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Effects of a Fundamental Athletics and Corrective Exercise Program on Athletic Performance, Postural Alignment, and Functional Movement in Youth Soccer Players

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Abstract
Although physical performance is central to talent development in young soccer players, it must be developed alongside movement quality and postural alignment to support long-term athletic progression. This study aimed to examine the effects of an eight-week fundamental athletics and corrective exercise program on functional movement quality, postural alignment, and selected physical performance parameters in U15 soccer players. A pretest-posttest quasi-experimental design with a control group was used, involving 37 male soccer players (experimental=21, age 14.50±0.44; control=16, age 14.32±0.80). The experimental group performed a structured program four days per week for eight weeks, while the control group continued regular training. Total FMS score showed a significant main effect of Time ($F=75.18$; $p<.001$; $\eta^2p=.68$), but neither Group ($p=.060$) nor the Time×Group interaction ($p=.067$) reached significance. The experimental group showed significant within-group improvements in deep squat, hurdle step, in-line lunge, and shoulder mobility; only deep squat showed a significant between-group difference ($p=.002$; $q=.012$; $d=1.16$). No significant between-group difference was found in overall postural score changes ($p=.205$). For physical performance, balance and vertical jump improved over time in both groups, but the Time×Group interaction was non-significant; vertical jump showed a significant main effect of Group only ($p=.023$). Horizontal jump ($F=8.92$; $p=.005$), agility ($F=10.93$; $p=.002$), and sprint ($F=28.28$; $p<.001$) showed significant Time×Group interactions favoring the experimental group. In conclusion, the fundamental athletics and corrective exercise program provided young soccer players with a targeted rather than general benefit, most reliably enhancing deep squat movement quality and explosive capacities such as horizontal jump, agility, and speed.

Keywords: Agility, Corrective Training, Explosive Power, FMS, Posture, Sprint.

Genç Futbolcularda Temel Atletizm ve Düzeltici Egzersiz Programının Atletik Performans, Postüral Hizalanma ve Fonksiyonel Hareket Üzerindeki Etkileri

Öz
Fiziksel performans, genç futbolcularda yetenek gelişiminin merkezi bir bileşeni olmakla birlikte, uzun dönemli atletik ilerlemeyi desteklemek için hareket kalitesi ve postüral hizalanma ile birlikte geliştirilmesi gerekmektedir. Bu araştırmanın amacı, sekiz haftalık temel atletizm ve düzeltici egzersiz programının U15 futbolcularda fonksiyonel hareket kalitesi, postüral hizalanma ve seçilmiş fiziksel performans parametreleri üzerindeki etkilerini incelemektir. Ön test–son test kontrol gruplu yarı deneysel desen kullanılan araştırmaya 37 erkek genç futbolcu katılmıştır (deney=21, yaş 14.50±0.44; kontrol=16, yaş 14.32±0.80). Deney grubu sekiz hafta boyunca haftada dört gün yapılandırılmış program uygularken, kontrol grubu rutin antrenmanlarına devam etmiştir. Toplam FMS skorunda anlamlı bir Zaman etkisi bulunmuş ($F=75.18$; $p<.001$; $\eta^2p=.68$), ancak Grup ($p=.060$) ve Zaman×Grup etkileşimi ($p=.067$) anlamlı bulunmamıştır. Deney grubunda deep squat, hurdle step, in-line lunge ve shoulder mobility alt testlerinde grup-içi anlamlı iyileşmeler saptanmış; gruplar arası karşılaştırmada yalnızca deep squat'ta anlamlı fark bulunmuştur ($p=.002$; $q=.012$; $d=1.16$). Postüral değerlendirmelerde genel skor değişiminde gruplar arasında anlamlı fark saptanmamıştır ($p=.205$). Fiziksel performansta denge ve dikey sıçramada zaman içinde her iki grupta da gelişme görülmüş, ancak Zaman×Grup etkileşimi anlamsız kalmıştır; dikey sıçramada yalnızca Grup ana etkisi anlamlı bulunmuştur ($p=.023$). Yatay sıçrama ($F=8.92$; $p=.005$), çeviklik ($F=10.93$; $p=.002$) ve sürat ($F=28.28$; $p<.001$) parametrelerinde ise deney grubu lehine anlamlı Zaman×Grup etkileşimleri saptanmıştır. Sonuç olarak, temel atletizm ve düzeltici egzersiz programının genç futbolculara genel değil hedefe yönelik bir fayda sağladığı; en güvenilir şekilde deep squat hareket kalitesini ve yatay sıçrama, çeviklik, sürat gibi patlayıcı performans kapasitelerini geliştirdiği görülmüştür.

Anahtar Kelimeler: Çeviklik, Düzeltici Antrenman, FMS, Patlayıcı Güç, Postür, Sprint.

Introduction

Contemporary soccer has evolved beyond a game requiring only tactical intelligence and technical skills. It has become a highly dynamic sport that places substantial physiological demands on athletes, including repeated requirements for explosive power, agility, and endurance. At the core of this complex structure lies the developmental process of young athletes and the biomechanical challenges they encounter during growth. In this context, the increasing physical and biomechanical demands of soccer necessitate a more careful and scientifically grounded evaluation, particularly in youth populations.

Soccer participation in children and adolescents involves frequent high-intensity sprints, rapid changes of direction, jumping actions, and continuous balance control, all of which require significant physiological and biomechanical adaptations (Mao et al., 2022). This developmental period is characterized by heightened neuromuscular plasticity, postural control, and motor learning capacity, making it a critical window for adaptation to environmental stimuli (Faigenbaum & Myer, 2010a). However, rapid growth and maturation during adolescence may lead to temporary imbalances, as bone growth can outpace the adaptive capacity of soft tissues such as muscles, tendons, and ligaments. This mismatch may result in reduced tissue tolerance and increased biomechanical vulnerability (Padua et al., 2015), a phenomenon often described as "adolescent awkwardness" and associated with temporary impairments in proprioception and balance control (Wachholz et al., 2020). In sports such as soccer that involve high-speed and multidirectional movements, these physiological discrepancies may lead to suboptimal load distribution across the musculoskeletal system. This, in turn, is associated with an increased risk of injury (Auer et al., 2021). Previous research has shown that a substantial proportion of soccer injuries are linked to modifiable risk factors, including insufficient fundamental movement skills (Moore et al., 2019), impaired postural alignment (Liu, 2022), inadequate neuromuscular control (Howell et al., 2018), and inefficient running mechanics (Ceyssens et al., 2019). Among these, postural misalignments—such as excessive anterior pelvic tilt, forward head posture, and scapular protraction—are of particular concern, as they alter joint loading patterns and force distribution during high-velocity movements, thereby compounding the biomechanical deficiencies described above. These deficiencies increase abnormal joint loading, particularly in the knee (e.g., anterior cruciate ligament injuries), ankle, and hamstring regions (Siegel et al., 2012).

Therefore, early identification and targeted correction of these modifiable risk factors are essential not only for reducing injury risk but also for enabling the safe and sustainable development of athletic performance. Accordingly, modern sports science has shifted from a reactive approach—treating injuries after they occur—to a proactive approach that identifies and corrects underlying biomechanical and neuromuscular limitations before injury onset (Khosravi, 2025). This proactive perspective requires a systematic and holistic methodological framework: one that objectively evaluates movement quality, identifies existing limitations and asymmetries, and informs the design of individualized intervention programs. Within this framework, the Youth Physical Development Model emphasizes that young athletes should be supported not only through sport-specific training but also through fundamental athletics and corrective exercise interventions (Lloyd & Oliver, 2012). The development of fundamental movement skills at an early age enhances physical fitness and contributes to long-term participation and success in sport (Lubans et al., 2010).

