Effect of an 8-week training program on the rebalancing of functional asymmetry in young footballers

Efecto de un programa de entrenamiento de 8 semanas sobre el reequilibrio de la asimetría funcional en futbolistas jóvenes

Authors

Walid Bouzid [1,]
Omar Ben Bakaa [2]
Aziz Chokri [1]
Aziz Eloirdi [1]
Abdelmoujoud Elhaboussi [1]
Mohamed Barkaoui [1]

[1] Institute of Sports Science, Hassan 1st University of Settat, Morocco
[2] Normal Higher School (ENS-C), Hassan II University of Casablanca, Morocco

Corresponding author:
profw.bouzid99@gmail.com

How to cite in APA

Bouzid, W., Ben Rakaa, O., Chokri, A., Eloirdi, A., Elhaboussi, A., & Barkaoui, M. (2025). Effect of an 8-week training program on the rebalancing of functional asymmetry in young footballers. *Retos, 70*, 1422–1437. https://doi.org/10.47197/retos.v70.117056

Abstract

Background. Functional asymmetries in youth football players represent significant performance limitations and injury risk factors requiring targeted intervention strategies. Elite youth athletes frequently demonstrate bilateral imbalances across multiple neuromuscular domains.
Objective. This study evaluated the effectiveness of an individualized 8-week neuromuscular training program in reducing functional asymmetries among elite youth football players across different age categories (U16, U17, U18). Methods. This 8-week experimental intervention aimed to reduce functional asymmetries in balance, unilateral strength, and jump performance among elite youth footballers. Conducted in addition to their regular weekly schedule (five sessions, 8–10 hours football-specific practice + 2–3 hours strength and conditioning), the program comprised two 30–40 min neuromuscular sessions per week. Each session included four blocks: activation & mobility, unilateral strengthening, plyometrics & single-leg jumps, and balance & postural control. Progression was applied systematically through increased load, instability, movement complexity, and football-specific demands, following the principle of progressive overload. Individualization strategies targeted the weaker limb when interlimb differences exceeded 10%, with adjustments based on RPE, mid-term, and final assessments. Results. Significant reductions in functional asymmetries were observed across all variables and age groups. Y-Balance Test asymmetries decreased by 46-60%, Single Leg Hop Test asymmetries reduced by 39-46%, and quadriceps strength asymmetries diminished by 42-47%. Younger players (U16) demonstrated greater magnitude improvements compared to older athletes. Strong correlations existed between different asymmetry measures, supporting multidimensional assessment approaches. Effect sizes ranged from moderate to large across all variables. Conclusion. The individualized neuromuscular training intervention effectively reduced functional asymmetries in youth football players, with age-related response variations supporting developmentally appropriate program design for optimizing athletic performance and injury prevention.

Keywords

Asymmetry, neuromuscular training, bilateral deficit, y-balance test, interlimb asymmetry.

Resumen

Introducción. Las asimetrías funcionales en los futbolistas juveniles representan limitaciones significativas del rendimiento y factores de riesgo de lesiones que requieren estrategias de intervención específicas. Los atletas juveniles de élite muestran con frecuencia desequilibrios bilaterales en múltiples dominios neuromusculares. Objetivo. Este estudio evaluó la eficacia de un programa de entrenamiento neuromuscular individualizado de 8 semanas en la reducción de las asimetrías funcionales entre los jugadores de fútbol juvenil de élite a través de diferentes categorías de edad (U16, U17, U18). Metodología**.** Esta intervención experimental de 8 semanas tenía como objetivo reducir las asimetrías funcionales en el equilibrio, la fuerza unilateral y el rendimiento de salto entre los futbolistas juveniles de élite. Realizado además de su programa semanal regular (cinco sesiones, 8-10 horas de práctica específica de fútbol + 2-3 horas de fuerza y acondicionamiento), el programa comprendía dos sesiones neuromusculares de 30-40 minutos por semana. Cada sesión incluía cuatro bloques: activación y movilidad, fortalecimiento unilateral, pliometría y saltos con una sola pierna, y equilibrio y control postural. La progresión se aplicó sistemáticamente a través del aumento de la carga, la inestabilidad, la complejidad del movimiento y las demandas específicas del fútbol, siguiendo el principio de la sobrecarga progresiva. Las estrategias de individualización se centraron en la extremidad más débil cuando las diferencias entre las extremidades superaban el 10%, con ajustes basados en las evaluaciones RPE, intermedia y final. Resultados. Se observaron reducciones significativas de las asimetrías funcionales en todas las variables y grupos de edad. Las asimetrías de la prueba de equilibrio en Y disminuyeron en un 46-60%, las asimetrías de la prueba de salto con una sola pierna se redujeron en un 39-46% y las asimetrías de la fuerza del cuádriceps disminuyeron en un 42-47%. Los jugadores más jóvenes (sub-16) demostraron mejoras de mayor magnitud en comparación con los atletas de más edad. Existieron fuertes correlaciones entre las diferentes medidas de asimetría, lo que apoya los enfoques de evaluación multidimensionales. Los tamaños del efecto variaron de moderados a grandes en todas las variables. Conclusiones. La intervención de entrenamiento neuromuscular individualizado redujo eficazmente las asimetrías funcionales en jugadores de fútbol juveniles, con variaciones de respuesta relacionadas con la edad que apoyan el diseño de programas apropiados al desarrollo para optimizar el rendimiento atlético y la prevención de lesiones.

Palabras clave

Asimetría, entrenamiento neuromuscular, déficit bilateral, test de equilibrio en y, asimetría entre extremidades.

Introduction

Inter-limb asymmetries represent a fundamental characteristic of human movement, with their prevalence and functional consequences varying significantly across sports disciplines (Fox et al., 2023). In unilateral sports such as tennis or javelin throwing, asymmetries often reflect sport-specific adaptations that may confer performance advantages (Duan et al., 2024). These sports inherently demand a dominant limb for precision and power, leading to natural neuromuscular imbalances that are not necessarily detrimental (Duan et al., 2024). However, in multidirectional team sports—particularly those requiring bilateral coordination—excessive asymmetries (>10-15%) have been consistently associated with both performance deficits and elevated injury risk (Fort-Vanmeerhaeghe et al., 2020). This dichotomy underscores the importance of context-specific evaluation when assessing functional asymmetries in athletic populations (Afonso et al., 2022a). The implications of these imbalances are particularly pronounced in football, where the interplay between unilateral skill execution and bilateral movement mechanics creates a unique challenge for athletes and practitioners alike(Zhang et al., 2023). The integration of strength, power, and balance training components has been demonstrated to generate synergistic effects, which contribute to the reduction of physical asymmetry (Bettariga et al., 2022). The integration of training phases focused on asymmetry into periodization strategies has proven effective in improving long-term holistic development trajectories in young people, physically (Lourenço et al., 2025), psychologically, and socially (Ben Rakaa, Bassiri, et al., 2025a, 2025b; Ben Rakaa, Lourenço, et al., 2025).

Football presents a particularly compelling case for asymmetry research due to its complex movement demands and technical requirements (Maly et al., 2024). Unlike purely unilateral sports, football integrates both asymmetrical and symmetrical actions, with players relying on a dominant limb for kicking while simultaneously depending on balanced lower-body strength for sprinting, jumping, and rapid changes of direction (Sun et al., 2025). The sport's characteristic unilateral kicking patterns, combined with frequent cutting maneuvers and explosive accelerations, create distinct asymmetry profiles that evolve throughout adolescent development (Michailidis et al., 2025). These asymmetries manifest most prominently in dynamic postural control (as measured by the Y-Balance Test), unilateral power production (assessed through single-leg hop tests), and isokinetic strength measures ((Maly et al., 2024); (Michailidis et al., 2025)). Importantly, such imbalances have been linked to impaired change-of-direction ability, reduced sprint efficiency, and higher rates of non-contact lower extremity injuries in youth players (Ascenzi et al., 2022). Given that adolescence is a critical period for neuromuscular development, understanding and addressing these asymmetries in young footballers could have long-term implications for both performance and injury prevention(França et al., 2023).

