Research Article

The effect of leg kicking exercise on the hip and knee isokinetic strength and maximal kicking speed in young soccer players

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Abstract

Background: Maximal kicking performance relies heavily on the coordinated involvement of the hip flexors and knee extensors, yet exercises that specifically target these muscle groups are rarely prioritized in soccer training regimens.
Objective: This study aimed to examine the effects of a leg-kicking exercise program (LKE) on the kicking speed, sprint performance, and agility of young players.
Methods: Thirty-nine youth players were randomly assigned to either an LKE group ($n = 18$; 15.9 ± 0.9 years) or a control group ($n = 21$; 15.8 ± 0.6 years). The LKE group performed a leg-kicking exercise three days a week. The participants underwent body composition analysis, isometric knee, isokinetic knee and hip strength tests, maximal ball speed, linear sprint, and agility tests at baseline and post-intervention.
Results: In the LKE group, muscle mass, maximal ball speed in both legs, and both isometric and isokinetic strength significantly increased ($p < 0.05$), while agility and sprint performance showed no significant changes ($p > 0.05$).
Conclusion: A 6-week LKE program, in addition to soccer training, may enhance kicking speed in youth players. The LKE may serve as a practical alternative to traditional strength training for improving muscle strength and kicking performance.

Keywords
Agility, isometric, sprint, strength training, performance

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1 Introduction

Elite soccer clubs spend vast amounts of time and money developing academies to prepare top-class players. The growing popularity, competitiveness, and evolving ethical standards in soccer have led to a more scientific and multidisciplinary approach to academy training.[1] Thus, an integrated approach aims to ensure players' continuous player development through training methods closest to the ideal, as well as to facilitate long-term monitoring.[2] Research suggests that both holistic and partial approaches can positively impact the long-term progress of academy players.[3] However, no consensus remains on the most effective training methodology for enhancing neuromuscular performance. Instead, much of the existing literature focuses on identifying the most time and cost-efficient strategies for developing elite athletes in the fastest and most reliable way.[4]

In this context, academy players' physical conditioning has emerged as a critical component of training

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methodologies, especially in the strength and mobility of the key muscle groups involved in soccer-specific movements. This focus is essential for addressing the growing physical demands of modern soccer, including sprinting, kicking, and rapid changes of direction.[5] Training programs must address overall athletic development and the biomechanical loads that act on players' muscles during fundamental movements, including sprinting, kicking, and change of direction.[6] Among these movements, maximal kicking speed, linear sprinting, and agility are performance metrics directly influenced by the strength and coordination of the hip flexors and knee extensors.[7]

The iliopsoas muscle is the primary hip flexor, contributing to pelvic tilt. This muscle, which connects the spine to the lower extremity, plays a critical role in sports-related movements, including running, where it initiates the swing phase through rapid hip flexion.[8] Additionally, the iliopsoas show high activation during kicking motions, remaining active throughout the entire movement, including the deceleration phase of the thigh.[9] Similarly, the quadriceps femoris muscle group- comprising the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius are fundamental to specific actions. The rectus femoris, which crosses both the hip and knee joints, enables hip flexion and knee extension, a dual function critical for dynamic movements like kicking and sprinting.[10] Furthermore, the quadriceps contribute to knee joint stabilization during rapid directional changes, highlighting their importance for performance and injury prevention.[11]

Given the evident importance of the hip flexors and knee extensors in soccer-specific movements, training programs often fail to incorporate exercises that effectively engage these muscle groups simultaneously. Existing studies have addressed hip flexion and knee extension through plyometric,[12] electrostimulation,[13] and explosive strength exercises[14]; however, these interventions have generally targeted the respective muscle groups in isolation. Only a limited number of studies have attempted to engage hip flexion and knee extension concurrently through simulated kicking exercises.[15–18] Moreover, these studies exhibit methodological inconsistencies in terms of exercise application and loading parameters, and none have comprehensively investigated the effects of such simulation exercises on both kicking performance and field performance test outcomes. Thus, the need for functionally integrative exercises targeting these key muscle groups remains largely unmet in the current literature.