In recent years, the Functional Movement Screen (FMS) has become a widely used tool for assessing movement quality, offering an objective evaluation of dynamic stability and neuromuscular control (Cook et al., 2014). It should be noted that although the FMS has also been investigated as a tool for identifying athletes at increased risk of injury, evidence regarding its predictive validity for this purpose remains inconsistent, and it should not be used as a standalone injury-prediction tool (Dorrel et al., 2015). In the present study, the FMS was therefore employed not to predict injury risk but as a practical, field-based instrument for evaluating movement quality and guiding individualized corrective exercise prescription—an application supported by its established practicality in sports settings (Kraus et al., 2014).

Although previous studies have demonstrated that structured resistance training and corrective exercise programs can improve movement quality and selected physical performance outcomes in youth populations (Faigenbaum & Myer, 2010b; Liao et al., 2019; Myers et al., 2017; Stricker et al., 2020), limited evidence exists regarding the combined implementation of fundamental athletics and individualized corrective exercise programs during the U15 developmental stage. This period generally coincides with peak height velocity, during which rapid skeletal growth may temporarily exceed the adaptive capacity of muscles, tendons, and neuromuscular control systems, thereby increasing injury susceptibility (Ribeiro et al., 2024). Consequently, young athletes may experience temporary reductions in coordination, movement efficiency, dynamic stability, and overall movement quality during growth and maturation (Ribeiro et al., 2024). The fundamental athletics program implemented in the present study was designed to improve locomotor skills and movement efficiency, while the corrective exercise component specifically targeted individual movement limitations, mobility restrictions, stability deficits, and neuromuscular asymmetries identified through FMS assessment (Cook et al., 2014; Kraus et al., 2014). Combining these two complementary approaches may therefore provide more comprehensive adaptations than applying either approach alone. However, previous studies have generally examined these interventions separately, and the effectiveness of an integrated program on functional movement quality, postural alignment, and sport-specific performance in youth soccer players remains insufficiently understood.

Technical deficiencies in running mechanics not only impair performance but also increase asymmetrical loading on the musculoskeletal system, thereby elevating the risk of chronic injuries (Gao et al., 2020). For instance, inadequate hip stability or limited ankle mobility may negatively influence lower-extremity biomechanics, balance, and movement efficiency (Kayhan et al., 2024a). Corrective exercises and fundamental athletics training target these biomechanical dysfunctions by optimizing force transmission, enhancing neuromuscular control, and improving movement efficiency throughout the kinetic chain (Almansoof et al., 2023; Fort-Vanmeerhaeghe et al., 2016). These physiological adaptations are reflected in improved performance outcomes, such as faster sprint times, enhanced agility, and increased jump height, while also promoting a more balanced distribution of mechanical loads and reducing injury incidence (Bishop et al., 2021; Henry et al., 2016; Hrysomallis, 2012; Manouras et al., 2016). From a practical standpoint, integrating test–intervention–retest models into field settings is essential for developing individualized training programs, continuously monitoring performance, and evaluating the effectiveness of injury prevention strategies—an approach particularly valuable for establishing comprehensive performance monitoring systems at the club level.

Therefore, the aim of this study was to examine the effects of an eight-week structured fundamental athletics and corrective exercise program on functional movement quality, postural alignment, and key performance parameters (sprint, agility, jump, and balance) in U15 youth soccer players. The results are expected to contribute to the existing literature by addressing this methodological gap and to provide a scientifically grounded, practical framework for coaches and sports scientists. It was hypothesized that the intervention would lead to significant improvements in functional movement quality, postural alignment, and performance parameters compared to routine training.

Materials and Methods

Participants

Sample size estimation was performed using G*Power software based on a medium effect size ($f = 0.25$), as recommended by Jacob Cohen, with a significance level of $\alpha = 0.05$ and statistical power $(1 - \beta) = 0.80$. The analysis, based on a two-group, two-measurement design, indicated a minimum required total sample size of 34 participants. Accordingly, a total of 42 male youth soccer players (U15 category), who were actively licensed and competing in amateur soccer clubs in the Beykoz district of Istanbul, voluntarily participated in the study. Participants were recruited using a club-based convenience sampling method and were allocated into two groups: an experimental group and a control group. The experimental group consisted of players from Yenimahalle Sports Club (n

= 21), while the control group comprised players from Paşabahçe Soğuksu Sports Club (n = 21). However, five participants from the control group did not complete the post-test assessments and were therefore excluded from the final analysis.

The inclusion criteria were as follows: being an actively licensed soccer player, regularly participating in training sessions, having no recent acute injuries, and providing voluntary consent to participate in the study. Participants who sustained injuries during the study period or failed to attend testing sessions regularly were excluded from the analysis.

Research Design

This study was conducted using a pre-test–post-test quasi-experimental research design with a control group to examine the effects of a structured fundamental athletics and corrective exercise program on functional movement quality, postural alignment, and physical performance parameters in youth soccer players. Within this design, the experimental group underwent the specified intervention program, while the control group continued their regular training routines without any additional intervention. Both groups were assessed using the same standardized measurement protocol at baseline (pre-test) and after the eight-week intervention period (post-test). This design allowed for the evaluation of both within-group changes over time and between-group differences in response to the intervention.

Data Collection Procedures

All measurements were conducted under standardized environmental conditions at the training facilities of the participating clubs located in the Beykoz district of Istanbul. To minimize the potential effects of circadian variation, data collection was performed within similar time intervals for both groups. Pre-test assessments were conducted prior to the initiation of the intervention program, while post-test assessments were completed within 72 hours following the conclusion of the eight-week intervention period. All measurements were carried out in the late afternoon, between 17:00 and 19:00, prior to regular training sessions.

The testing protocol was administered over two separate days. Anthropometric measurements, postural analysis, FMS, and balance assessments were conducted on the same day in an indoor setting. Sprint, jump, and agility tests were performed on a synthetic turf field one day later to minimize fatigue effects, with participants wearing standard soccer training attire. A passive recovery period of 2–3 minutes was provided between tests to ensure adequate recovery (Bompa & Buzzichelli, 2019). All assessments were performed by the same research team to ensure consistency. Testing procedures, equipment, test order, and environmental conditions were standardized across all participants. Given the club-based, non-randomized allocation of participants, assessors were not blinded to participants' group membership (experimental vs. control) during testing.

Prior to testing, all participants completed a standardized warm-up protocol lasting approximately 15 minutes, consisting of three phases. The first phase involved ~5 minutes of low-intensity, self-paced running to increase muscle temperature, activate the circulatory system, and prepare the neuromuscular system for exercise. The second phase consisted of ~5 minutes of dynamic mobility exercises, including walking lunges (10 repetitions), high knees (20 m), butt kicks (20 m), leg swings (anterior–posterior and lateral; 10 repetitions per leg), arm circles (10 repetitions), and trunk rotations (10 repetitions). The third phase included ~5 minutes of neuromuscular activation exercises aimed at preparing participants for performance testing, including submaximal jumps (5 repetitions), short acceleration runs (10 m, 2 repetitions), and change-of-direction drills.