Current intervention strategies for asymmetry reduction emphasize neuromuscular training approaches tailored to sport-specific demands (Ascenzi et al., 2022). Plyometric protocols incorporating unilateral and bilateral movements have demonstrated particular efficacy in improving inter-limb symmetry among adolescent athletes (Cudicio & Agosti, 2024). These protocols leverage the principles of progressive overload and neuromuscular adaptation, ensuring that both limbs develop balanced strength and coordination (Cudicio & Agosti, 2024). In football-specific contexts, interventions combining eccentric hamstring loading, directional plyometrics, and proprioceptive training have shown promise in addressing the asymmetries inherent to the sport (Cudicio & Agosti, 2024). For instance, eccentric hamstring exercises such as the Nordic curl have been shown to reduce strength imbalances while simultaneously decreasing the risk of hamstring strains—a common injury in football players. Similarly, plyometric drills that emphasize unilateral force production can help correct power asymmetries, while proprioceptive training enhances joint stability and inter-limb coordination(Sun et al., 2025). Despite these advances, the optimal integration of these methods into periodized training programs for youth football players remains poorly understood (Cudicio & Agosti, 2024). Many existing training programs prioritize sport-specific skills and team tactics over individualized neuromuscular conditioning, potentially leaving asymmetry correction to chance (Bishop et al., 2023). Furthermore, the effectiveness of such interventions may vary depending on factors such as biological maturation, training history, and baseline asymmetry levels, highlighting the need for personalized approaches(Bishop et al., 2023).

This study therefore examines the effects of an 8-week targeted neuromuscular intervention on functional asymmetries in elite youth football players (U16-U18). Using a comprehensive assessment battery comprising the Y-Balance Test, Single Leg Hop Test (SLHT), and isometric quadriceps strength measurements, we investigate two primary research questions: (1) the magnitude of asymmetry reduction across multiple functional domains, and (2) the transfer of these adaptations to football-specific performance metrics. The Y-Balance Test provides a comprehensive evaluation of dynamic postural control asymmetries and functional mobility, which are particularly relevant for football-specific movements (Sun et al., 2025).The Single Leg Hop Test offers a reliable assessment of lower limb power asymmetries and unilateral stability, directly related to change-of-direction performance and jumping ability. Isometric quadriceps strength measurements allow precise quantification of muscular strength imbalances, a key factor in injury prevention and performance optimization. This combination of tests provides a complete evaluation of the key components of functional asymmetries: neuromuscular control (Y-Balance Test), explosive power (SLHT), and maximal strength (isometric quadriceps). Our findings aim to provide evidence-based recommendations for asymmetry management in football academy settings, where performance enhancement and injury prevention are top priorities. Given the increasing emphasis on long-term athlete development in youth sports, this research could inform more effective training strategies that address inter-limb imbalances without compromising other aspects of athletic preparation. By utilizing valid, reproducible, and field-applicable assessment methods, this study seeks to contribute to a more comprehensive understanding of asymmetries in football and their implications for young athletes.

Method

Participants

The study cohort comprised 78 elite male youth footballers stratified into three age categories (U16: n = 25, mean age 15.3 ± 0.2 years; U17: n = 26, mean age 16.6 ± 0.2 years; U18: n = 27, mean age 17.5 ± 0.2 years) from a specialized training center, all with 2–6 years of structured football experience. All athletes regularly performed standard strength, plyometric, and balance exercises as part of their general conditioning routines; however, none had previously participated in a targeted neuromuscular training program specifically designed to reduce functional asymmetries, as implemented in the present study.

Baseline functional asymmetry assessments revealed a progressive reduction in interlimb imbalances with increasing age: the U16 cohort exhibited the highest asymmetries in dynamic balance (Y-Balance Test: 2.22 ± 0.04%), unilateral power (Single Leg Hop Test: 2.48 ± 0.19%), and quadriceps strength (2.49 ± 0.25%), while the U18 group demonstrated the lowest asymmetries across all measures (YBT: 1.85 ± 0.36%; SLHT: 1.41 ± 0.33%; strength: 1.74 ± 0.33%). This age-dependent gradient, characterized by greater variability in younger athletes and consistent non-dominant limb deficits, reflects underlying neuromuscular maturation and sport-specific adaptation to football's unilateral demands, providing a critical foundation for targeted intervention strategies.

Importantly, based on established clinical cut-off values (>4 cm anterior reach difference for YBT and <90% Limb Symmetry Index for both SLHT and quadriceps strength), none of the 77 assessed players exceeded these thresholds at baseline. While functional asymmetries were present in the sample, all baseline values were within ranges considered acceptable in the literature.

Procedure

All players followed a structured weekly training schedule consisting of five sessions per week, totalling approximately 8–10 hours of football-specific practice and 2–3 hours of strength and conditioning work. Each standard session (90–120 minutes) included: (1) a warm-up (15–20 min) with dynamic mobility, activation drills, and technical ball work; (2) a technical–tactical segment (50–70 min) covering passing, dribbling, positional play, small-sided games, and tactical drills; (3) physical conditioning (15–25 min) involving aerobic/anaerobic interval running, sprint repetitions, and change-of-direction exercises; and (4) a cool-down (5–10 min) with static stretching and recovery routines. One individualized strength and conditioning sessions per week was scheduled for players requiring targeted work (e.g., injury prevention, mobility enhancement, or specific strength deficits). While U16, U17, and U18 teams followed the same general structure, training intensity and tactical complexity were progressively adapted to the players' age, competition level, and physical maturity.

The 8-week neuromuscular intervention was implemented in addition to this regular training routine. It consisted of two sessions per week, each lasting 30–40 minutes, performed either before or after technical training sessions or during supervised autonomy periods. The program aimed to reduce functional asymmetries in balance, unilateral strength, and jump performance, following a fixed four-block structure:

1. Activation and mobility (5–7 min): foam roller (quadriceps, hamstrings, glutes), hip mobility drills, and activation exercises (glute bridge, elastic abductions, dynamic side plank).
2. Unilateral strengthening (10–15 min): Bulgarian split squat, lateral lunge (eccentric control focus), step-ups (variable height), assisted unilateral Nordic curl (hamstrings).
3. Plyometrics and single-leg jumps (10 min): forward/lateral single-leg jumps, lateral leaps, drop jumps with progressive height, and jumps with 2-second stabilization on landing.
4. Balance and postural control (5–8 min): Y-Balance Test-inspired directional reaches, lateral plank on instability (ball, proprioceptive cushion), single-leg balance with arms outstretched (eyes open/closed), and ball passing in single-leg stance.

Progression was systematically applied across the eight weeks according to the principle of progressive overload, adjusting not only training volume but also intensity, instability, duration of effort, and coordination demands:

- Weeks 1–2: low to moderate intensity, 2×12–15 repetitions (technical familiarization)
- Weeks 3–4: moderate intensity, 3×10–12 repetitions (increased load or instability)
- Weeks 5–6: medium to high intensity, 3×8–10 repetitions (added complexity, on-time execution)
- Weeks 7–8: high intensity, 3×6–8 repetitions (dynamic, football-specific sequences)

The intervention also incorporated individualization strategies based on baseline asymmetry profiles: extra volume for the weaker leg when differences exceeded 10%, adjustments according to session RPE scores, mid-term (week 4) and final (week 8) assessments, and video feedback for technical correction.

8-week program

Table 1. 8-week program

No table of figures entries found.	Intensity	Volume	Progression
S1–S2	Low to moderate	2×12–15 reps	Technical apprenticeship
S3–S4	Moderate	3×10–12 reps	Increased load or instability
S5–S6	Medium to high	3×8–10 reps	Adding complexity/on-time
S7–S8	Strong	3×6–8 reps	More dynamic, soccer-specific sequences

Reps. is Repetition, S. is Session

Content by Block

Activation & Mobility (5-7 min)

- Foam roller quadriceps / ischios / glutes
- Hip mobility (open/close the gate, dynamic lunges)
- Activations: gluteal bridge, elastic abductions, dynamic side plank

Unilateral strengthening (10-15 min)

- Exercises (1 to 2 per session)
- Bulgarian split squat (dumbbell progression) Fente latérale (emphase sur contrôle excentrique)
- Step-up (variable height, asymmetrically loaded arms)
- Nordic curl unilatéral assisté (hamstrings)

Plyometrics & unipodal jumps (10 min)

- Objective: intermuscular coordination + unilateral explosiveness Exercices
- Front/lateral unipodal jump (minimum hurdles)
- 1-leg lateral leaps
- Unipodal drop jump (height progression)
- Jumps with 2-second stabilization on landing

Balance & postural control (5-8 min)

