries, the average height and body weight of female handball players were also comparable (170.8 ± 0.068 cm and 64.6 ± 7.7 kg) [23].

Based on these findings, the physical characteristics of the female handball players in this study can be considered close to the average for this population.

Effect of Core Training on Vertical Jump Performance

The findings of this study support the assumption that a combined core training intervention can significantly improve jumping performance in female handball players ($p < .001$). Recent studies analyzing the impact of core training on jump performance have demonstrated medium to large effects in favor of core training [24, 25, 26, 27]. In this study, the effect size was particularly large ($\eta^2 \geq .528$).

Countermovement jump (CMJ) tests are typically used to measure jump performance with the hands placed on the hips [28, 29]. However, this approach does not reflect the natural jumping technique used by handball players during training and matches. When arm movement is incorporated into the jump, the core muscles are more actively engaged as part of the kinetic chain. The use of arm-involved jumping tests in this study likely contributed positively to the athletes' performance outcomes.

In addition, the core exercises in the training program closely mimicked the intended sport-specific movements, maximizing the transfer training effect [30, 31]. The improvement in jumping performance may also be attributed to the program's design, which enhanced core strength and, in turn, improved the ability to control trunk position and movement over the pelvis. As suggested by previous researchers, improved neuromuscular function optimizes the production, transfer, and control of force and movement in integrated athletic kinetic chain activities [32].

Another potential explanation is that nearly all exercises in the program involved isometric or dynamic contractions of the hip extensor muscles. This could serve as an effective stimulus for increasing strength in these muscles, thereby positively transferring to jump performance.

Effect of Core Training on Accurate Throwing Velocity

The findings indicate that the combined core exercise intervention significantly improved the throwing velocity of the experimental group. A stronger and more stable lumbo-pelvic-hip complex likely contributes to greater rotational velocity during multi-segmental movements. In addition, high-velocity, multiplanar resistance exercises that replicate overhead throwing motions, such as those using a medicine ball, appear to promote training adaptations that are transferable to throwing performance [15, 23].

This improvement may also depend on specific characteristics of the training intervention, including exercise type, intensity, structure, and the role of motor learning. Therefore, training programs

should be aligned with the movement patterns required for effective handball throwing [33].

The findings of this study are consistent with those of Saeterbakken et al. [17] and Stary et al. [34], who reported improvements in throwing velocity within experimental groups following unstable core training, although between-group differences were not statistically significant. Other studies have shown that endurance training can also lead to increased throwing speed without negatively affecting accuracy [35].

The extent of improvement may also depend on training frequency and duration. Wagner et al. [36] noted that long-term sport-specific training might reduce the impact of additional training performed only twice per week. For more substantial gains in strength and velocity, increasing the frequency to three or four additional sessions per week is recommended. According to Behm [37], neural adaptations tend to dominate during the initial stages of resistance training, typically within the first eight to twelve weeks. As a result, the positive transfer from improved lateral core stability to throwing performance may require a similar duration of intervention.

The core training protocol used in this study produced a large effect size, which is comparable to the results reported in previous studies involving dynamic core exercises that included medicine balls and resistance-based training [17, 19].

The results of this study confirm the effectiveness of a combined core training program in enhancing both vertical jump performance and ball throwing velocity in young female handball players. The findings highlight the importance of targeting core musculature through dynamic, sport-specific exercises to improve key physical abilities directly related to handball performance. These results align with previous findings that demonstrate the benefits of core strength training for explosive movements and throwing actions in youth athletes [15, 16, 19].

Taken together, these findings underscore the novelty of combining progressive core training with performance testing that mirrors actual gameplay in a specific athletic population. The use of arm-involved jump assessments and multi-planar throwing tests enhances ecological validity and increases the practical applicability of the outcomes for coaches and trainers. While earlier studies have evaluated the effects of unstable or sling-based core training [17, 18], the present study's design expands on this by integrating both stable and dynamic core modalities in conjunction with sport-specific movement patterns.

Compared to earlier studies that employed either static or general dynamic core training protocols [14, 15], the current intervention is distinguished by its integration of multiple functional components into a cohesive, handball-specific regimen. The inclusion

of test protocols involving arm motion and game-like throwing mechanics further strengthens the transferability of improvements to real competitive scenarios, supporting the application of such training approaches in youth female handball development programs [10, 11, 20].

Limitations and Future Directions

This study has certain limitations that should be acknowledged. The sample size was relatively small and limited to licensed female handball players from two teams within a single national league, which may restrict the generalizability of the findings. Additionally, only short-term effects were evaluated, without follow-up assessments to determine the long-term sustainability of improvements. Future research should aim to evaluate the long-term effects of core strength training on the efficiency of jumping and ball throwing velocity by extending follow-up durations and conducting comparative analyses of various training techniques and age-related variables. Studies involving larger and more diverse populations across different age groups, genders, and competitive levels are also recommended. Furthermore, the inclusion of biomechanical and neuromuscular assessments

could offer deeper insights into the underlying mechanisms of performance enhancement.

Conclusions

Core training is considered a critical component for enhancing sports performance. It is acknowledged that the effects of such interventions on ball speed may vary among athletes participating in different sports. Structuring core training programs in a sport-specific manner plays a significant role in the development of athletes who require both general and specialized training. In this context, it is essential for coaches to closely observe athlete movements, identify which components effectively enhance specific skills, and determine which areas require additional focus.

Conflicts of Interest

The authors declare no relevant financial or non-financial conflicts of interest.

Data Availability

The dataset generated during the current study is available from the corresponding author upon reasonable request.

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