In this context, the leg-kicking exercise employed in our study—characterized by its dynamic and functional movement pattern resembling the stretch-shortening cycle (SSC)—facilitates the simultaneous activation of the hip flexors and knee extensors. This coordinated activation may positively influence soccer-specific performance, neuromuscular function, and muscle mass development. Accordingly, we hypothesized that a six-week leg-kicking exercise program would enhance soccer-specific performance parameters such as maximum kicking velocity, linear sprint speed, and change-of-direction ability by functionally engaging the major lower-limb muscle groups. Furthermore, the intervention was expected to yield significant improvements in the isokinetic and isometric strength of the hip and knee joints through targeted muscular loading. This study evaluated the impact of the proposed exercise program on these performance metrics. The findings may contribute to evidence-based training strategies aligned with the biomechanical demands of soccer, offering valuable guidance for coaches and practitioners working with developing athletes.

2 Methods

2.1 Subjects

Thirty-nine youth soccer players voluntarily participated in the study. The participants had an average training background of 4.2 ± 1.7 years. Following the pre-tests, they were randomly assigned to two groups: the experimental group (n = 18; age 15.9 ± 0.9 years, height 172.1 ± 5.5 cm, body weight 63.1 ± 10.3 kg) and the control group (n = 21; age 15.8 ± 0.6 years, height 172.7 ± 8.4 cm, body weight 60.8 ± 2 kg). The study was conducted in accordance with the principles of the Declaration of Helsinki. Before the intervention, coaches, players, and their families were informed about the study's objectives, and written informed consent was obtained. The study protocol was approved by the Cukurova University Clinical Studies Ethics Committee (2017/66).

2.2 Procedures

The study included pre-tests in the first phase, followed by six weeks of leg-kicking training, and concluded with post-tests. During the training period, both the experimental and control groups participated in one soccer match and two routine soccer training sessions per week. Additionally, the experimental group performed an extra training program three days a week. The players performed the leg kicking exercise on the same days and at the same time per week (Monday-Wednesday-Friday). During the training period, the experimental and control groups were prohibited from performing extra conditioning exercises (strength, power, plyometric, etc.). Goalkeepers were excluded from the study. Tests were performed on all soccer players of the same order (laboratory and field tests, respectively) before and after the training period. At least 48-h time periods were scheduled between the tests, and the soccer players were asked to avoid performing any high-intensity exercise, as outlined in Figure 1.