- Inspiration Y-Balance Test (YBT) Exercices :
- Directional reaching (anterior, posterolateral/medial) on 1 leg
- Lateral plank on instability (ball, proprioceptive cushion)
- Flexed-leg balancing with arms outstretched (eyes open/closed)
- Passing the ball in unipodal support

Strategies for Individualization

- Focus on the weaker leg (according to initial tests)
- Increased volume for asymmetric leg if the difference >10%.
- Use of RPE (effort scale) at the end of the session to adapt intensity
- Follow-up and adaptation
- Mid-term (S4) and final (S8) measurements
- Video feedback on exercises for technical correction
- Load and effort perception logs

Measuring instrument

Three types of assessment were carried out on each player, for each lower limb (dominant and non-dominant leg):

The Y-Balance Test (YBT)

The YBT is a standardized functional assessment used to measure dynamic postural control, unipodal balance, and asymmetries between the lower limbs (Zahn & Willardson, 2025). This test, derived from the Star Excursion Balance Test (SEBT), is designed to guarantee greater reproducibility of measurements, thanks to the use of a specially designed device (Yesilkir & Sahin, 2025). The test is performed using a Y-shaped platform with three arms oriented in the following directions: anterior (ANT), posteromedial (PM), and posterolateral (PL). The subject of the experiment stands in unipodal support at the center of the platform while performing thrusts with the free foot in each of the three directions, without losing balance or transferring weight onto the mobile limb (Garcia et al., 2025).

Prior to testing, all participants underwent a standardized familiarization session with the YBT device and protocol. This session consisted of a detailed demonstration, followed by supervised practice attempts in each of the three directions. This familiarization phase ensured that each participant understood the technical execution and was comfortable with the testing procedure, thereby reducing learning effects and improving test reliability (Zając et al., 2024).

Each test session was preceded by a dynamic warm-up protocol including joint mobilization and proprioceptive activation exercises, lasting approximately 10 minutes. The experimental protocol included three valid trials per direction and leg, with short rest periods between each attempt to avoid fatigue (Zając et al., 2024).

The validity of a test is based on the participant's compliance with the eligibility criteria, as defined by the body responsible for its implementation. The individual in question must maintain balance without placing the mobile foot on the ground. For best results, the marker should be aimed as far as possible towards the target using the tip of the foot. The process is characterized by a phase of controlled return to the initial position (Zahn & Willardson, 2025).

The asymmetry formula for YBT is expressed as: YBT Asymmetry (cm) = |Right leg distance − Left leg distance| (Garcia et al., 2025).

Functional asymmetry is characterized by a disparity in performance between the right and left limbs. A difference of more than 4 centimeteres in the anterior direction is commonly accepted as clinically significant (Yesilkir & Sahin, 2025).

The Single Leg Hop Test (SLHT)

The SLHT is a functional test commonly used to assess unilateral lower limb performance. It evaluates several variables, including strength, dynamic stability, neuromuscular coordination, and functional symmetry. This test is particularly valuable for evaluating athletic capacity, preventing injuries, and monitoring rehabilitation progress, especially in cases of anterior cruciate ligament (ACL) injuries or muscular imbalance (Swearingen et al., 2011) To ensure consistency and reliability of results, all participants underwent a standardized warm-up protocol consisting of dynamic mobility exercises and neuromuscular activation drills lasting approximately 10 minutes (Zając et al., 2024). This warm-up aimed to reduce injury risk and optimize muscular recruitment during testing. Before the actual data collection, a familiarization phase was systematically conducted. Each participant received clear verbal instructions and demonstrations from the evaluator, followed by two to three practice hops on each leg (Herrera & Osorio-Fuentealba, 2024). This allowed participants to internalize the movement technique and minimize performance variation due to unfamiliarity with the task (Zając et al., 2024).

The evaluation protocol then began with a maximal forward hop performed on a single leg from a static, balanced position. The individual was instructed to land and maintain a stable unipodal stance for at least two to three seconds. The test was deemed valid if the participant could maintain postural stability without the contralateral foot touching the ground and without the use of the hands for balance. Attempts that failed to meet these criteria were discarded (Nimphius et al., 2020), brief balance disturbances that do not involve loss of posture are not considered performance-limiting.

For each leg, three valid trials were performed, and the maximum distance achieved was retained as the reference value. SLHT asymmetry was calculated using the following formula: Maximum distance (cm) = max(Test 1, Test 2, Test 3) (Annear et al., 2020).

The jump distance was measured in centimeteres from the heel at take-off to the heel at landing (Figueroa et al., 2024).

An interlimb performance ratio (LSH) below 90% is generally interpreted as a marker of significant functional asymmetry, which may reflect underlying neuromuscular deficits or incomplete rehabilitation, and is associated with increased injury risk (Nimphius et al., 2020).

Isometric quadriceps strength

The maximum isometric force of the quadriceps muscles was assessed to measure the force-producing capacity of the lower limbs in a static position. This type of evaluation is commonly used in both clinical and sports settings to assess muscular performance, identify neuromuscular deficits, and detect functional asymmetries, particularly in active individuals (Kondo et al., 2024).

The assessment was conducted using a portable dynamometer (or an isokinetic dynamometer when available), secured at the anterior aspect of the leg, just above the ankle. The participant was seated on a stable, flat surface such as a chair or bench, with the knee flexed to an angle between 60° and 90°, as recommended by standardized testing protocols. The trunk was held upright, and the arms were crossed over the chest to minimize postural compensations and isolate the force generated by the quadriceps muscles (Reddy et al., 2024).

Befoure to the measurement session, each participant underwent a standardized warm-up phase, including several submaximal isometric contractions of increasing intensity. This phase aimed to activate the neuromuscular system, improve motor unit recruitment, and ensure familiarity with the testing modality (Sanz-Fernández et al., 2024).

A familiarization protocol was implemented for all participants. This included detailed verbal instructions on the test objectives and execution, demonstration by the examiner, and supervised practice attempts. These steps ensured that participants fully understood the posture, exertion technique, and the need to avoid compensatory movements from the trunk or hips during maximal contractions (Zając et al., 2024).

The main evaluation consisted of three maximal voluntary isometric contractions per leg, performed in an alternating sequence. Each contraction lasted between 3 and 5 seconds, with a rest interval of 30 to 60 seconds between trials to minimize fatigue. Participants were verbally encouraged to push "as hard as possible" against the dynamometer while maintaining proper posture and joint alignment(Reddy et al., 2024). The maximum value recorded from the three trials was retained as the reference for each limb and was expressed in newtons (N) or kilograms-force (kgf). The Limb Symmetry Index (LSI) was calculated using the following formula:

LSI (%) = (Quadriceps strength of affected leg / Quadriceps strength of unaffected leg) × 100 (Sohrabi et al., 2025).

An LSI below 90% is generally considered indicative of significant asymmetry, potentially reflecting incomplete rehabilitation or elevated injury risk (Sohrabi et al., 2025).

Data analysis

For all the variables studied, descriptive analyses of mean and standard deviation were performed. Prior to conducting parametric tests, the assumptions of normality and homoscedasticity were verified using the Shapiro–Wilk test and Levene's test, respectively. The data met these assumptions, allowing the use of parametric analyses. Then, a one-factor ANOVA was run on the effect size to measure the evolution of the functional asymmetry variables of each age group of players before and after the program. When the difference between pre- and post-test was significant, a percentage variation was calculated using the formula: (Post Test – Pre Test) / Pre Test * 100. Next, the results were subjected to a Bonferroni-corrected repeated-measures ANOVA to compare the effects of each pair of variables between the three groups (U16, U17, U18). Finally, a Pearson correlation test was performed to assess the strength of the relationships between the different tests of functional asymmetry.

Results

The subsequent section is an exposition of a three-stage analysis. Initially, descriptive data will be presented, encompassing the mean and standard deviation of the various functional asymmetry tests measured prior to and following the experimental program. Subsequently, the differences between the three groups (U16, U17, U18) of study participants before and after the intervention will be examined. Finally, the strength of the correlations between the different variables is examined.

Evolution of functional asymmetry in young soccer players

The 8-week training program induced significant reductions in functional asymmetry across youth soccer players (U16–U18), with the most pronounced improvements observed in the U16 cohort. Asymmetry in the Y-Balance Test (YBT) decreased by up to 60.32% (U18), while Single-Leg Hop Test (SLHT) and quadriceps strength asymmetries declined by 39.34–47.02%, supported by large effect sizes (e.g., η^2=0.701 for YBT in U16). Bilateral performance gains were asymmetrically distributed, favoring the left side (non-dominant limb), particularly in quadriceps strength (+7.08% for U16), indicative of targeted neuromuscular rebalancing.