Measurement Instruments

FMS: FMS, developed by Gray Cook, was used to assess participants' functional movement quality (Cook et al., 2014). All assessments were conducted on a flat and firm surface, with participants wearing appropriate sportswear and athletic shoes. Prior to testing, standardized instructions were provided by a certified examiner, and no corrective feedback or coaching cues were given during test execution. The FMS battery consisted of seven movement patterns: Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-Up, and Rotary Stability(Gulgin & Hoogenboom, 2014). Each movement was scored on a scale from 0 to 3, with a maximum composite score of 21 points. The FMS has demonstrated acceptable reliability (ICC ≥ 0.767) in previous studies (Gulgin & Hoogenboom, 2014). All assessments were performed by a certified FMS Level 2 specialist.

Postural Analysis (PostureScreen Mobile): Postural alignment was evaluated using photometric analysis based on images captured in anterior, posterior, and lateral planes in front of a standardized posture grid. To ensure consistency, a digital camera was positioned on a tripod at a distance of 3 m from the participant and at a height of 120 cm. The captured images were analyzed by an experienced physiotherapist, focusing on head–neck, shoulder, spinal, pelvic, and lower extremity (leg–foot) segments. Postural deviations and asymmetries were classified using a three-level scale: no deviation (−), mild deviation (1/2 +), and marked deviation (+).

Sprint Test (20 m): Sprint performance was assessed using a 20 m sprint test. Timing was recorded using a high-precision photocell system (VALD Performance SmartSpeed, Fusion Sport, Australia). Photocells were positioned at approximately 100 cm above ground level to minimize timing errors and were placed at the start and 20 m finish lines (Holmberg et al., 2025). The test was initiated from a static standing start. Participants positioned their dominant foot forward behind the starting line and stood approximately 30 cm behind the first photocell to avoid premature triggering. No auditory or visual start signal was provided; participants initiated the sprint voluntarily when ready (Holmberg et al., 2025). Each participant performed two trials with 3 minutes of passive recovery between attempts, and the best time (shortest duration, in seconds) was used for analysis.

Agility Test (Pro-Agility / 5–10–5 Test): Agility performance was evaluated using the Pro-Agility (5–10–5) test. The test was conducted on a grass field, with distances of 5 yards (4.57 m) marked on either side of a central line, totaling 10 yards (9.14 m). Timing was measured using the same photocell system (VALD Performance SmartSpeed) (Stewart et al., 2014). The test has demonstrated high reliability in previous studies (ICC $\geq$ 0.90) (Stewart et al., 2014). Photocells were positioned at the central line at approximately 100 cm height. Participants adopted a lateral starting position at the center line and were allowed to choose their preferred initial direction. They were instructed to sprint 5 yards in one direction, change direction and sprint 10 yards in the opposite direction, and finally change direction again to return to the starting point at maximal speed (Stewart et al., 2014). Two trials were performed with 1 minute of passive rest between attempts, and the best performance (shortest time) was recorded.

Jump Performance Tests: Explosive lower-body performance was assessed using vertical and horizontal jump tests. Vertical jump performance was measured using the Countermovement Jump (CMJ). Participants started from an upright position with feet shoulder-width apart and hands placed on the hips. They were instructed to perform a rapid downward movement (hip and knee flexion) followed immediately by a maximal vertical jump. Full extension of the hips and knees was encouraged, and participants were required to land in a controlled and balanced manner (Dobbin et al., 2017). Horizontal jump performance was assessed using the standing long jump test. Participants started just behind the take-off line with feet parallel and shoulder-width apart. They were instructed to perform a maximal forward jump using a countermovement and arm swing, landing with both feet while maintaining balance. Jump distance was measured from the take-off line to the rearmost point of contact (heel) and recorded in centimeters (Kayhan et al., 2024b). Each participant performed two trials for both jump tests, with 1 minute of rest between attempts. The best performance was used for analysis.

Exercise Intervention Protocol

The exercise program implemented in the experimental group consisted of fundamental athletics drills combined with corrective exercises based on individual FMS results. The program was performed four times per week and was integrated into the second phase of the warm-up and the initial part of the main training session. Each session lasted approximately 20–25 minutes. All training sessions were conducted under standardized field conditions, within the same time interval (17:00–19:00), and under the supervision of the same coach. The eight-week fundamental athletics program was designed progressively in accordance with the principle of progressive overload and structured into two distinct training phases. The first program was applied during the initial four weeks, followed by a second program in the subsequent four weeks. The transition between phases was determined based on the athletes' technical proficiency and adaptation level.

During the first phase (Weeks 1–4), the primary objective was to develop basic running mechanics, postural control, rhythm, and coordination. Exercises in this phase primarily emphasized technical learning and movement quality. Athletes were instructed to maintain an upright trunk position, ensure pelvic stability, minimize ground contact time, and perform coordinated arm–leg movements. Rest intervals of approximately 20–30 seconds were provided between sets and 45–60 seconds between exercises. Training intensity was maintained at a moderate level to preserve technical accuracy.

In the second phase (Weeks 5–8), the focus shifted to improving acceleration mechanics, increasing single-leg force production, and optimizing the use of elastic energy. During this phase, both the neuromuscular demand and technical complexity of the exercises were progressively increased, and the applied exercises are presented in Table 1 (second phase). Athletes were instructed to produce maximal horizontal force with minimal ground contact time, increase stride frequency, and maintain an optimal acceleration angle. Exercise intensity was higher compared to the first phase; however, technical execution remained a priority throughout.

Table 1

Content of the Applied Fundamental Athletics Training Program

Phase		Exercise	Sets	Distance
Program I (Weeks 1–4)	1	Forward and Back Lunge	2	15m
	2	A March	4	10m
	3	A Skips	4	10-15m
	4	Straight Leg Scissors Run	2-3	15-30m
	5	45 Deg. High Knees	2-3	10m
	6	90 Deg. High Knees	2-3	10m
Program II (Weeks 5–8)	1	Forward and Back Lunge	2	15m
	2	A Skips	4	10-15m
	3	Straight Leg Scissors Run	2-3	15-30m
	4	Single Leg Knee Drive Runs	2-3	30m
	5	SL Bouncing Knee Drive	2	15m
	6	From 45 to 90 Deg. High Knees	2	15m

In addition to the fundamental athletics training, individualized corrective exercises were implemented weekly based on the results of the FMS assessments. Following the FMS evaluation, movement deficiencies specific to each athlete (e.g., limitations in deep squat, in-line lunge, hamstring mobility, shoulder mobility, and trunk stability) were identified, and tailored exercise programs were developed accordingly. The corrective exercise program was structured into three main components: (1) mobility and activation, (2) core stabilization, and (3) functional strength and stability. The mobility and activation component included foam rolling and mini-band activation exercises to prepare muscle and connective tissue for exercise, along with ankle–hip mobility drills, deep squat hip opening, active hamstring stretching, and thoracic rotation exercises.

The core stabilization component consisted of exercises such as dead bug, single-leg hip hinge, plank, and side plank, aimed at improving trunk control and neuromuscular stability. The functional strength and stability component included bodyweight squat, rear-leg elevated split squat, glute bridge, jump squat, push-up, superman, and wall squat snow angels, targeting improvements in both upper and lower extremity strength as well as postural control (Table 2).

All exercises were performed in 2 sets of 8–12 repetitions or for 30 seconds, with 30–45 seconds of rest between sets. To ensure proper supervision and standardization, fundamental athletics sessions were conducted by a certified athletics coach, whereas FMS assessments and corrective exercise programs were administered by practitioners holding FMS Level 2 certification.

