

Effects of a six-month technical–tactical training program on jump performance and lower-limb muscular symmetry in young football players

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Published online: May 31, 2026

Accepted for publication: May 15, 2026

DOI:10.7752/jpes.2026.05086

Abstract:

Explosive lower-limb power and inter-limb muscular symmetry are important factors in athletic performance and injury prevention in youth football. This study investigated the effects of a six-month technical–tactical training program on vertical jump height and lower-limb muscular symmetry in male football players aged 12–13 years. Twenty-three male youth football players (age: 12.71 ± 0.27 years) from the under-13 squad of Olympia Football Club (Sofia, Bulgaria) participated in two assessment sessions: pre-intervention (January 2025) and post-intervention (May 2025). Vertical jump height was assessed using the Squat Jump and Countermovement Jump tests with the OptoJump Next photoelectric timing system (Microgate, Italy). Unilateral lower-limb strength and inter-limb asymmetry were evaluated using the Kineo electromechanical training system (Globus, Italy). Asymmetry was calculated as the absolute percentage difference between the stronger and weaker limb. The Wilcoxon signed-rank test and Cohen's *d* effect size were used for the statistical analysis. No statistically significant changes were observed in Squat Jump ($p = 0.847$) or Countermovement Jump height ($p = 0.851$) during the intervention period, and both showed negligible effect sizes. In contrast, unilateral right-leg strength increased significantly ($p = 0.002$) with a large effect size, whereas left-leg strength showed a large effect size without reaching statistical significance. Mean inter-limb asymmetry increased substantially from 7.4% before the intervention to 13.2% after the intervention, exceeding the 10%–15% injury-risk threshold reported in the literature. One participant reached an asymmetry value of 54.4%. These findings suggest that a technical–tactical training program of this type is not sufficient to improve bilateral explosive power and may contribute to the development of clinically relevant inter-limb asymmetries. Dedicated unilateral strength training and systematic asymmetry monitoring are recommended in youth football conditioning programs, particularly during the critical developmental stage of early adolescence.

Keywords: explosive strength, inter-limb asymmetry, OptoJump, Kineo, unilateral strength, adolescent athletes

Introduction

Football is a dynamic, multidirectional sport in which technical execution, tactical decision-making, and physical performance constantly interact during training and competition. Even at the youth level, players must accelerate, decelerate, jump, land, change direction, strike the ball, and perform repeated unilateral actions under time and space pressure. These actions place considerable demands on the neuromuscular system, making lower-limb explosive power and muscular symmetry important components of both performance development and injury prevention. In modern football, high-speed movements and changes of direction are no longer isolated physical qualities but decisive match-related behaviors that influence attacking transitions, defensive recovery, duels, pressing actions, and ball-winning situations (Gutsev, 2026). Therefore, the development and monitoring of lower-limb power in young players should be considered an essential component of long-term football preparation.

The importance of explosive lower-limb performance is well recognized in football. Vertical jump ability, sprint acceleration, change-of-direction capacity, and unilateral force production are closely linked to many decisive actions in the game, including aerial duels, first-step acceleration, tackling, shooting, and rapid transitions between offensive and defensive phases. Previous research has shown that strength and power variables are key determinants of explosive football performance. Pérez-Contreras et al. (2025), for example, demonstrated that countermovement jump height and lower-limb strength variables were significantly associated with sprint performance in professional football players, confirming the practical value of neuromuscular testing for performance profiling. Likewise, lower-limb explosive strength has been associated with speed and coordination in school-age populations, underscoring the importance of early monitoring and development of these qualities during childhood and adolescence (Çaushi & Ibrahimi, 2025).

The ages of 12–13 represent a particularly important developmental stage in youth football. During this period, players are approaching or entering a phase of rapid biological maturation, when changes in body size, coordination, muscle strength, and neuromuscular control may occur at different rates. This creates both

opportunities and risks. On the one hand, this period offers a favorable window for developing fundamental strength, coordination, jumping ability, and movement efficiency. Conversely, if the training process depends only on technical–tactical content without structured physical preparation, young players may not develop sufficient bilateral explosive power or may develop growing differences between their limbs. This is particularly relevant in football, where repeated kicking, cutting, planting, and turning actions are often performed preferentially with or from one limb.