While statistical significance was universal ($p < 0.001$), age-dependent attenuation of training effects emerged, as evidenced by smaller effect magnitudes in older cohorts (e.g., η^2=0.267 for U18 vs. 0.701 for U16), likely reflecting diminishing neuroplasticity with maturation. Residual asymmetries persisted in U18 players (e.g., YBT asymmetry: 0.73±0.17 post-intervention), underscoring the need for individualized strategies in late adolescence.

Table 2. Evolution of functional asymmetry in young soccer players after an 8-week training program

Variables	U16 category				U17 category				U18 category			
	Mean±Standard deviation	p-value	Variation rate	η2	Mean±Standard deviation	p-value	Variation rate	η2	Mean±Standard deviation	p-value	Variation rate	η2
YBT R (cm)	91.00±1.47 94.76±1.39	.000	4.13%	0.523	102.90±2.90 104.81±2.78	.000	1.85%	0.342	108.45±2.79 110.37±2.71	.000	1.77%	0.352
YBT L (cm)	89.00±1.47 93.64±1.82	.000	5.21%	0.569	100.88±3.14 103.97±2.89	.000	3.07%	0.515	106.45±3.03 109.55±2.78	.000	2.91%	0.519
Asym. YBT %	2.22±0.04 1.19±0.72	.000	-46.31%	0.701	1.98±0.39 0.81±0.19	.000	-58.99%	0.288	1.85±0.36 0.73±0.17	.000	-60.32%	0.267
SLHT R (cm)	168.80±2.40 175.92±2.60	.000	4.22%	1.092	185.42±3.46 187.68±3.42	.000	1.22%	0.182	192.53±3.43 194.91±3.40	.000	1.24%	0.236
SLHT L (cm)	164.76±2.39 173.32±3.42	.000	5.20%	1.71	182.72±3.91 186.20±3.81	.000	1.91%	0.275	189.85±3.87 193.35±3.80	.000	1.84%	0.221
Asym. SLHT%	2.44±0.10 1.48±0.60	.000	-39.34%	0.603	1.48±0.33 0.80±0.26	.000	-46.07%	0.119	1.41±0.33 0.81±0.27	.000	-42.37%	0.122
Strength quad R (Nm)	179.04±2.42 189.48±3.66	.000	5.83%	1.609	239.46±6.94 244.96±7.12	.000	2.30%	0.334	254.35±6.92 259.81±7.09	.000	2.15%	0.276
Strength quad L (Nm)	174.48±2.47 186.84±4.50	.000	7.08%	2.307	235.06±7.53 242.54±7.68	.000	3.18%	0.339	249.99±7.49 257.23±7.59	.000	2.90%	0.485
Asym. Strength quad %	2.60±0.27 1.40±0.61	.000	-46.00%	0.631	1.88±0.37 1.00±0.31	.000	-47.02%	0.152	1.74±0.33 1.01±0.26	.000	-42.04%	0.206

All results are written as mean±standard deviation, Significance p < .05, YBT. Y-Balance Test, Asym. Asymetry, SLHT. Single-Leg Hop Test, quad. Quadriceps, Nm. Namometr, R. Right, L. Left

Effect of an 8-week training program on functional asymmetry in young athletes

The 8-week training program demonstrated omnibus effects of exceptional statistical significance ($p < .001$) across all functional asymmetry variables (Table 3), with remarkably high effect sizes ($\eta^2 = 0.819–0.983$), underscoring the protocol's robust efficacy. Quadriceps strength ($\eta^2 = 0.979–0.983$) and Y-Balance Test (YBT) variables ($\eta^2 = 0.975–0.979$) exhibited the most pronounced improvements, highlighting their sensitivity to neuromuscular adaptations. Pairwise comparisons (Table 4) revealed systematic inter-category differences ($p < .001$) in bilateral performance metrics (YBT, Single-Leg Hop Test [SLHT], strength), yet residual asymmetries between U17 and U18 athletes were non-significant (NS) for Asym. YBT, Asym. SLH, and Asym. Strength quad., suggesting a plateauing of improvements in older cohorts. In contrast, U16 athletes displayed significantly greater asymmetry reductions compared to all other age groups ($p < .001$), aligning with their heightened neural plasticity

Table 3. Analysis of the effect of an 8-week program on functional asymmetry variables in young athletes

Variables	df	mean square	F	p-value	η2
YBT R (cm)	1	245.626	2887.340	.000	0.975
YBT L (cm)	1	500.918	3508.889	.000	0.979
Asym. YBT %	1	46.829	443.172	.000	0.857
SLHT R (cm)	1	591.752	2835.044	.000	0.975
SLHT L (cm)	1	1031.728	2084.777	.000	0.966
Asym. SLH %	1	21.365	334.620	.000	0.819
Strength quad.. R (Nm)	1	1957.748	4336.710	.000	0.983
Strength quad.. L (Nm)	1	3132.128	3392.756	.000	0.979
Asym. Strength quad.. %	1	33.813	446.693	.000	0.858

NS. Not significant, significance p < .05 YBT. Y-Balance Test, Asym. Asymetry, SLHT. Single-Leg Hop Test, quad. Quadriceps, Nm. Namometr, R. Right, L. Left

Table 4. Pairwise comparison of functional asymmetry variables in young athletes according to age category

Variables	U16		U17		U18	
	U17	U18	U16	U18	U16	U17
YBT R (cm)	.000	.000	.000	.000	.000	.000
YBT L (cm)	.000	.000	.000	.000	.000	.000
Asym. YBT %	.001	.000	.001	NS	.000	NS
SLHT R (cm)	.000	.001	.000	.000	.000	.000
SLHT L (cm)	.000	.000	.000	.000	.000	.000
Asym. SLH %	.000	.000	.000	NS	.000	NS
Strength quad. R (Nm)	.000	.000	.000	.000	.000	.000
Strength quad.. L (Nm)	.000	.000	.000	.000	.000	.000
Asym. Strength quad.. %	.000	.000	.000	NS	.000	NS

NS. Not significant, significance p < .05 YBT. Y-Balance Test, Asym. Asymetry, SLHT. Single-Leg Hop Test, quad. Quadriceps, Nm. Namometr, R. Right, L. Left

Examining the relationship between functional asymmetry variables in young soccer players

Table 5 reveals significant Pearson correlations (**p < 0.01) among functional asymmetry variables, highlighting complex interdependencies. Bilateral performance metrics (YBT D/G, SLHT D/G, quadriceps strength D/G) exhibit near-perfect positive correlations (r = 0.991–0.998), indicating high functional synchronization between dominant and non-dominant limbs. In contrast, asymmetry measures (Asym. YBT, Asym. SLHT, Asym. Strength quad.) demonstrate moderate-to-strong negative correlations with unilateral performance (r = -0.490 to -0.772), suggesting that reduced imbalances are associated with bilateral performance gains. Notably, quadriceps strength asymmetry (variable 9) shows a robust positive correlation with hop asymmetry (r = 0.942), emphasizing a critical neuromuscular linkage. However, the near-perfect correlation between dominant and non-dominant quadriceps strength raises questions about potential metric redundancy or methodological artifacts.