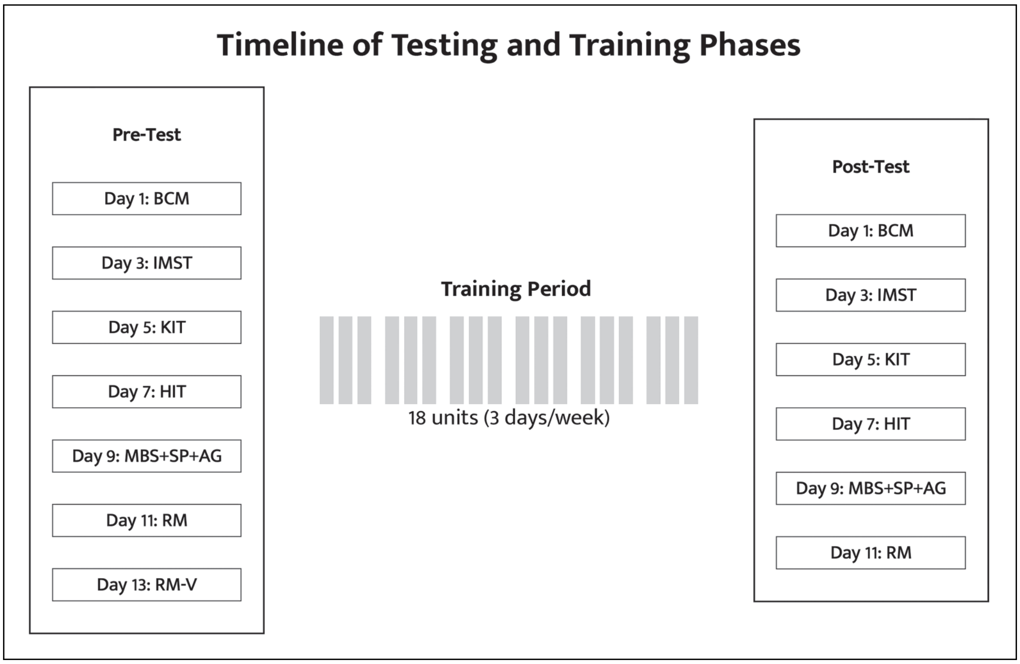

Figure 1. Timeline of testing and training phases. BCM –Body composition measurement; IMST – Isometric Muscle Strength Test; KIT – Knee Isokinetic Test; HIT – Hip Isokinetic Test; MBS – Maximum Ball Speed Test; SP – Sprint Test; AG – Agility Test; RM – Repetition Maximum Test; RM-V – Repetition Maximum Validation Test.

2.3 Body composition measurement

Anthropometric measurements were conducted to determine the body composition of the athletes. The same researcher measured body weight and height using a scale and a stadiometer before and after the training period. Calf, mid-thigh, and forearm circumferences were measured with an elastic tape. Body fat percentage was calculated according to the Siri method,[19] and body muscle mass was estimated using Martin's formula.[20]

2.4 Training protocol and determination of one repetition of Maximum (1RM)

The training program designed for soccer players included 70–85% of the 1RM intensity weights individually determined for each player. The players' 1RM was calculated according to the instructions of the "National Strength and Conditioning Association" and using indirect means of calculating Brzycki's formula (Equations 1).[21]

$$\frac{Weight\ lifted}{(1.0278\ -\ (0.278 \times repetition\ number))} \quad (1)$$

The load weight increase of the players was performed by measuring their 1RM per week starting from the first week. The number of repetitions in the training sessions ranged from 8 to 12 in three sets for the first two weeks and four sets for the following weeks. A passive rest of 90 s of the same leg was given between the sets, but three minutes of active rest were provided between the legs (Equations 2).[22] Details on the weekly increase in weight applied to subjects during leg-kicking exercise are shown in Figure 2.

$$Training\ Load\ (kg) = Number\ of\ Sets \times Number\ of\ Repetitions \times Weight\ Lifted\ (kg) \quad (2)$$

Before each training session and measurement, participants performed a standardized warm-up protocol consisting of a 10-min jogging phase and 5-min stretching and tension exercises specifically targeting lower-extremity musculature. Following this general warm-up, athletes executed a targeted warm-up utilizing the leg-kicking exercise (LKE), performing two sets of 12 repetitions at an intensity corresponding to 30–50% of their one-repetition maximum (1RM). The LKE was conducted using a multicable crossover apparatus designed to closely replicate the biomechanical motion of a soccer kick, with the athlete's ankle securely connected to the cable mechanism. A unilateral training approach was employed to prevent inter-limb asymmetry. Each repetition started with the leg in full extension and proceeded with a controlled hip flexion resembling a kicking motion, mobilizing the resistance load, and was executed at approximately 1– 4 tempo for forward swing and backward swing, respectively. In the subsequent six-week resistance training intervention,