Inter-limb asymmetry has attracted increasing attention in football science because it may affect both performance and injury risk. Although some degree of asymmetry is expected in football owing to the sport's unilateral nature, excessive differences between the limbs may indicate an imbalance in force production, neuromuscular control, or movement strategy. Such imbalances can be especially problematic in young athletes whose musculoskeletal and neuromuscular systems are still developing. Recent evidence from elite youth football shows that lower-limb injuries are common and may negatively affect both performance and long-term player development. Schulz et al. (2025) reported that youth football players face a high risk of lower-limb injuries and found that injury frequency increased significantly from 13 years of age, highlighting the need for systematic injury-prevention strategies in academy environments. These findings are highly relevant to this study because they emphasize the importance of accurately monitoring lower-limb status at the developmental age examined in our sample.

Despite the growing body of evidence on physical performance in youth football, a considerable practical issue remains. Many youth football programs, particularly during early adolescence, are still dominated by technical drills, tactical games, small-sided games, and general conditioning exercises, while structured bilateral and unilateral strength training is often limited or absent. Although this approach may be appropriate for developing football-specific skills, it may not provide sufficient progressive overload to enhance explosive lower-limb power or to manage the development of inter-limb asymmetry. This creates a gap between the physical demands of modern football and the actual content of some youth training programs. For coaches and sports scientists, the key question is not only whether young players improve technically and tactically, but also whether their neuromuscular profile develops in a balanced and safe way.

Vertical jump testing offers a practical way to evaluate lower-limb explosive power in young football players. The Squat Jump mainly reflects concentric force production, whereas the Countermovement Jump also involves the stretch-shortening cycle and is therefore widely used to assess elastic-explosive capacity. However, bilateral jump tests alone may not identify meaningful between-limb differences. A player may maintain similar bilateral jump performance while developing unilateral strength differences that remain hidden unless each limb is assessed separately. For this reason, combining OptoJump-based vertical jump testing with unilateral strength assessment using the Kineo Training System provides a more complete picture of lower-limb neuromuscular status. From a practical standpoint, the issue addressed in this study has direct implications for youth football training. If a technical–tactical program enhances football-specific skills but does not improve jump performance or lead to greater muscular asymmetry, coaches may need to reconsider how strength, plyometric, and unilateral exercises are incorporated into the weekly microcycle. Conversely, if systematic monitoring identifies players with increasing asymmetry, individualized corrective strategies can be implemented before the imbalance becomes more pronounced. This is especially important in academy football, where the long-term goal is not only short-term match performance but also safe athletic development and preparation for higher levels of competition.

Problem Statement

Research was needed because longitudinal evidence is limited on how a regular technical–tactical football training program affects both bilateral explosive power and unilateral lower-limb muscular symmetry in 12–13-year-old football players. Although previous studies have examined jump performance, sprint ability, injury risk, or inter-limb asymmetry separately, fewer have analyzed these outcomes together within the same youth football training context. Therefore, the context of this work is the everyday academy training environment, in which young players often complete several technical–tactical sessions per week but may not engage in dedicated strength or plyometric training. This creates a practical and scientific need to determine whether such a program is sufficient to promote positive neuromuscular adaptations or whether it may leave important physical qualities underdeveloped.

Approach

To address this problem, this study used a pre–post longitudinal design involving a group of male under-13 football players. The players were assessed before and after a structured football training period using two complementary methods. Bilateral explosive power was evaluated through Squat Jump and Countermovement Jump tests using the OptoJump Next photoelectric system. Unilateral lower-limb strength and inter-limb asymmetry were assessed using the Kineo Training System, which enabled separate evaluation of the right and left limbs. This combined approach allowed us to examine not only whether jump performance changed over the training period, but also whether unilateral strength development remained balanced between limbs. Therefore, this study aimed to assess the effects of a technical–tactical football training program on vertical jump performance and lower-limb muscular symmetry in 12–13-year-old male football players. We hypothesized that the program would enhance Squat Jump and Countermovement Jump performance and reduce

inter-limb asymmetry. The findings are expected to offer practical guidance for coaches, conditioning specialists, and youth academy staff regarding the need for systematic neuromuscular monitoring and the potential integration of structured unilateral strength and plyometric training into youth football programs.

Materials and Methods

Participants

Twenty-three male football players from the under-13 squad of Olympia Football Club (Sofia, Bulgaria) participated in the study ($n = 23$; age: 12.71 ± 0.27 years; range: 12.1–13.1 years). Only participants with complete data from both testing sessions were included in the final analysis. All participants had been free of any musculoskeletal injury for at least two months before each testing session. This study was performed in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from a parent or legal guardian of each participant prior to enrollment.