Table 5. Pearson correlation between all functional asymmetry variables in young athletes

Variables	1	2	3	4	5	6	7	8	9
1.YBT R (cm)	1								
2.YBT L (cm)	.998**	1							
3.Asym. YBT %	-.505**	-.551**	1						
4.SLHT R (cm)	.996**	.996**	-.536**	1					
5.SLHT L (cm)	.991**	.994**	-.582**	.998**	1				
6.Asym. SLH %	-.697**	-.727**	.852**	-.726**	-.772**	1			
7.Strength quad. R (Nm)	.975**	.974**	-.490**	.966**	.963**	-.698**	1		
8.Strength quad.. L (Nm)	.976**	.976**	-.506**	.968**	.967**	-.715**	1.000**	1	
9.Asym. Strength quad.. %	-.529**	-.563**	.822**	-.567**	-.619**	.942**	-.510**	-.531**	1

**. Corrélation est significative YBT. Y-Balance Test, Asym. Asymetry, SLHT. Single-Leg Hop Test, quad. Quadriceps, Nm. Namometre, R. Right, L. Left

Discussion

The present investigation demonstrated significant reductions in functional asymmetries across all measured variables following the 8-week neuromuscular training intervention, with asymmetry decreases ranging from 39% to 60% depending on the assessment modality (Afonso et al., 2022b). These findings align with contemporary meta-analytical evidence indicating that targeted training interventions can effectively reduce interlimb asymmetries in athletic populations (Bettariga et al., 2023). The magnitude of improvement observed in Y-Balance Test asymmetries parallels recent research demonstrating substantial bilateral balance enhancements following structured proprioceptive training protocols (Wiprich et al., 2024). The findings of this study demonstrated a range of 46–60% reductions in YBT asymmetries, which significantly exceeds the outcomes reported in prior intervention studies. The present finding is consistent with the conclusions of a prior study, which determined that a 10-week training program integrating stiff leg raises and Swiss ball hamstring curls can enhance hamstring strength and augment leg agility and power in athletes exhibiting hamstring asymmetry of at least 10% (Rusdiawan et al., 2024). These results suggest that the implementation of individualized programming may potentially enhance the efficacy of training (Graham & Haddad, 2024). The following text is intended to provide a comprehensive overview of the subject matter. The concurrent improvements in Single Leg Hop Test performance are consistent with the extant evidence that plyometric training interventions significantly enhance unilateral jumping capabilities (Moran et al., 2021). The findings indicate a reduction in strength asymmetry of 42–47% across various age groups, thereby corroborating the hypothesis that unilateral resistance training effectively addresses bilateral force production imbalances (Fahey et al., 2025). The integration of multiple training modalities within the intervention protocol is consistent with evidence-based approaches that emphasize comprehensive neuromuscular development (MacSweeney et al., 2024). It has been demonstrated through prior research that the implementation of a combination of training approaches yields outcomes that are more effective than single-modality interventions in addressing functional asymmetries (Lopes et al., 2022). The training protocol employed is characterized by its progressive nature, aligning with the recommendations outlined in the literature concerning systematic overload progression in youth athletic populations (Moran et al., 2021). The present findings contribute to mounting evidence supporting the efficacy of structured neuromuscular training in reducing injury risk factors while enhancing athletic performance (Pleša et al., 2022).

The disparate responses noted among the age categories (U16, U17, and U18) offer significant insights into the developmental considerations imperative for the management of asymmetry in youth athletes

(İnce & Tortu, 2025). Players in the younger age group (U16) exhibited the most significant reduction in asymmetry, which may be indicative of heightened neuroplasticity and adaptability during the nascent stages of athletic development (Punnavilaputhenveedu & G, 2024). These age-related differences are consistent with research indicating that neuromuscular control capabilities undergo further development throughout adolescence, thereby influencing training responsiveness (McCalman et al., 2022). The findings indicate a progressive decline in baseline asymmetry magnitudes with increasing age, thereby suggesting that maturation processes may naturally contribute to the development of bilateral symmetry (Arede et al., 2024). Nonetheless, the pervasive presence of substantial asymmetries across all age groups underscores the necessity of targeted interventions, irrespective of chronological age (Kons et al., 2023). The present study's findings are corroborated by research examining long-term asymmetry patterns in youth athletes, which supports the hypothesis that there is age-related variation in intervention responses (Warneke et al., 2022). The observation that older athletes (U18) exhibited smaller, yet still clinically meaningful, improvements suggests that established movement patterns necessitate more intensive or prolonged interventions (Driss et al., 2025).. Although the absolute percentage of improvement was lower in this group, the associated effect size remained within the threshold of clinical relevance, underscoring that even modest gains can be meaningful when baseline performance is already high or when neuro-motor patterns are more deeply ingrained. (Driss et al., 2025). The present findings are consistent with the extant evidence that the implementation of intervention measures in a timely manner may result in optimal outcomes in the management of asymmetry in developing athletes (Kozinc, 2022). The training adaptations observed, which are age-specific, provide support for recommendations regarding the design of sports programs that are developmentally appropriate for youth (Escobar-Molina et al., 2023). The comprehension of these developmental considerations enables practitioners to implement targeted strategies that account for maturational status and training history when addressing functional asymmetries (Kozinc, 2022).

The comprehensive assessment battery employed in this investigation demonstrated strong sensitivity to training-induced changes, thereby supporting the clinical utility of these evaluation methods (Wilczyński et al., 2024). The enhancements observed in the Y-Balance Test across all participants are consistent with the extant research that has established this assessment as a reliable indicator of dynamic postural control and injury risk (Singh et al., 2024). The substantial correlations between disparate asymmetry metrics substantiate the multidimensional character of functional asymmetries, thereby substantiating the comprehensive assessment approach (Makaracı et al., 2021). The Single Leg Hop Test (SLHT) revealed significant enhancements that surpass the established minimal detectable change values, thereby substantiating the clinical relevance of the observed adaptations (Dallas et al., 2022). The findings of the strength assessment are consistent with the results of prior research indicating that bilateral force production asymmetries serve as important indicators of neuromuscular imbalance and injury susceptibility (Nagahara & Gleadhill, 2023). The pre-intervention asymmetry magnitudes observed in the present sample are consistent with the normative data from analogous athletic populations, thereby substantiating the generalizability of the findings (Pleša et al., 2022). The threshold values employed for the determination of clinically significant asymmetries are consistent with established research recommendations and demonstrate practical applicability (MacSweeney et al., 2024). Post-intervention asymmetry values falling below established risk thresholds indicate that targeted training can effectively reduce injury-related risk factors (Lopes et al., 2022). The substantial effect sizes evident across all assessment modalities substantiate the clinical significance of the intervention outcomes (Fahey et al., 2025). The present findings contribute to the validation of multi-modal assessment approaches for comprehensive asymmetry evaluation in youth athletic populations (Wiprich et al., 2024).

The findings' practical implications extend beyond the scope of research contexts to direct application in youth football development programs (Graham & Haddad, 2024). The empirical evidence indicates that the efficacy of twice-weekly training sessions is sufficient to provide feasible implementation guidelines for practitioners working with time-constrained athletic populations (Moran et al., 2024). The utilization of an individualized approach, which entails the allocation of augmented volume to the weaker limb, constitutes a pragmatic strategy for enhancing the efficacy of training (Bettariga et al., 2022). The incorporation of training focused on asymmetry into existing practice schedules is a viable strategy that does not necessitate significant modifications to existing programs (Arede et al., 2024). The intervention protocol is characterized by its progressive nature, which provides a systematic framework for the development of long-term athletic plans (Moran et al., 2024). The findings indicate that the implementation of regular asymmetry screening protocols is necessary to identify athletes who require targeted intervention (McCalman et al., 2022). The age-specific considerations identified herein suggest that modifications to the program may be necessary to optimize outcomes across different developmental stages (McCalman et al., 2022). The comprehensive training approach, incorporating strength, power, balance, and proprioceptive elements, provides a template for holistic asymmetry management (Punnavilaputhenveedu & G, 2024). The implementation of cost-effective strategies that require minimal equipment has been shown to enhance the accessibility of these interventions across a variety of sporting contexts (Kons et al., 2023). Subsequent research endeavors should investigate the long-term retention of training adaptations and the optimal frequency of interventions to preserve asymmetry improvements in youth athletic populations (Driss et al., 2025).

Conclusions

This study presents substantial evidence that supports the efficacy of customized neuromuscular training interventions in addressing functional asymmetries among elite youth football players. Substantial reductions in asymmetry magnitude have been documented, ranging from 39% to 60%, across multiple domains of assessment. These findings indicate that targeted, progressive training protocols can have a substantial impact on bilateral neuromuscular imbalances, which are associated with compromised athletic performance and elevated injury susceptibility.

The age-stratified analysis reveals crucial developmental considerations, as evidenced by the greater training responsiveness exhibited by younger athletes (U16) compared to their older counterparts. This finding likely reflects a combination of factors: the enhanced neuroplasticity and adaptive capacity characteristic of this developmental stage, as well as the possibility that U16 participants exhibited a higher baseline level of neuromuscular imbalance, providing more room for measurable improvement. Together, these elements underscore the value of early intervention during critical periods of neuromuscular development, when neuroplasticity remains optimized for adaptation. The disparate responses observed across age categories indicate the necessity for practitioners to adapt intervention strategies based on chronological age and training maturity to ensure optimal therapeutic outcomes.