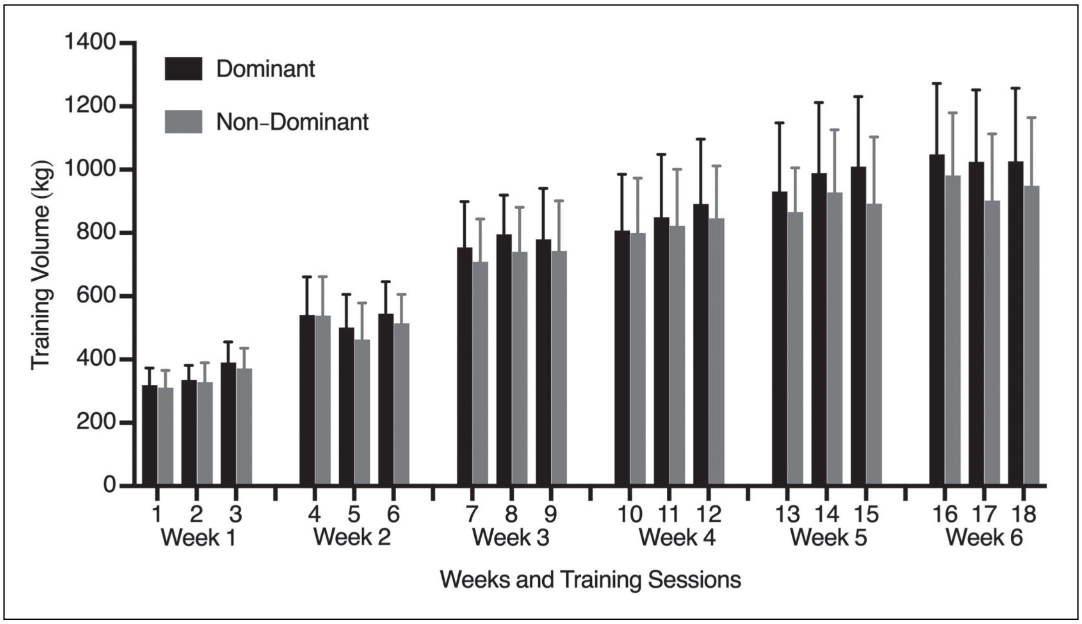

Figure 2. Results of the 6-week leg-kicking exercise program (mean ± SD).

the LKE program initially included three sets per session, progressively advancing to four sets, while repetitions remained consistently between 10 and 12 (Figure 3-A/B). The training volume of the experimental group throughout the training period is presented in Figure 2.

2.5 Muscle strength tests

Isometric knee and isokinetic knee and hip extension/flexion strength measurements were conducted using the CSMI Cybex NORM 6000 isokinetic dynamometer. Isometric strength assessments were performed at 60–90° joint angles, with a 1-min rest between each angle. Isometric knee extension strength was measured first, and participants rested for 30 s before the subsequent flexor muscle strength measurement. The contraction duration was set to 10 s during each measurement.[23] Isokinetic knee and hip extension/flexion strength assessments were conducted at angular velocities of 60, 180, and 240°/sec. The testing protocol included three repetitions at 60°/sec, 10 repetitions at 180°/sec, and 15 repetitions at 240°/sec. Participants rested for 1 min between sets. Prior to isokinetic strength testing, all participants completed a standardized 10-min warm-up using a bicycle ergometer (Monark 894 E, Sweden). This protocol included five minutes of cycling at a load of 1 kg and a cadence of 65 ± 5 rpm, followed by two minutes of cycling with a load of 0.05 g/kg at the same cadence. In the final phase of the warm-up, participants completed three 10-s submaximal sprints interspersed with 50 s of active recovery, using their individually determined final load. Additionally, stretching exercises were performed prior to each isokinetic strength assessment.[24] Hip flexion and extension tested in the supine position, with the dynamometer lever arm aligned with the anatomical axis of the femur at the level of the greater trochanter. Assessments were performed at angular velocities of $60°\cdot s^{-1}$, $180°\cdot s^{-1}$, and $240°\cdot s^{-1}$ using concentric muscle actions. All measurements were conducted with the hip joint positioned at 90° of flexion. For each velocity, participants executed six consecutive maximal voluntary contractions in alternating antagonist directions, with a 90-s rest interval between each velocity condition. As the tests were conducted in the supine position, gravitational correction was not required. Knee flexion and extension were assessed in a seated position, with the backrest angle set at 90°. The rotational axis of the knee was aligned with the mechanical axis of the dynamometer arm, and the ankle cuff was positioned approximately 3 cm above the dorsal surface of the foot. Stabilization straps were placed over the pelvis and chest to minimize compensatory movements, and participants kept