Test Protocol and Procedures

Testing was performed at two time points: pre-intervention (30 January 2025) and post-intervention (26 May 2025), separated by six months of structured technical–tactical training. Both sessions took place indoors at a controlled ambient temperature of 19°C and began at 16:30 to minimize diurnal variation in neuromuscular performance. All participants completed a standardized 12-minute warm-up consisting of light jogging, dynamic mobility drills, and progressive activation exercises. The testing sequence was identical in both sessions: the Kineo unilateral strength assessment was performed first, followed by the OptoJump jump tests.

Instruments and Measurements

The Squat Jump assesses pure concentric explosive power without a pre-stretch component, whereas the Countermovement Jump also quantifies the contribution of the stretch-shortening cycle. Both tests were recorded using the OptoJump Next photoelectric timing system (Microgate, Italy), which calculates jump height based on flight time. Inter-limb asymmetry was assessed through a unilateral leg press on the Kineo Training System (Globus, Italy), an electromechanical device that provides real-time concentric and eccentric force feedback, along with peak force output for each limb independently (Spudić et al., 2020; McNeill et al., 2021). Inter-limb asymmetry was calculated using the following formula:

$$\text{Asymmetry (\%)} = \frac{|\text{Strong} - \text{Weak}|}{\text{Strong}} \times 100$$

where "Strong" refers to the better-performing limb and "Weak" to the worse-performing limb at each assessment time point.

Training Program

The training intervention consisted of a six-week cyclical program implemented with the U13 group and repeated with minor variations throughout the six-month study period (approximately four complete cycles, January–May 2025). Participants trained three times per week, resulting in approximately 72 training sessions in total. Each six-week cycle was organized around four content categories applied in every session: technique, individual and group tactical principles, and conditioning. Weeks one to five focused primarily on attacking play, while week six was devoted to defensive organization.

The technical content developed systematically throughout the cycle: week one focused on ball dribbling and feinting in 1v1 situations; week two introduced ball reception, control, and passing; week three developed striking with the foot, including near-post, far-post, and long-distance shooting; week four emphasized receiving under pressure, combining with teammates, and heading; week five consolidated ball retention and positional switching; and week six introduced defensive actions, including tackling, pressing, and recovery runs. Group tactical work addressed positional principles such as playing behind the back line, pressing and possession, combination play, and small-sided game formats ranging from 2v1 to 4v3. The conditioning component included coordination and balance, speed and agility, injury prevention exercises, situational awareness, and acceleration work. No dedicated bilateral or unilateral strength training, plyometric program, or resistance training was included during the intervention period.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics v.26. Descriptive statistics (mean $\pm$ standard deviation, minimum, and maximum) were calculated for all variables at both time points. The Shapiro–Wilk test was used to assess the normality of distribution. Because several variables violated the normality assumption, the Wilcoxon signed-rank test was used for all pre–post comparisons. Effect sizes were calculated using Cohen's d and interpreted according to standard thresholds: small ($d \geq 0.2$), medium ($d \geq 0.5$), and large ($d \geq 0.8$). The significance level was set at $p < 0.05$ for all analyses.

Results

Table 1 shows descriptive statistics from the pre-intervention (January) assessment. Mean Countermovement Jump height (30.42 ± 2.38 cm) was slightly higher than Squat Jump height (29.14 ± 2.17 cm), reflecting the expected contribution of the elastic-reflex component. Kineo unilateral strength values were similar between limbs (left: 14.82 ± 4.27 kg; right: 14.56 ± 3.85 kg), and the mean inter-limb asymmetry was $7.40\% \pm 6.12\%$, with individual values reaching as high as 20.27%.

Table 1. Descriptive statistics — Pre-intervention (January 2025)

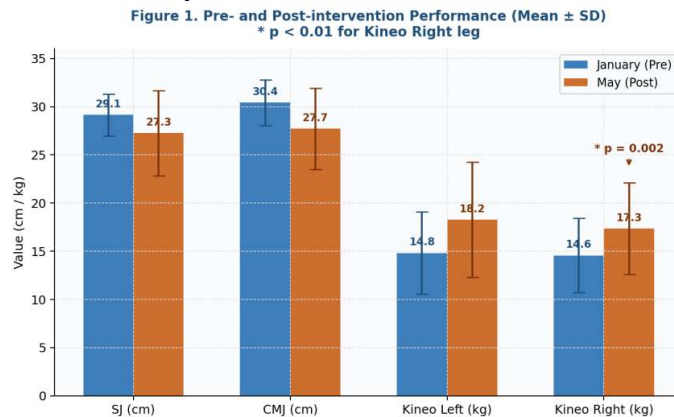
Variable	Mean	SD	Min	Max
Squat Jump (cm)	29.14	2.17	26.6	33.2
Countermovement Jump (cm)	30.42	2.38	27.2	35.6
Kineo Left (kg)	14.82	4.27	8.6	24.8
Kineo Right (kg)	14.56	3.85	9.8	23.1
Asymmetry (%)	7.40	6.12	0.0	20.27