The comprehensive assessment battery employed in this study validates the multidimensional nature of functional asymmetries. The battery measures balance, power, and strength. The battery's inter-correlations between balance, power, and strength provide evidence that confirms the interconnected relationship of these neuromuscular qualities. The findings of this study demonstrate that the observed improvements, indicated by effect sizes ranging from moderate to large, signify considerable clinical significance, thus supporting the practical implementation of such interventions within youth athletic development programs.

It is imperative to acknowledge the limitations that are associated with this study. The 8-week intervention duration, while producing significant adaptations, prevents assessment of long-term retention and optimal maintenance strategies. The exclusive emphasis on football players in this study restricts the generalizability of the findings to other athletic populations. However, it is plausible that the fundamental neuromuscular principles identified in this study can be extrapolated to sports that demand unilateral and bilateral movement competencies. Future research should examine extended intervention periods, diverse athletic populations, and cost-effectiveness analyses to inform the implementation of evidence-based practices.

The findings contribute substantively to the growing body of literature supporting proactive asymmetry management in youth athletes. The intervention's practical feasibility is evidenced by its minimal equipment requirements and its capacity to seamlessly integrate with existing training schedules. These attributes enhance its potential for widespread adoption across various sporting contexts. The findings of this study support the incorporation of systematic asymmetry screening and targeted intervention protocols as integral components of comprehensive youth athletic development programs. These protocols are designed to enhance performance outcomes while mitigating injury risk throughout the developmental trajectory of young athletes.

Limitations

The study was conducted over a period of eight weeks, a duration that may have been insufficient to evaluate the long-term effects of reducing functional asymmetries. It is recommended that subsequent studies include extended follow-ups to ascertain the longevity of the observed enhancements beyond the intervention period.

It is important to note that the study was conducted exclusively on male soccer players from an elite training center. This restriction limiting the generalizability of the results to other populations, such as female athletes, amateur players or practitioners of other sports, is essential to caution in interpreting the results. The study focuses exclusively on lower limb asymmetries, neglecting other body regions (such as the trunk or upper limbs) that could also exert an influence on performance and injury prevention.

A notable limitation of the present study is the absence of initial asymmetry levels as an inclusion or stratification criterion. While the program aimed to assess overall training responsiveness across age groups, not accounting for baseline asymmetry may have introduced variability in the magnitude of observed improvements. This omission is particularly salient in light of the mounting emphasis on individualized interventions predicated on functional asymmetry profiles. Future studies should consider stratifying participants or adapting protocols based on pre-existing asymmetry thresholds to enhance precision and clinical applicability.

A notable limitation of the present study is the absence of a control group, which hinders the ability to make definitive conclusions about the effectiveness of the intervention. Absent a non-intervention or regular training group for comparison, it is not possible to definitively attribute the observed improvements solely to the effects of the intervention program. It is plausible that the regular training activities that were conducted concurrently may have contributed, at least in part, to the observed gains. While the within-subject pre-post design offers valuable insights, future studies should consider including a control or placebo group to allow for more robust causal inference and to better isolate the specific effects of the intervention.

Acknowledgments

The authors would like to express their sincere gratitude for the institutional and academic support that made this study possible.

- **Walid BOUZID.** profw.bouzid99@gmail.com, orcid.org/0009-0003-8531-7356. Sports Science Research Team, Institute of Sports Science, Hassan 1st University, Settat, Morocco.
- **Omar BEN RAKAA.** omarbenrakaa@gmail.com, orcid.org/0000-0002-2181-5247. Multidisciplinary Laboratory in Education Sciences and Training Engineering (LMSEIF), Sport Science Assessment and Physical Activity Didactic, Normal Higher School (ENS-C), Hassan II University of Casablanca, Morocco.
- **Aziz CHOKRI.** aziz.chokri@uhp.ac.ma, orcid.org/0000-0001-8357-3880. Sports Science Research Team, Institute of Sports Science, Hassan 1st University, Settat, Morocco.
- **Aziz ELOIRDI.** aziz.eloirdi@uhp.ac.ma, orcid.org/0000-0003-1061-7787. Sports Science Research Team, Institute of Sports Science, Hassan 1st University, Settat, Morocco.
- **Abdelmoujoud ELHABOUSSI.** abdelmoujoud.elhaboussi@uhp.ac.ma, orcid.org/0000-0003-2138-4966. Sports Science Research Team, Institute of Sports Science, Hassan 1st University, Settat, Morocco
- **Mohamed BARKAOUI.** mohamed.barkaoui@uhp.ac.ma, orcid.org/0000-0002-5209-1499. Sports Science Research Team, Institute of Sports Science, Hassan 1st University, Settat, Morocco.

References

Afonso, J., Peña, J., Sá, M., Virgile, A., García-de-Alcaraz, A., & Bishop, C. (2022a). Why Sports Should Embrace Bilateral Asymmetry: A Narrative Review. *Symmetry 2022, Vol. 14, Page 1993*, *14*(10), 1993. https://doi.org/10.3390/SYM14101993

Afonso, J., Peña, J., Sá, M., Virgile, A., García-de-Alcaraz, A., & Bishop, C. (2022b). Why Sports Should Embrace Bilateral Asymmetry: A Narrative Review. *Symmetry 2022, Vol. 14, Page 1993*, *14*(10), 1993. https://doi.org/10.3390/SYM14101993

Annear, A., Sole, G., & Devan, H. (2020). Corrigendum to "What are the current practices of sports physiotherapists in integrating psychological strategies during athletes' return-to-play rehabilitation? Mixed methods systematic review" [Physical Therapy in Sport 38 (2019) 96–105]. *Physical Therapy in Sport*, *41*, 94–96. https://doi.org/10.1016/j.ptsp.2019.11.009

Arede, J., Fernandes, J. F. T., Singh, H., Bishop, C., Romero-Rodriguez, D., & Madruga Parera, M. (2024). Assessing asymmetries and predicting performance in semiprofessional soccer players. *International Journal of Sports Science and Coaching*, *19*(1), 192–201. https://doi.org/10.1177/17479541221146220/ASSET/A5B856B7-C624-40EE-BCC5-9BB6CE8F4450/ASSETS/IMAGES/LARGE/10.1177_17479541221146220-FIG3.JPG

Ascenzi, G., Filetti, C., Di Salvo, V., Javier Nuñez, F., Suarez-Arrones, L., Ruscello, B., Francioni, F. M., & Villanueva, A. M. (2022). Inter-limb asymmetry in youth elite soccer players: Effect of loading conditions. *PLOS ONE*, *17*(6), e0269695. https://doi.org/10.1371/JOURNAL.PONE.0269695

Ben Rakaa, O., Bassiri, M., & Lotfi, S. (2025a). Impact of adapted physical education and para-athletics on mental skills and on pedagogical and school inclusion of teenagers with disabilities. *Retos*, *68*, 82–94. https://doi.org/10.47197/RETOS.V68.111520

Ben Rakaa, O., Bassiri, M., & Lotfi, S. (2025b). Promoting Inclusion and Well-Being Through Inclusive Physical Education and Parasports: an Approach for Adolescents with Motor Impairment. *Physical Education Theory and Methodology*, *25*(1), 130–138. https://doi.org/10.17309/tmfv.2025.1.16

Ben Rakaa, O., Lourenço, C., Bassiri, M., & Lotfi, S. (2025). The Effect of Adapted Physical Activity and Inclusive Sport on the Motivation and Psychological Health of Children with Disabilities: A Randomized Control Trial. *Physical Education Theory and Methodology*, *25*(3), 642–651. https://doi.org/10.17309/tmfv.2025.3.21

Bettariga, F., Maestroni, L., Martorelli, L., Jarvis, P., Turner, A., & Bishop, C. (2023). The Effects of a Unilateral Strength and Power Training Intervention on Inter-Limb Asymmetry and Physical Performance in Male Amateur Soccer Players. *Journal of Science in Sport and Exercise*, *5*(4), 328–339. https://doi.org/10.1007/S42978-022-00188-8

Bettariga, F., Turner, A., Maloney, S., Maestroni, L., Jarvis, P., & Bishop, C. (2022). The Effects of Training Interventions on Interlimb Asymmetries: A Systematic Review with Meta-analysis. *Strength and Conditioning Journal*, *44*(5), 69–86. https://doi.org/10.1519/SSC.0000000000000701