Table 2

Content of the Corrective Exercise Program

Phase	Exercise	Sets × Repetitions / Duration	Tempo	Rest
General Warm-Up	Foam Roller	5 min	-	-
	Bicycle	5 min	-	-
	Mini Band	5 min	-	-
Warm-Up / Mobility / Activation	Ankle Hip Mobility	10 reps / leg	2-2	-
	Deep Squat Hip Opening	12 reps / leg	2-2	-
	Lying Ham Active Stretch	12 reps / leg	1-1	-
	Dead Bug	2 x 12 reps / leg	-	-
	Rib Grab T-Spine Rotation	2 x 10 reps / leg	-	-
	Single Leg Hip Hinge with Dowel	2 x 6 reps / leg	-	-
	Plank	2 x 30 s	-	30 s
	Side Plank	2 x 30 s	-	30 s
Development	Body Weight Squat	2 x 10 reps	1-1	45 s
	Rear Leg Elevated Split Squat	2 x 30 s / leg	-	45 s
	Glute Bridge	2 x 12 reps	1-1	45 s
	Jump Squat	2 x 10 reps	1-1	45 s
	Push Up	2 x 5-10 reps	1-1	45 s
	Pull Up Superman	2 x 5-10 reps	1-1	45 s
	Wall Squat Snow Angels	2 x 5-10 reps	1-1	45 s

Ethical Considerations

Ethical approval for this study was obtained from the Scientific Research and Publication Ethics Committee of Iğdır University (Decision No: 2025/35; Date: 20 August 2025). The study was conducted in accordance with the principles of the Declaration of Helsinki. All participants and their legal guardians were informed about the study procedures, and written informed consent was obtained prior to participation. During the present study, all procedures were conducted in accordance with the ‘Directive on Scientific Research and Publication Ethics of Higher Education Institutions.

Data Analysis

Sample size estimation was performed using G*Power software (version 3.1.9.7). Statistical analyses were conducted using SPSS (version 27.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables and are presented as mean, standard deviation, minimum, and maximum values.

The normality of the data distribution was assessed using the Shapiro–Wilk test. In addition, normality assumptions were verified through visual inspection of histogram and Q–Q plots, as well as skewness and kurtosis values. For continuous variables meeting the assumption of normality — namely the Total FMS score and the physical performance parameters (balance, vertical jump, horizontal jump, agility, and sprint) — a 2 (Group: Experimental, Control) × 2 (Time: Pre-test, Post-test) mixed-design ANOVA was performed to examine the main effects of Time and Group, as well as the Time × Group interaction effect. Partial eta squared (η^2p) was reported as the effect size for the ANOVA results. For variables that did not meet the normality assumption — namely the FMS subtest scores — the Wilcoxon signed-rank test was used for within-group comparisons, and the Mann–Whitney U test was applied for between-group comparisons. Homogeneity of variances was assessed using Levene's test. When the assumption of homogeneity was violated, corrected test results were considered. The level of statistical significance was set at $p < 0.05$. Differences in the distribution of overall postural scores between groups were analyzed using the chi-square test. In cases where more than 20% of expected cell frequencies were less than 5, the Fisher–Freeman–Halton exact test was applied. Effect sizes were calculated using Cohen's d for t-test/non-parametric comparisons, interpreted as small (0.2), medium (0.5), and large (0.8) in accordance with the guidelines of Jacob Cohen (Cohen, 2013).

Since multiple comparisons were performed across several outcome variables within the same analytical family (e.g., the six FMS subtests and the five physical performance parameters), the Benjamini–Hochberg false discovery rate (FDR) correction was applied to control for Type I error inflation. Corrections were applied separately within each family of related tests — namely, within-group comparisons for the experimental and control groups, between-group comparisons, and the Time, Group, and Time × Group interaction effects for each outcome domain. Both raw (uncorrected) and FDR-adjusted p-values are reported in the corresponding tables, and statistical significance was evaluated based on the FDR-adjusted p-values.

Results

Table 3

Descriptive Characteristics of the Participants

Variable	Experimental Group (n = 21) Mean ± SD	Control Group (n=16) Mean ± SD
Age (years)	14.50 ± 0.44	14.32 ± 0.80
Body Mass (kg)	57.12 ± 13.64	50.91 ± 18.75
Height (cm)	160.55 ± 11.28	154.18 ± 13.16
BMI (kg/m²)	21.87 ± 3.21	20.75 ± 4.59

Abbreviations: n = number of people, SD = standard deviation, kg = kilogram, cm = centimeter, m = meter.

As presented in Table 3, the mean age of the experimental group (n = 21) was 14.50 ± 0.44 years, whereas the control group (n = 16) had a mean age of 14.32 ± 0.80 years. Mean body mass was 57.12 ± 13.64 kg in the experimental group and 50.91 ± 18.75 kg in the control group. Mean height values were 160.55 ± 11.28 cm and 154.18 ± 13.16 cm for the experimental and control groups, respectively. Body mass index (BMI) values were 21.87 ± 3.21 kg/m² in the experimental group and 20.75 ± 4.59 kg/m² in the control group.

Table 4

Pre- and Post-Test Results of the FMS Subtests and Within-Group and Between-Group Comparisons

Group/ Test	Pre-Test Mean ± SD	Post-Test Mean ± SD	Change Mean ± SD	Within-Group Analysis	Between-Group Analysis
Deep Squat					
Experimental (n=21)	1.24 ± 0.54	2.00 ± 0.84	0.76 ± 0.62	W:105.000; Z:3.557; **p<0.001;** q:0.003	U:77.500; **p:0.002**;
Control (n=16)	1.31 ± 0.60	1.38 ± 0.62	0.06 ± 0.57	W:9.000; Z:0.447; p:0.655; q:0.655	d:1.159 q:0.012
Hurdle Step					
Experimental (n=21)	1.67 ± 0.48	2.00 ± 0.32	0.33 ± 0.48	W:28.000; Z:2.646; **p:0.008;** q:0.016	U:126.000; p:0.096 q:0.288
Control (n=16)	1.88 ± 0.34	1.94 ± 0.25	0.06 ± 0.44	W:4.000; Z:0.577; p:0.564; q:0.655	
In-Line Lunge					
Experimental (n=21)	1.52 ± 0.51	2.05 ± 0.67	0.52 ± 0.51	W:66.000; Z:3.317; **p:0.001;** q:0.003	U:149.000; p:0.508 q:0.610
Control (n=16)	1.25 ± 0.77	1.75 ± 0.58	0.50 ± 0.82	W : 15.000; Z : 2.070; **p : 0.038;** q:0.103	
Shoulder Mobility					
Experimental (n=21)	2.14 ± 1.15	2.57 ± 0.60	0.43 ± 0.81	W:33.000; Z:2.165; **p:0.030;**q:0.045	U:174.500; p:0.814 q:0.814
Control (n=16)	1.81 ± 1.05	2.38 ± 0.72	0.56 ± 0.96	W:15.000 Z:2.041**; p:0.041;** q:0.103	
Active Straight Leg Raise					
Experimental (n=21)	1.95 ± 0.67	2.00 ± 0.55	0.05 ± 0.50	W:9.000; Z:0.447; p:0.655; q:0.655	U:189.000; p:0.408 q:0.610
Control (n=16)	1.38 ± 0.62	1.56 ± 0.51	0.19 ± 0.54	W:12.000; Z:1.342; p:0.180; q:0.300	
Trunk Stability Push-Up					
Experimental (n=21)	1.00 ± 0.00	1.00 ± 0.00	-	-	-
Control (n=16)	1.00 ± 0.00	1.00 ± 0.00	-	-	
Rotary Stability					
Experimental (n=21)	0.95 ± 0.22	1.00 ± 0.00	0.05 ± 0.22	W:1.000; Z:1.000; p: 0.317; q:0.380	U:160.000; p:0.383 q:0.610
Control (n=16)	1.00 ± 0.00	1.00 ± 0.00	-	-	

Abbreviations: p = significance level, W = Wilcoxon signed-rank test, U = Mann–Whitney U test, n = number of people, SD = standard deviation; d = Cohen's d,

Table 4 presents the within-group and between-group comparison results for the seven Functional Movement Screen (FMS) subtests.