Post-intervention (May) results are shown in Table 2. Mean Squat Jump height decreased slightly to 27.26 ± 4.42 cm, and Countermovement Jump decreased to 27.71 ± 4.20 cm. In contrast, Kineo unilateral strength values increased in both limbs (left: 18.25 ± 5.98 kg; right: 17.33 ± 4.75 kg). Mean inter-limb asymmetry increased substantially to $13.24\% \pm 13.34\%$, with one participant reaching an asymmetry value of 54.41%.

Table 2. Descriptive statistics — Post-intervention (May 2025)

Variable	Mean	SD	Min	Max
Squat Jump (cm)	27.26	4.42	19.9	34.7
Countermovement Jump (cm)	27.71	4.20	19.75	35.0
Kineo Left (kg)	18.25	5.98	13.1	33.6
Kineo Right (kg)	17.33	4.75	11.9	29.8
Asymmetry (%)	13.24	13.34	2.0	54.41

As shown in Figure 1, right-leg Kineo strength was the only variable to show a statistically significant improvement. The mean values for the Squat Jump and Countermovement Jump decreased slightly, while both Kineo limb values increased substantially.

**Figure 1. Pre- and post-intervention group performance (mean $\pm$ SD). * $p < 0.01$ for the Kineo right leg**

A comparative statistical analysis is summarized in Table 3. No statistically significant changes were observed in the Squat Jump ($p = 0.847$) or Countermovement Jump ($p = 0.851$), with negligible effect sizes ($d = 0.18$ and $d = 0.15$, respectively). Kineo right-leg strength showed a statistically significant increase ($p = 0.002$) with a large effect size ($d = 0.90$). Left-leg strength showed a similarly large effect size ($d = 0.97$) without reaching statistical significance. Inter-limb asymmetry increased with a medium effect size ($d = 0.41$), but the change was not statistically significant.

Table 3. Pre-post comparative analysis (Wilcoxon signed-rank test)

Variable	Test	Statistic	p-value	Cohen's d
Squat Jump (cm)	Wilcoxon	56.0	0.847	0.18 (small)
Countermovement Jump (cm)	Wilcoxon	49.5	0.851	0.15 (small)
Kineo Left (kg)	Wilcoxon	n/a	n.s.	0.97 (large)
Kineo Right (kg)	Wilcoxon	4.0	0.002 *	0.90 (large)
Asymmetry (%)	Wilcoxon	n/a	n.s.	0.41 (medium)

* $p < 0.01$; n.s. = not statistically significant; n/a = statistic not reported

Figure II shows the distribution of individual inter-limb asymmetry values before and after the training program. Most players moved into or above the 10%–15% injury-risk zone after the intervention, with substantial individual variability.

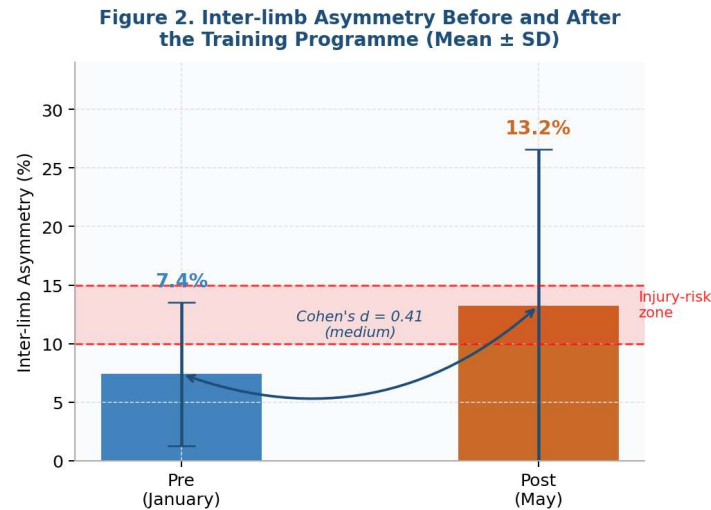


Figure II. Inter-limb asymmetry before and after the training program. The shaded band indicates the 10%–15% injury-risk threshold. Cohen's $d = 0.41$

Discussion

The main finding of this study was that a six-month technical and tactical football training program led to no statistically significant improvements in bilateral vertical jump performance, while at the same time producing a significant increase in unilateral right-leg strength and a clinically relevant increase in inter-limb muscular asymmetry. These results have important implications for the design of physical conditioning programs in youth football academies, particularly during the developmentally sensitive under-13 period.