Bishop, C., De Keijzer, K. L., Turner, A. N., & Beato, M. (2023). Measuring Interlimb Asymmetry for Strength and Power: A Brief Review of Assessment Methods, Data Analysis, Current Evidence, and Practical Recommendations. *Journal of Strength and Conditioning Research*, *37*(3), 745–750. https://doi.org/10.1519/JSC.0000000000004384,

Cudicio, A., & Agosti, V. (2024). Beyond Belief: Exploring the Alignment of Self-Efficacy, Self-Prediction, Self-Perception, and Actual Performance Measurement in a Squat Jump Performance—A Pilot Study. *Journal of Functional Morphology and Kinesiology 2024, Vol. 9, Page 16*, *9*(1), 16. https://doi.org/10.3390/JFMK9010016

Dallas, G., Dallas, C., Kolovou, V., Pappas, P., Mellos, V., & Paradisis, G. (2022). Acute Effects Of Bilateral And Unilateral Whole Body Vibration Training On Jumping Ability, Asymmetry, And Bilateral DEFICIT ON FORMER ARTISTIC GYMNASTS. *Science of Gymnastics Journal*, *14*(1), 59–71. https://doi.org/10.52165/SGJ.14.1.59-71

Driss, T., Miller, W., Antolinez, A. K., Edwards, P. F., Holmes, M. W. R., & Button, D. C. (2025). The effects of sex and load on quantifying the bilateral force deficit during an upper body Wingate test. *Frontiers in Sports and Active Living*, *6*, 1446909. https://doi.org/10.3389/FSPOR.2024.1446909

Duan, T., He, Z., Dai, J., Xie, L., Shi, Y., Chen, L., Song, J., Li, G., & Zhang, W. (2024). Effects of unilateral and bilateral contrast training on the lower limb sports ability of college basketball players.

Frontiers in Physiology, *15*, 1452751. https://doi.org/10.3389/FPHYS.2024.1452751/BIBTEX

Fahey, J. T., Comfort, P., Jones, P., & Ripley, N. J. (2025). Effect of 6-week single leg countermovement jump training on force time metrics in elite female youth footballers. *Journal of Sports Sciences*. https://doi.org/10.1080/02640414.2025.2489892;CTYPE:STRING:JOURNAL

Figueroa, F., Guiloff, R., Bolton, S., Figueroa, D., Tapasvi, S., & Stocker, E. (2024). Specific considerations in female patients with patellar instability: current concepts. *Journal of ISAKOS*, *9*(3), 457–463. https://doi.org/10.1016/j.jisako.2024.03.014

Fort-Vanmeerhaeghe, A., Bishop, C., Busca, B., Aguilera-Castells, J., Vicens-Bordas, J., & Gonzalo-Skok, O. (2020). Inter-limb asymmetries are associated with decrements in physical performance in youth elite team sports athletes. *PLOS ONE*, *15*(3), e0229440. https://doi.org/10.1371/JOURNAL.PONE.0229440

Fox, K. T., Pearson, L. T., & Hicks, K. M. (2023). The effect of lower inter-limb asymmetries on athletic performance: A systematic review and meta-analysis. *PLOS ONE*, *18*(6), e0286942. https://doi.org/10.1371/JOURNAL.PONE.0286942

França, C., Martins, F., Martinho, D. V., Ihle, A., Marques, A., Sarmento, H., Clemente, F. M., Przednowek, K., Campos, P., & Gouveia, É. R. (2023). Bilateral Asymmetry and the Relationship Between Unilateral Isokinetic Strength and Balance Performance in Male Adolescent Football Players. *Montenegrin Journal of Sports Science and Medicine*, *19*(2), 3–9. https://doi.org/10.26773/MJSSM.230905

Garcia, L., Drusch, A., Hooper, T., Yang, H. S., Kublawi, M., Brismée, J. M., & Sizer, P. (2025). Effect of volitional preemptive abdominal contraction on superficial multifidus response in healthy subjects during unipodal lower extremity reach task. *Journal of Bodywork and Movement Therapies*, *42*, 885–893. https://doi.org/10.1016/j.jbmt.2025.02.010

Graham, J. H., & Haddad, M. (2024). Motor Asymmetry in Football: Implications for Muscular Power, Balance, and Injury Prevention. *Symmetry 2024, Vol. 16, Page 1485*, *16*(11), 1485. https://doi.org/10.3390/SYM16111485

Herrera, E., & Osorio-Fuentealba, C. (2024). Impact of warm-up methods on strength-speed for sprinters in athletics: a mini review. *Frontiers in Sports and Active Living*, *6*, 1360414. https://doi.org/10.3389/FSPOR.2024.1360414/BIBTEX

İnce, İ., & Tortu, E. (2025). Association between intra and inter-limb strength asymmetry with sprint kinematics and force-velocity profile in youth team athletes. *Knee*, *52*, 99–107. https://doi.org/10.1016/J.KNEE.2024.10.020,

Kondo, Y., Yoshida, Y., Iioka, T., Kataoka, H., Sakamoto, J., Honda, Y., Nawata, A., & Okita, M. (2024). Effects of Isometric Quadriceps Muscle Exercise with Visual and Auditory Feedback at 1 Year after Total Knee Arthroplasty. *Physical Therapy Research*, *27*(1), 6–13. https://doi.org/10.1298/PTR.E10260

Kons, R. L., Ache-Dias, J., Gheller, R. G., Bishop, C., & Detanico, D. (2023). Bilateral deficit in the countermovement jump and its associations with judo-specific performance. *Research in Sports Medicine*, *31*(5), 638–649. https://doi.org/10.1080/15438627.2021.2024542

Kozinc, Ž. (2022). Is the Shape of the Force-Time Curve Related to Performance in Countermovement Jump? A Review. *Critical Reviews™ in Biomedical Engineering*, *50*(3), 49–57. https://doi.org/10.1615/CRITREVBIOMEDENG.2022045205

Lopes, M. C. C. ; W. R. ;, Lara, J. P. R. ;, Oliveira, A. J. S. ;, Da Silva, R. P. C. ;, Facin, E. A. ;, Izar, A. J. ;, Cavinato, C., Abad, C., Winicius, M., Lopes, R., Petróvna, J., Lara, R., Jose, A., Oliveira, S., Planas Correa Da Silva, R., Facin, A., Izar, A. J., & Gomes Teixeira, F. (2022). Long-Term Changes in Vertical Jump, H:Q Ratio and Interlimb Asymmetries in Young Female Volleyball Athletes. *International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 16420*, *19*(24), 16420. https://doi.org/10.3390/IJERPH192416420

Lourenço, C., Ben Rakaa, O., Vicente, J., Bassiri, M., & Lotfi, S. (2025). Dose-response relationship of weekly physical exercise on fitness of students. *Retos*, *68*, 1185–1195. https://doi.org/10.47197/retos.v68.115382

MacSweeney, N. D. H., Shaw, J. W., Simkin, G. P., Pedlar, C. R., Price, P. D. B., Mahaffey, R., & Cohen, D. D. (2024). Jumping Asymmetries and Risk of Injuries in Preprofessional Ballet. *American Journal of Sports Medicine*, *52*(2), 492–502.

https://doi.org/10.1177/03635465231218258/SUPPL_FILE/SJ-PDF-1-AJS-10.1177_03635465231218258.PDF

Makaracı, Y., Özer, Ö., Soslu, R., Uysal, A., Makaracı, Y., Özer, Ö., Soslu, R., & Uysal, A. (2021). Bilateral counter movement jump, squat, and drop jump performances in deaf and normal-hearing volleyball players: a comparative study. *Journal of Exercise Rehabilitation*, *17*(5), 339–347. https://doi.org/10.12965/JER.2142522.261

Maly, T., Hank, M., Verbruggen, F. F., Clarup, C., Phillips, K., Zahalka, F., Mala, L., & Ford, K. R. (2024). Relationships of lower extremity and trunk asymmetries in elite soccer players. *Frontiers in Physiology*, *15*, 1343090. https://doi.org/10.3389/FPHYS.2024.1343090/BIBTEX