For the Deep Squat subtest, the experimental group's score increased significantly from 1.24±0.54 at pre-test to 2.00±0.84 at post-test (Δ=0.76±0.62; W=105.000; Z=3.557; $p<0.001$; FDR-adjusted q=0.003), whereas no significant change was observed in the control group (1.31±0.60 to 1.38±0.62; Δ=0.06±0.57; W=9.000; Z=0.447; p=0.655; q=0.655). The between-group comparison revealed a significant difference favoring the experimental group (U=77.500; p=0.002; q=0.012; d=1.159).

For the Hurdle Step subtest, the experimental group demonstrated a significant improvement from 1.67±0.48 to 2.00±0.32 (Δ=0.33±0.48; W=28.000; Z=2.646; p=0.008; q=0.016), while the control group showed no significant change (1.88±0.34 to 1.94±0.25; Δ=0.06±0.44; W=4.000; Z=0.577; p=0.564; q=0.655). No significant between-group difference was found (U=126.000; p=0.096; q=0.288).

For the In-Line Lunge subtest, both groups exhibited significant within-group improvements: the experimental group from 1.52±0.51 to 2.05±0.67 (Δ=0.52±0.51; W=66.000; Z=3.317; p=0.001; q=0.003), and the control group from 1.25±0.77 to 1.75±0.58 (Δ=0.50±0.82; W=15.000; Z=2.070; p=0.038; q=0.103). No significant between-group difference was observed (U=149.000; p=0.508; q=0.610).

For the Shoulder Mobility subtest, both groups showed significant within-group improvements: the experimental group from 2.14±1.15 to 2.57±0.60 (Δ=0.43±0.81; W=33.000; Z=2.165; p=0.030; q=0.045), and the control group from 1.81±1.05 to 2.38±0.72 (Δ=0.56±0.96; W=15.000; Z=2.041; p=0.041; q=0.103). No significant between-group difference was found (U=174.500; p=0.814; q=0.814).

For the Active Straight Leg Raise subtest, neither the experimental group (1.95±0.67 to 2.00±0.55; Δ=0.05±0.50; W=9.000; Z=0.447; p=0.655; q=0.655) nor the control group (1.38±0.62 to 1.56±0.51; Δ=0.19±0.54; W=12.000; Z=1.342; p=0.180; q=0.300) demonstrated a significant within-group change. No significant between-group difference was observed (U=189.000; p=0.408; q=0.610).

For the Trunk Stability Push-Up subtest, scores remained unchanged at 1.00±0.00 for both groups at pre- and post-test, precluding statistical comparison.

For the Rotary Stability subtest, the experimental group's score increased from 0.95±0.22 to 1.00±0.00 (Δ=0.05±0.22), although this change did not reach statistical significance (W=1.000; Z=1.000; p=0.317; q=0.380). The control group's score remained unchanged at 1.00±0.00. No significant between-group difference was found (U=160.000; p=0.383; q=0.610).

Table 5

Comparison of Total FMS by Group and Time

Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Δ (Mean ± SD)	Time	Group	Time X Group
Balance						
Experimental (n=21)	10.48±2.44	12.62±2.06	↓0.39	**F:** 75.177 **p:** <0.001 **η²p:** 0.682 **q:** 0.001	**F:** 3.791 **p:** 0.060 **η²p:** 0.098 **q:** 0.067	**F:** 3.582 **p:** 0.067 **η²p:** 0.093 **q:** 0.067
Control (n=16)	9.63±1.86	11.00±1.32	↓0.12			

Abbreviations: p = significance level, F = F test, n = number of people, SD = standard deviation; **Δ =** change, η²p = partial eta square, q = FDR, cm = centimeter, sec = second.

Table 5 presents the results of the mixed-design ANOVA conducted on the Total FMS score across groups and time points.

The Total FMS score increased in both the experimental group (10.48±2.44 at pre-test to 12.62±2.06 at post-test; Δ=0.39) and the control group (9.63±1.86 to 11.00±1.32; Δ=0.12) over the course of the intervention. A significant main effect of Time was observed (F=75.177; p<0.001; η^2p=0.682; FDR-adjusted q=0.001), indicating that Total FMS scores improved significantly across both groups from pre-test to post-test. However, the main effect of Group did not reach statistical significance (F=3.791; p=0.060; η^2p=0.098; q=0.067), suggesting no significant overall difference in Total FMS scores between the experimental and control groups. Similarly, the Time × Group interaction effect was not statistically significant (F=3.582; p=0.067; η^2p=0.093; q=0.067), indicating that the magnitude of improvement in Total FMS scores over time did not differ significantly between the two groups.

Table 6

Pre- and Post-Test Distribution of Postural Assessments According to Groups

Group	Postural Parameter	Pre-Test (n)	Post-Test (n)	Improvement (n)
Experimental Group (n=21)	Shoulder Elevation	11	9	2
	Protraction	18	17	1
	Lumbar Lordosis	14	13	1
	Anterior Pelvic Tilt	15	14	1
	Forward Head Posture / Cervical Straightening	7	7*	0 (4 minimal improvements)
	Scapular Wings	6	6	0
	Knee Alignment Problems	9	9	0
Control Group (n=16)	Shoulder Elevation	6	5	1
	Protraction	13	13	0
	Lumbar Lordosis	5	5	0
	Anterior Pelvic Tilt	10	10	0
	Forward Head Posture / Cervical Straightening	5	5	0

Scapular Wings	5	5	0
Knee Alignment Problems	7	6	1

Abbreviations: n = number of people.

As presented in Table 6, frequency analysis was used to evaluate the distribution of pre-test and post-test postural assessment results in the experimental group. The number of participants presenting with shoulder elevation decreased from 11 at pre-test to 9 at post-test, indicating improvement in 2 participants. Protraction was observed in 18 participants at pre-test and decreased to 17 participants at post-test, with improvement identified in 1 participant. Lumbar lordosis results decreased from 14 participants at pre-test to 13 participants at post-test, corresponding to improvement in 1 participant. Similarly, anterior pelvic tilt was observed in 15 participants at pre-test and 14 participants at post-test, with improvement recorded in 1 participant.

Forward head posture/cervical straightening was identified in 7 participants at pre-test and remained present in the same number of participants at post-test; however, minimal postural improvement was observed in 4 participants, although no complete correction was achieved. Scapular winging remained unchanged in 6 participants, and no improvement was observed. Likewise, knee alignment problems were identified in 9 participants at both pre-test and post-test, with no observable improvement.

In the control group, shoulder elevation decreased from 6 participants at pre-test to 5 participants at post-test, indicating improvement in 1 participant. Knee alignment problems decreased from 7 to 6 participants, with improvement observed in 1 participant. In contrast, no changes were observed in the frequency of protraction, lumbar lordosis, anterior pelvic tilt, forward head posture/cervical straightening, or scapular winging between pre-test and post-test assessments.