The lack of significant change in Squat Jump or Countermovement Jump height after six months of training is consistent with evidence showing that technical–tactical football practice alone is not enough to stimulate meaningful neuromuscular adaptations in explosive power. França et al. (2021), publishing in the *Journal of Physical Education and Sport*, showed that explosive leg power in youth football players across a broad age range (12.9–21.7 years) was significantly predicted by strength-related variables, including handgrip force and lower-limb conditioning, highlighting that sport-specific technical training does not provide the progressive overload stimulus required for improvement in vertical jump performance. Similarly, Villaseca-Vicuña et al. (2021), also in the *Journal of Physical Education and Sport*, reported that Countermovement Jump performance varied significantly across youth age categories, with under-20 players clearly outperforming the under-15 and under-17 groups, reflecting the accumulation of targeted physical conditioning over the years rather than football practice volume alone.

The negligible effect sizes observed for both the Squat Jump ($d = 0.18$) and the Countermovement Jump ($d = 0.15$) further confirm that the training stimulus was insufficient to induce neuromuscular adaptation. These findings align with the meta-analytic evidence reported by Lesinski et al. (2016), who found that programs lacking structured plyometric or resistance training components resulted in negligible improvements in vertical jump performance among youth populations. The contrast with dedicated interventions is striking: Ramírez-Campillo et al. (2014) showed that a seven-week in-season plyometric program produced a 4.3% improvement in Countermovement Jump height in young football players of comparable age (13.2 ± 1.8 years), while Oliver et al. (2023) reported moderate-to-large effect sizes ($g = 0.73$ – 1.08) for improvements in vertical jump when dedicated strength or plyometric training was included in youth football training. The under-13 period represents a critical window of neuromuscular trainability (Lloyd & Oliver, 2012), and these data suggest this opportunity was not fully leveraged by the purely technical–tactical program.

Singh et al. (2024), in a *Journal of Physical Education and Sport* study of muscle activation patterns during the Squat Jump and Countermovement Jump in male and female soccer players, reported that bilateral jump tests produce complex and often asymmetric activation patterns across the lower limb and trunk muscles. Their finding that men show more pronounced inter-limb activation asymmetries than women during these tests supports the interpretation that bilateral explosive tasks may mask developing unilateral muscular imbalances that would not be detected without unilateral assessments. This mechanistic insight is especially relevant to this study, in which bilateral jump height remained statistically unchanged despite substantial increases in unilateral Kineo strength and a progressive increase in inter-limb asymmetry.

The significant improvement in right-leg unilateral Kineo strength ($p = 0.002$, $d = 0.90$) and the large but non-significant improvement in left-leg strength ($d = 0.97$) represent the most notable positive training

responses in this data. These large effect sizes suggest that six months of technical–tactical training led to meaningful increases in unilateral force production capacity, likely owing to the repeated unilateral loading demands of football-specific movements such as planting, kicking, and change-of-direction actions. However, the different rates of adaptation between limbs provide a plausible explanation for the simultaneous increase in inter-limb asymmetry, a pattern consistent with the findings of Śliwowski et al. (2024), who documented that junior players show greater inter-limb asymmetries than senior players, reflecting the cumulative effects of asymmetric sport-specific loading over developmental years.

The increase in mean inter-limb asymmetry from $7.40\% \pm 6.12\%$ before the intervention to $13.24\% \pm 13.34\%$ after the intervention is arguably the most concerning finding of this study. The post-intervention mean exceeded the widely cited 10%–15% injury-risk threshold, and one participant reached an asymmetry value of 54.41%. Michailidis et al. (2020), in a study published in the *Journal of Physical Education and Sport* that examined lower-limb asymmetries in under-10 and under-15 youth football players, reported that asymmetries in the single-leg countermovement jump were associated with slower performance on the 505 change-of-direction test ($p = 0.017$), and concluded that inter-limb differences exceeding 10% should be actively addressed through individualized strength and power programs. In this study, the group mean already reached this threshold after the intervention, with a substantial number of individuals clearly surpassing it.