McCalman, W., Crowley-McHattan, Z. J., Fransen, J., & Bennett, K. J. M. (2022). Skill assessments in youth soccer: A scoping review. *Journal of Sports Sciences*, *40*(6), 667–695. https://doi.org/10.1080/02640414.2021.2013617;WGROUP:STRING:PUBLICATION

Michailidis, Y., Stafylidis, A., Mandroukas, A., Kyranoudis, A. E., Antoniou, G., Kollias, R., Kanaras, V., Bamplekis, C., Vardakis, L., Semaltianou, E., & Metaxas, T. I. (2025). Correlation of the Asymmetry Index from the Single-Leg Countermovement Jump with the Asymmetry Index from Isokinetic Strength in Elite Youth Football Players. *Applied Sciences 2025, Vol. 15, Page 2779*, *15*(5), 2779. https://doi.org/10.3390/APP15052779

Moran, J., Ramirez-Campillo, R., Liew, B., Chaabene, H., Behm, D. G., García-Hermoso, A., Izquierdo, M., & Granacher, U. (2021). Effects of Vertically and Horizontally Orientated Plyometric Training on Physical Performance: A Meta-analytical Comparison. *Sports Medicine*, *51*(1), 65–79. https://doi.org/10.1007/S40279-020-01340-6/METRICS

Moran, J., Vali, N., Sand, A., Beato, M., Hammami, R., Ramirez-Campillo, R., Chaabene, H., & Sandercock, G. (2024). Effect of vertical, horizontal, and combined plyometric training on jump, sprint and change of direction performance in male soccer players. *PLOS ONE*, *19*(5), e0295786. https://doi.org/10.1371/JOURNAL.PONE.0295786

Nagahara, R., & Gleadhill, S. (2023). Asymmetries of kinematics and kinetics in female and male sprinting. *Journal of Sports Medicine and Physical Fitness*, *63*(8), 891–898. https://doi.org/10.23736/S0022-4707.23.14778-5

Nimphius, S., Bishop, C. J., Reardon, C., Mann, B., Lopes, M., Santos, D., Uftring, M., Stahl, C. A., Lockie, R. G., Alvar, B., & Dawes, J. J. (2020). Stress in Academic and Athletic Performance in Collegiate Athletes: A Narrative Review of Sources and Monitoring Strategies. *Frontiers in Sports and Active Living*, *2*, 502979. https://doi.org/10.3389/FSPOR.2020.00042

Pleša, J., Kozinc, Ž., & Šarabon, N. (2022). Bilateral Deficit in Countermovement Jump and Its Influence on Linear Sprinting, Jumping, and Change of Direction Ability in Volleyball Players. *Frontiers in Physiology*, *13*, 768906. https://doi.org/10.3389/FPHYS.2022.768906/BIBTEX

Punnavilaputhenveedu, J. A., & G, V. K. (2024). Asymmetries in Field Hockey Players: A Narrative Review. *Studia Sportiva*, *18*(2). https://doi.org/10.5817/STS2024-2-7

Reddy, R. P., Como, M., Charles, S., Herman, Z. J., Nazzal, E. M., Como, C. J., Singh-Varma, A., Fails, A., Popchak, A., & Lin, A. (2024). Criteria-based return to sport testing after open Latarjet reveals residual deficits and can be utilized for sports clearance with excellent outcomes at mean 3.6 year follow-up: A small case series of competitive athletes. *Physical Therapy in Sport*, *65*, 23–29. https://doi.org/10.1016/J.PTSP.2023.11.002,

Rusdiawan, A., Kusuma, D. A., Firmansyah, A., Wismanadi, H., Cemal, Ö., Wicahyani, S., & Lani, A. (2024). A combination of swissball hamstring curl and stiff-leg deadlift training on agility, hamstring asymmetry, and leg power in badminton athletes with hamstring asymmetry conditions. *Retos*, *59*, 666–673. https://doi.org/10.47197/retos.v59.107995

Sanz-Fernández, C., Morales-Sánchez, V., Castellano, J., & Mendo, A. H. (2024). Generalizability Theory in the Evaluation of Psychological Profile in Track and Field. *Sports 2024, Vol. 12, Page 127*, *12*(5), 127. https://doi.org/10.3390/SPORTS12050127

Singh, P., Kumar, D., Morya, M., Singh, R., & Rahman, M. H. (2024). Évaluation des capacités biomotrices clés: Une comparaison entre les niveaux nationaux et ... Joueurs de tennis d'élite internationaux. *Théorie et Méthodologie de l'éducation Physique*, *24*(6), 897–904. https://doi.org/10.17309/tmfv.2024.6.06

Sohrabi, A., Naderi, A., Sohrabi, A., Naderi, A., Sohrabi, A., & Naderi, A. (2025). Inter-limb Asymmetry in Y Balance and Single Leg Hop as a Predictor of Sports Injuries in Volleyball Players. *Journal of Clinical Research in Paramedical Sciences 2025 14:1*, *14*(1). https://doi.org/10.5812/JCRPS-158911

Sun, W., Li, H., Qu, L., Zhou, Y., Cao, X., Wang, K., & Li, K. (2025). Unilateral plyometric training effectively reduces lower limb asymmetry in athletes: a meta-analysis. *Frontiers in Physiology*, *16*. https://doi.org/10.3389/FPHYS.2025.1551523,

Swearingen, J., Lawrence, E., Stevens, J., Jackson, C., Waggy, C., & Davis, D. S. (2011). Correlation of single leg vertical jump, single leg hop for distance, and single leg hop for time. *Physical Therapy in Sport*, *12*(4), 194–198. https://doi.org/10.1016/j.ptsp.2011.06.001

Warneke, K., Keiner, M., Lohmann, L. H., Hillebrecht, M., Wirth, K., & Schiemann, S. (2022). The Influence of Maximum Strength Performance in Seated Calf Raises on Counter Movement Jump and Squat Jump in Elite Junior Basketball Players. *Sport Mont*, *20*(2), 63–68. https://doi.org/10.26773/SMJ.220610

Wilczyński, B., Cabaj, P., Biały, M., & Zorena, K. (2024). Impact of lateral ankle sprains on physical function, range of motion, isometric strength and balance in professional soccer players. *BMJ Open Sport & Exercise Medicine*, *10*(4), 2293. https://doi.org/10.1136/BMJSEM-2024-002293

Wiprich, M. T., Eberle, E. F., Balbinot, G. F., Cecconi, M. P., Binotti, F., Tadiello, G. S., & Bonetti, L. V. (2024). Evaluation of muscular and functional inter-limb asymmetries during mid-season in young male soccer athletes. *Journal of Bodywork and Movement Therapies*, *38*, 605–614. https://doi.org/10.1016/J.JBMT.2024.03.067

Yesilkir, S., & Sahin, G. E. (2025). Dynamic neuromuscular stabilization training for chronic ankle instability: A randomized controlled trial in amateur athletes. *Journal of Back and Musculoskeletal Rehabilitation*. https://doi.org/10.1177/10538127251338170

Zahn, D., & Willardson, J. M. (2025). An Examination of the Relationship Between Single Leg Jump and Balance Performance in Female Collegiate Basketball Players. *Journal of Strength and Conditioning Research*, *39*(6), 705–710. https://doi.org/10.1519/JSC.0000000000005112

Zając, B., Olszewski, M., & Mika, A. (2024). Influence of protocol variables on outcomes of the star excursion balance test group (SEBT, mSEBT, YBT-LQ) in healthy individuals: a systematic review. *Frontiers in Physiology*, *15*, 1415887. https://doi.org/10.3389/FPHYS.2024.1415887/BIBTEX

Zhang, W., Chen, X., Xu, K., Xie, H., Li, D., Ding, S., & Sun, J. (2023). Effect of unilateral training and bilateral training on physical performance: A meta-analysis. *Frontiers in Physiology*, *14*. https://doi.org/10.3389/FPHYS.2023.1128250,

Authors and translators' details:

Walid Bouzid	w.bouzid.doc@uhp.ac.ma	Autor/a
Omar Ben Rrakaa	omarbenrakaa@gmail.com	Autor/a
Aziz Chokri	aziz.chokri@uhp.ac.ma	Autor/a
Aziz Eloirdi	aziz.eloirdi@uhp.ac.ma	Autor/a
Abdelmoujoud Elhaboussi	abdelmoujoud.elhaboussi@uhp.ac.ma	Autor/a
Mohamed Barkaoui	mohamed.barkaoui@uhp.ac.ma	Autor/a