Table 7

Distribution of Changes in Overall Postural Scores According to Groups

Group	No Change n (%)	Minimal Improvement n (%)	Marked Improvement n (%)	p
Experimental (n=21)	13 (%61.90)	6 (%28.60)	2 (%9.50)	0.205
Control (n=16)	14 (%87.50)	2 (%12.50)	0 (%0.0)	

Abbreviations: p = significance level, n = number of people, % = percent.

As presented in Table 7, analysis of changes in overall postural scores in the experimental group revealed that no change was observed in 61.90% of participants (n = 13), whereas minimal improvement was identified in 28.60% (n = 6) and marked improvement in 9.50% (n = 2) of participants. In the control group, no change was observed in 87.50% of participants (n = 14), while minimal improvement was identified in 12.50% (n = 2). No marked improvement was observed in the control group. The Fisher–Freeman–Halton exact test was performed to determine whether differences existed between the experimental and control groups regarding the distribution of overall postural score changes. The analysis revealed no statistically significant difference between groups (p = 0.205).

Table 8

Comparison of Physical Performance Parameters by Group and Time

Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Δ (Mean ± SD)	Time	Group	Time X Group
Balance						
Experimental (n=21)	3.08±0.79	2.70±0.66	↓0.39	**F:** 4.774 **p:** 0.036	**F:** 0.111 **p:** 0.741	**F:** 1.288 **p:** 0.264
Control (n=16)	2.86±1.15	2.74±0.78	↓0.12	**η^2p:** 0.120 **q:**0.036	**η^2p:** 0.003 **q:**0.926	**η^2p:** 0.035 **q:**0.330
Vertical Jump (cm)						
Experimental (n=21)	25.22±4.63	26.46±4.98	↑1.24	**F:** 15.205 **p:** <0.001	**F:** 5.659 **p:** 0.023	**F:** 0.278 **p:** 0.602
Control (n=16)	20.89±7.00	21.83±6.59	↑0.94	**η^2p:** 0.303 **q:**0.0008	**η^2p:** 0.139 **q:**0.115	**η^2p**: 0.008 **q:**0.602
Horizontal Jump (cm)						
Experimental (n=21)	158.10±19.74	174.19±19.25	↑16.10	**F:** 20.619 **p:** <0.001	**F:** 3.101 **p:** 0.087	**F:** 8.916 **p:** 0.005
Control (n=16)	152.13±28.09	155.45±21.83	↑3.33	**η^2p:** 0.371 **q:**<0.001	**η^2p:** 0.081 **q:**0.218	**η^2p:** 0.203 **q:**0.008
Agility (sec)						
Experimental (n=21)	6.25±0.39	5.91±0.29	↓0.34	**F:** 10.383 **p:** 0.003	**F:** 0.005 **p:** 0.943	**F:** 10.926 **p:** 0.002
Control (n=16)	6.08±0.39	6.09±0.31	↑0.00	**η^2p:** 0.229 **q:**<0.001	**η^2p:** 0.000 **q:**0.943	**η^2p:** 0.238 **q:**0.005
Sprint (sec)						
Experimental (n=21)	3.88±0.25	3.66±0.19	↓0.22	**F:** 27.652 **p:** <0.001	**F:** 1.667 **p:** 0.205	**F:** 28.283 **p:** <0.001
Control (n=16)	3.87±0.31	3.88±0.25	↑0.00	**η^2p:** 0.441 **q:**<0.001	**η^2p:** 0.045 **q:**0.342	**η^2p:** 0.447 **q:**0.002

Abbreviations: p = significance level, F = F test, n = number of people, SD = standard deviation; **Δ =** change, η^2p = partial eta square, q = FDR, cm = centimeter, sec = second.

Table 8 presents the results of the mixed-design ANOVA conducted on the physical performance parameters (balance, vertical jump, horizontal jump, agility, and sprint) across groups and time points.

For Balance, a significant main effect of Time was observed (F=4.774; p=0.036; η^2p=0.120; q=0.036), indicating that balance scores changed significantly from pre-test to post-test across both groups, with the experimental group decreasing from 3.08±0.79 to 2.70±0.66 (Δ=0.39) and the control group decreasing from 2.86±1.15 to 2.74±0.78 (Δ=0.12). Neither the main effect of Group (F=0.111; p=0.741; η^2p=0.003; q=0.926) nor the Time × Group interaction (F=1.288; p=0.264; η^2p=0.035; q=0.330) reached statistical significance.

For Vertical Jump, a significant main effect of Time was found (F=15.205; p<0.001; η^2p=0.303; q=0.0008), with performance improving in both the experimental group (25.22±4.63 to 26.46±4.98 cm; Δ=1.24) and the control group (20.89±7.00 to 21.83±6.59 cm; Δ=0.94). A significant main effect of Group was also observed ($F=5.659$; $p=0.023$; $\eta^2p=0.139$; $q=0.115$), indicating an overall difference between groups. However, the Time × Group interaction was not significant ($F=0.278$; $p=0.602$; $\eta^2p=0.008$; $q=0.602$), suggesting that the rate of improvement did not differ significantly between groups.

For Horizontal Jump, a significant main effect of Time was observed ($F=20.619$; $p<0.001$; $\eta^2p=0.371$; $q<0.001$), with the experimental group improving from 158.10±19.74 to 174.19±19.25 cm (Δ=16.10) and the control group improving from 152.13±28.09 to 155.45±21.83 cm (Δ=3.33). The main effect of Group was not statistically significant ($F=3.101$; $p=0.087$; $\eta^2p=0.081$; $q=0.218$); however, a significant Time × Group interaction was found ($F=8.916$; $p=0.005$; $\eta^2p=0.203$; $q=0.008$), indicating that the experimental group demonstrated a significantly greater improvement in horizontal jump performance over time compared to the control group.

For Agility, a significant main effect of Time was found ($F=10.383$; $p=0.003$; $\eta^2p=0.229$; $q<0.001$), with the experimental group's time improving from 6.25±0.39 to 5.91±0.29 sec (Δ=0.34), while the control group showed negligible change (6.08±0.39 to 6.09±0.31 sec; Δ=0.00). The main effect of Group was not significant ($F=0.005$; $p=0.943$; $\eta^2p=0.000$; $q=0.943$); however, a significant Time × Group interaction was observed ($F=10.926$; $p=0.002$; $\eta^2p=0.238$; $q=0.005$), indicating that the experimental group achieved significantly greater improvement in agility performance than the control group.

For Sprint, a significant main effect of Time was found ($F=27.652$; $p<0.001$; $\eta^2p=0.441$; $q<0.001$), with the experimental group's sprint time decreasing from 3.88±0.25 to 3.66±0.19 sec (Δ=0.22), while the control group showed no improvement (3.87±0.31 to 3.88±0.25 sec; Δ=0.00). The main effect of Group was not statistically significant ($F=1.667$; $p=0.205$; $\eta^2p=0.045$; $q=0.342$); however, a significant Time × Group interaction was observed ($F=28.283$; $p<0.001$; $\eta^2p=0.447$; $q=0.002$), indicating that the experimental group demonstrated a significantly greater improvement in sprint performance over time compared to the control group.

Discussion and Conclusion

Analysis of the participants' age, height, body mass, and body mass index (BMI) values indicated that the experimental and control groups exhibited broadly comparable physical and developmental characteristics at baseline. The mean age values of both groups were consistent with the U15 category and reflected variations typical of the growth and maturation period. Although the experimental group demonstrated numerically higher values for height and body mass, the overall distribution of the variables confirmed that both groups were physically well-matched prior to the intervention. This baseline equivalence strengthens confidence that the performance and movement-quality changes observed over the course of the study can be more directly attributed to the implemented exercise program rather than to pre-existing group differences.