The marked individual variability in post-intervention asymmetry values (standard deviation = 13.34%, range 2.0%–54.4%) warrants particular attention. Fort-Vanmeerhaeghe et al. (2020) showed that inter-limb asymmetries are associated with significant decrements in sprint and change-of-direction performance in youth elite team-sport athletes, emphasizing the importance of individual screening rather than reliance on group means. Ramírez-Campillo et al. (2024) further showed that an eight-week plyometric jump training program in prepubertal male football players of nearly identical age (12.7 ± 0.2 years) produced a significant reduction in inter-limb asymmetry ($d = 0.43$; decrease of 45.2%), confirming that targeted interventions can reverse the asymmetric trends observed in this study.

Taken together, the results suggest that a technically focused training program without specific bilateral and unilateral strength components is insufficient not only for developing explosive power in under-13 football players but may also actively contribute to the emergence of clinically relevant inter-limb asymmetries. The Kineo electromechanical system proved to be a sensitive tool for detecting between-limb differences that were not apparent in bilateral jump scores. Future studies should examine the effects of supplementary unilateral resistance training or plyometric programs added to the standard technical–tactical curriculum, with particular attention to individual asymmetry trajectories across the competitive season.

Several limitations should be noted. The lack of a control group restricts causal inference because the observed changes may partly reflect growth related to maturation. The sample was taken from a single club, which limits the generalizability of the findings. Biological maturity status was not assessed; at 12–13 years of age, inter-individual variation in somatic maturation can be considerable, and the lack of peak height velocity (PHV) data means that maturational differences may have confounded the observed neuromuscular outcomes. Although the content of the training program has been described in terms of technical, tactical, and conditioning themes across the six-week cycle, quantitative session-load parameters such as external workload, internal intensity, and cumulative training volume were not recorded, which limits precise dose-response interpretation. Nonetheless, the six-month longitudinal design is consistent with comparable Bulgarian youth football research by Ivanov (2025b), who examined changes in body composition and aerobic capacity over an equivalent seasonal period in a similar U14-15 population, further supporting the feasibility and relevance of this study duration for monitoring physical development in the domestic youth football context.

Conclusions

This study examined the effects of a six-month technical–tactical training program on bilateral vertical jump performance and inter-limb muscular symmetry in male under-13 football players. Three main conclusions can be drawn. First, six months of technical–tactical football training produced no statistically significant improvements in Squat Jump or Countermovement Jump height, with negligible effect sizes for both measures ($d = 0.18$ and $d = 0.15$, respectively), confirming that standard sport-specific practice alone is insufficient to produce meaningful neuromuscular adaptations in bilateral explosive power at this developmental stage. Second, unilateral right-leg strength increased significantly over the intervention period ($p = 0.002$), with large effect sizes observed for both limbs (right: $d = 0.90$; left: $d = 0.97$), indicating that the repetitive unilateral demands of football-specific actions led to genuine gains in isolated limb force production. Third, mean inter-limb muscular asymmetry increased from 7.40% to 13.24% over the training period, exceeding the clinically significant 10%–15% injury-risk threshold, with one participant reaching an asymmetry value of 54.41%.

These results have clear practical implications for youth football practitioners. These findings do not support relying only on technical–tactical training to develop physical capacities in under-13 players. Coaches and sports scientists working with this age group should incorporate structured bilateral and unilateral strength training into the weekly microcycle, taking advantage of the heightened neuromuscular trainability characteristic of the pre-pubertal period. Furthermore, routine monitoring of inter-limb asymmetry using validated unilateral assessment tools such as the Kineo Training System is strongly recommended because bilateral jump tests may

conceal clinically meaningful between-limb imbalances. Early identification and targeted correction of asymmetries in this age group is a practical, evidence-based strategy for both injury prevention and long-term athletic development in youth football.

Acknowledgments

The author gratefully acknowledges the National Sports Academy "Vassil Levski" (Sofia, Bulgaria) for supporting this scientific research by providing the OptoJump Next photoelectric system and the Kineo Training System used in this study.

Conflicts of Interest

The author declares that there are no conflicts of interest related to this study.

Declaration on the use of AI-assisted technologies

AI-assisted tools were used only for grammar, spelling, and language clarity checks. No AI tool was used for data generation, statistical analysis, result interpretation, or scientific conclusions.

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