Analysis of the functional movement assessment results revealed clear improvements in the experimental group, particularly in the deep squat, hurdle step, in-line lunge, and shoulder mobility tests (Table 4). Among these, the deep squat subtest stands out as the clearest demonstration of a program-specific effect, as it was the only FMS measure in which the experimental group's advantage over the control group was confirmed through direct between-group comparison even after correcting for multiple testing. This provides solid evidence that the corrective exercise program produced a genuine, targeted benefit for this movement pattern rather than a change attributable to general activity or maturation. For the remaining subtests, both groups tended to improve over time, but the magnitude of improvement could not be reliably distinguished between groups, indicating that the program's added value was most clearly and consistently detectable for deep squat performance rather than uniformly distributed across all FMS components.

At the level of the total FMS score (Table 5), both groups improved meaningfully across the intervention period; however, the interaction between time and group was not confirmed, meaning that the rate of improvement in the experimental group could not be statistically distinguished from that of the control group. This is an important qualification: although the corrective exercise program clearly supports functional movement quality, its superiority over standard soccer training was not established at the level of the composite FMS score. This likely reflects the fact that subtest-level gains—most notably in deep squat—did not uniformly extend to other components such as trunk stability push-up and active straight leg raise, which showed minimal change in either group and would be expected to dilute any group-specific signal once aggregated into a single composite score.

Consistent with the view that FMS primarily reflects movement quality and neuromuscular control rather than serving as a validated injury-prediction instrument (Dorrel et al., 2015), the present results are interpreted strictly in terms of movement-quality change rather than as evidence of reduced injury risk. Considering that FMS subtests are designed to assess multi-joint, multiplanar, and stability-demanding movement patterns (Cook et al., 2014), the program-specific improvement in deep squat performance observed in the experimental group likely reflects an enhanced interaction between lower-extremity mobility and lumbopelvic control—a demand distinct from the more isolated mobility or stability requirements of subtests where no comparable interaction effect emerged. Similarly, the shoulder mobility test reflects scapulothoracic mobility and muscular balance around the shoulder complex (Singh et al., 2023), and the improvements noted in this subtest further support the notion that the mobility- and stabilization-based components of the intervention meaningfully engaged the neuromuscular systems underlying these specific movement patterns.

Previous studies have similarly reported that corrective exercise and core stabilization programs can significantly improve total FMS scores. Bodden et al. (2015) demonstrated that an 8-week functional and core-focused exercise program improved total FMS scores, particularly in lower-extremity-related components, while Dorrel et al. (2015) found that corrective exercise interventions increased FMS scores while reducing movement asymmetries. The present study's more nuanced pattern—where deep squat showed a clear, statistically confirmed program-specific effect but the composite FMS score did not—suggests a somewhat more conservative picture than these earlier reports, and may reflect differences in intervention duration or the specific combination of subtests targeted. In contrast, minimal change was observed in the trunk stability push-up and rotary stability tests in both groups (Table 4), with no interaction effect emerging for rotary stability. This points to core stability components requiring longer intervention durations and more targeted loading strategies before a measurable, program-specific adaptation can emerge. Consistent with this interpretation, Silfies et al. (2005) argued that improvements in lumbopelvic stability depend on progressive, neuromuscular-control-based loading, and that short-term interventions such as the present eight-week program may be insufficient to produce a detectable time-by-group interaction in these more complex control-based parameters.

With respect to postural assessments (Tables 6 and 7), a considerably larger number of participants in the experimental group showed reductions in postural deviations such as shoulder elevation, protraction, lumbar lordosis, and anterior pelvic tilt compared with the control group, indicating a favorable directional trend attributable to the intervention. However, the distribution of overall postural change categories—no change, minimal improvement, and marked improvement—did not differ significantly between groups, indicating that these encouraging trends did not translate into a statistically confirmed group-specific advantage. This suggests that any postural benefit of the intervention remained at a descriptive or clinical level rather than reaching the threshold of a demonstrable program effect, plausibly because structural postural adaptations are understood to depend on cumulative, longer-term changes in muscular strength and neuromuscular control (Granacher et al., 2016) that an eight-week period may not be sufficient to consolidate. This interpretation is broadly consistent with prior work indicating that core stabilization exercises can meaningfully improve sagittal-plane alignment such as anterior pelvic tilt and lumbar lordosis (Akuthota & Nadler, 2004), and that neuromuscular training targeting scapular stabilization can support the correction of postural abnormalities such as shoulder protraction (Kibler et al., 2012)—both of which align with the favorable, if not yet statistically confirmed, directional improvements observed here in shoulder elevation and protraction.

The most consistent and interpretively important pattern in the present study emerged in the motor performance domain (Table 8), where horizontal jump, agility, and sprint were the only three variables for which the interaction between time and group was clearly confirmed. In each of these three measures, the experimental group's improvement over the intervention period was reliably and substantially greater than that of the control group, providing strong evidence that the corrective and athletics-based exercise program produced a genuine, program-attributable enhancement in explosive strength, change-of-direction ability, and linear sprint capacity. By contrast, balance and vertical jump improved over time in both groups without a distinguishable group-specific advantage, suggesting that these particular gains may instead reflect a general training or maturation effect common to any structured physical activity, including standard soccer training, rather than a unique contribution of the corrective exercise program itself.

This pattern of confirmed, program-specific improvement in horizontal jump and sprint aligns well with the broader plyometric and neuromuscular training literature. Markovic (2007) reported that plyometric training exerts a significant moderate-to-large effect on jump performance, and Saez de Villarreal et al. (2010) demonstrated that plyometric- and sprint-based training programs meaningfully improve both sprint time and jump performance in young athletes. The clearly confirmed interaction effects for sprint and horizontal jump in the present study reinforce these earlier results, while the absence of a comparable interaction for vertical jump suggests that the plyometric stimulus embedded within this particular program may have been more specifically suited to enhancing horizontal power expression than vertical power expression—a distinction that may be valuable for practitioners designing similarly structured programs for youth athletes.

The confirmed interaction effect observed for agility likewise aligns with evidence that plyometric-based training enhances change-of-direction performance (Miller et al., 2006) and that combined strength and plyometric training improves change-of-direction speed and sprint performance (Chaouachi et al., 2014). Because this improvement was specific to the experimental group relative to the control group, it provides compelling evidence of genuine program-driven adaptations in lower-extremity force-production capacity and eccentric-to-concentric transition efficiency, rather than adaptations attributable to soccer training or maturation alone.

The absence of a confirmed interaction for balance, despite a general time-related improvement occurring in both groups, tempers the broader claims found in the balance-training literature (Zech et al., 2010) regarding program-specific superiority; in the present study, balance appears to have improved as a function of regular physical activity rather than as a distinguishing feature of the corrective exercise program specifically. Nevertheless, given the close interrelation between balance, sprint, and agility performance in open-skill sports such as soccer (Table 8), it remains plausible that balance-related neuromuscular adaptations indirectly supported the confirmed improvements in sprint and agility, even though balance itself did not demonstrate an independent program-specific advantage. Consistent with this overall picture, only limited change was observed in the control group across most motor performance measures, underscoring that meaningful improvements in these components are difficult to achieve without regular and specifically targeted training stimuli. Behm et al. (2017) similarly emphasized that strength and neuromuscular training interventions are effective in improving sprint, jump, and agility performance in youth athletes, but that such adaptations require planned and progressive loading strategies—a requirement that the present, more targeted intervention appears to have successfully met for horizontal jump, agility, and sprint specifically.

Taken together, Tables 4, 5, and 8 point to a coherent and interpretively meaningful pattern: the intervention's clearest and most statistically defensible advantages over standard soccer training were concentrated in deep squat performance and in horizontal jump, agility, and sprint performance, all of which demonstrated a confirmed time-by-group interaction. In contrast, total FMS score, balance, and vertical jump improved over time in both groups without a distinguishable program-specific advantage, and postural outcomes showed favorable but statistically unconfirmed directional trends specific to the experimental group. Rather than indicating a limited or inconsistent effect, this pattern suggests that the corrective and athletics-based exercise program conferred a targeted, mechanistically coherent benefit, concentrated precisely in the movement patterns and performance qualities most directly addressed by its plyometric and mobility-based components. Given that performance adaptations are strongly influenced by intervention duration, training intensity, and exercise specificity, a longer-term and more sport-specific program could plausibly extend this confirmed superiority to additional outcome domains—such as total FMS score, balance, vertical jump, and overall postural alignment—where only a general, time-related improvement was observed in the present eight-week study.

Limitations

Several limitations of this study should be acknowledged. First, the experimental and control groups were recruited from two different soccer clubs rather than being randomly allocated within the same club. Consequently, factors such as coaching philosophy, weekly training load, technical preparation, seasonal scheduling, and club-specific athlete-development culture may have differed systematically between groups and could have contributed to the observed between-group differences independently of the intervention itself. Given this non-randomized, club-based allocation, the improvements observed cannot be attributed solely to the fundamental athletics and corrective exercise program, and the present results should be regarded as preliminary rather than confirmatory evidence of a causal effect. Future studies should therefore employ randomized allocation within the same club or multicenter randomized designs to isolate the intervention effect from club-level confounders.

Second, both the FMS and postural assessments were conducted by a single evaluator, and no intra-rater or inter-rater reliability testing was performed within the present study to confirm scoring consistency. Although the FMS has previously demonstrated acceptable reliability (ICC ≥ 0.767) in the literature (Gulgin & Hoogenboom, 2014), this reliability estimate was derived from prior research rather than being independently verified for the specific evaluator in the present study. Furthermore, neither evaluator was blinded to participants' group allocation (experimental vs. control) during assessment, which introduces a risk of detection bias, as awareness of group membership could have unconsciously influenced scoring, particularly for the more subjective postural classifications. In addition, the postural assessment relied on categorical, rater-based classifications rather than objective angular measurements, and no operational definitions were established prior to data collection. Although the PostureScreen Mobile application was used to standardize image acquisition, its quantitative angular output was not extracted or reported in this study; instead, deviations were classified subjectively by a single evaluator. As a result, the postural results should be regarded as observational and hypothesis-generating rather than as confirmatory measurements of postural change. Future studies should report inter-rater/intra-rater reliability coefficients and utilize the objective angular data available through PostureScreen Mobile rather than categorical judgments.

Third, the intervention was a composite program combining fundamental athletics training, FMS-based corrective exercises, mobility work, stabilization exercises, neuromuscular training, and plyometric-related elements delivered concurrently. This multi-component design does not allow the relative contribution of any single element to be isolated, and the observed improvements in performance and movement quality should therefore be interpreted as the combined effect of the overall program rather than evidence for the efficacy of any individual component. Future studies employing dismantling designs with separate intervention arms are needed to identify which specific components drive the observed adaptations.

Finally, the sample size was relatively small and limited to male U15 soccer players, which may restrict the generalizability of the results to other age groups, competitive levels, or female athletes. Furthermore, the intervention period was limited to eight weeks, which may not have been sufficient to induce substantial adaptations in more complex domains such as postural alignment, total FMS score, and core-stability-related components. In addition, no long-term follow-up assessments were performed to determine the persistence of the observed performance improvements. Future studies involving larger samples, longer intervention durations, and longitudinal follow-up designs are warranted. Finally, although the Benjamini–Hochberg FDR correction was applied to reduce the risk of Type I error across multiple comparisons, this approach inherently increases the risk of Type II error, meaning that some true intervention effects may have been rendered statistically non-significant following correction.

Conclusion

The results of the present study demonstrated that both groups improved over the eight-week period, with the experimental group showing significantly greater between-group gains specifically in horizontal jump, sprint, and agility performance — effects that remained robust even after correcting for multiple comparisons. In contrast, between-group differences in total FMS score, balance, and vertical jump did not reach statistical significance, indicating that the added benefit of the fundamental athletics and FMS-based corrective exercise program over regular soccer training was outcome-specific rather than uniform across all measures. In particular, the large effect-size improvements observed in sprint, agility, and horizontal jump performance indicate that such structured exercise interventions can effectively enhance soccer-specific performance capacities, including acceleration ability, change-of-direction performance, and explosive force production.

At the level of functional movement quality, the clearest program-specific benefit was observed in deep squat performance, where the experimental group demonstrated a significant and FDR-confirmed advantage over the control group. This result suggests that the performance gains achieved in the experimental group were associated not only with increases in physical capacity but also with improved movement efficiency in this specific pattern. However, for the remaining FMS subtests and the total FMS score, both groups improved comparably over time, indicating that these particular movement-quality gains may reflect a general training effect rather than one attributable specifically to the corrective exercise program. Although postural improvements remained limited and did not reach statistical significance between groups, the positive trends observed in the experimental group suggest that longer-term interventions may be required to induce substantial and measurable adaptations in postural alignment, total FMS score, and other core-stability-related components.

Overall, the present results suggest that fundamental athletics training combined with individualized corrective exercises represents a targeted rather than globally uniform strategy, with its most robust and reliably confirmed benefits concentrated in explosive performance qualities (horizontal jump, sprint, and agility) and in deep squat movement quality specifically. Nonetheless, this pattern indicates that such structured programs represent an important training component for improving both physical performance and specific aspects of movement quality, supporting long-term athletic development in youth soccer players. Therefore, the systematic integration of such structured exercise programs into youth soccer training systems may contribute to optimizing both current and future athletic performance, particularly with respect to explosive performance capacities, while longer or more sport-specific program designs may be needed to extend these benefits more broadly across functional movement and postural domains.

Practical Applications

From a practical perspective, the results of this study suggest that integrating fundamental athletics drills and individualized FMS-based corrective exercises into youth soccer training programs may substantially improve sprint performance, agility, explosive strength, and functional movement quality. Coaches and practitioners may particularly benefit from incorporating mobility, stabilization, and neuromuscular training components during the warm-up and early phases of training sessions. In addition, individualized corrective exercises targeting specific movement deficiencies may contribute to improved movement efficiency and long-term athletic development in youth soccer players.

Abbreviations

FMS: Functional Movement Screen, BMI: Body Mass Index, CMJ: Countermovement Jump,

SD: Standard Deviation

Ethics Committee Permission Information

Ethics committee: Scientific Research and Publication Ethics Committee of Iğdır University

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Authors' Contribution Statement

The design, data collection, analysis, and interpretation processes of the study were carried out collaboratively by the authors. The introduction and literature review sections were primarily prepared by the first author. The methods and results sections were developed jointly by the researchers. The discussion, conclusion, and final revision processes of the manuscript were completed with the contribution of all authors.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding this research.

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