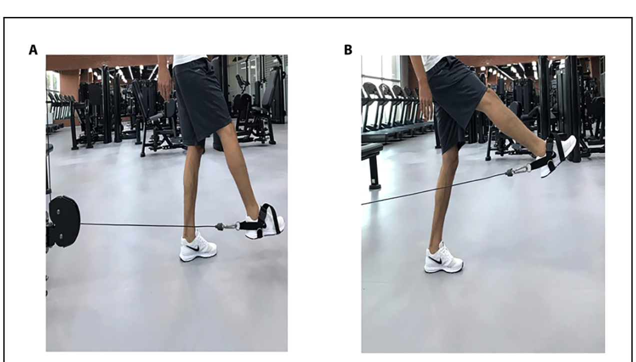

Figure 3. Leg-Kicking exercise.

their arms crossed over the chest throughout both familiarization and testing. Gravity correction was applied during all knee strength assessments. Both isometric and isokinetic contraction forces were evaluated using normalized peak moment values (Peak Moment/Body Weight).

2.6 Maximum kicking speed test

The maximal kicking speed of the players was assessed using a FIFA-approved, size five soccer ball inflated to 11 psi. Players were instructed to kick the ball as forcefully as possible from a distance of 11 meters without constraints regarding accuracy.[25] Each participant performed five consecutive kicks with each leg. The approach distance was standardized at 2 meters, while the player individually selected the approach angle within a range of 0° to 30°. A rest interval of one minute was allowed between kicks. The ball velocity generated following a maximal-effort instep kick was measured using a radar gun (Bushnell Speed Gun, USA), placed 1 meter above ground level and 14 meters behind the kicking location. The radar device provided measurements with an accuracy of ±2 km/h, covering velocities ranging from 16 to 177 km/h. For validation and reliability purposes, the radar device had previously been tested using various sound frequencies generated by a 'Tone Generator'.[26] The velocities calculated from these frequencies demonstrated a strong correlation with radar-measured speeds (r⊃2 = 0.99, $p < 0.05$). The highest recorded ball speed among the five trials was used for subsequent evaluation.

2.7 Linear sprint test

The 30-meter distance was accurately measured and marked before positioning the electronic timing gates (TC Photogate; Brower Timing Systems LLC, Draper, UT, USA). Gates were set up at the start of the 30-m track, and each player started the test 30 cm behind the first timing gate. Two plastic markers were placed 2 m beyond the last pair of timing gates, and each player was encouraged not to decelerate until they were past these markers. Each player completed three maximum effort sprints with the fastest time for the 30-meter distance recorded.[27]

2.8 Agility T test

The Agility T-Test was performed on a course with four 30 cm cones arranged in a T-shape (9.14 m forward, 4.57 m lateral). Participants sprinted forward, touched the central cone with the right hand, shuffled left and right to touch lateral cones with alternating hands, then returned and sprinted backward to the start line.[28] Three maximal trials were completed, and the best time was used for analysis. Trials were repeated if the subject crossed feet, failed to touch cones, or did not face forward. Timing was recorded using an electronic photogate system (TC Photogate; Brower Timing Systems LLC, Draper, UT, USA).

2.9 Statistical analysis

Continuous variables were presented as mean ± standard deviation. Normality of data distribution was assessed using the Shapiro-Wilk test. Comparisons between two independent groups were performed using Student's t-test for variables with normal distribution and the Mann-Whitney U test for variables without normal distribution. Comparisons of two related (paired) continuous variables were analyzed using the paired samples t-test when the data were normally distributed, and the Wilcoxon Signed-Rank test when the data did not follow a normal distribution. Within-group effect sizes for paired comparisons (pre- to post-test) were calculated using Cohen's d. According to Cohen's conventions, effect sizes were interpreted as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$). According to Cohen's d, effect sizes were interpreted as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$).[29] Statistical analyses were conducted with IBM SPSS Statistics version 20.0, and a p-value <0.05 was considered statistically significant.

3 Results

3.1 Body composition measurements

The results indicated a statistically significant increase in body muscle mass and thigh circumference for both experimental and control groups (body muscle mass: 7.8% ± 7.9 and 4.5% ± 6.3; thigh circumference: 5.3% ± 4.5 and 1.8% ± 3.2 for experimental and control groups, respectively) ($p < 0.05$). However, no significant differences were observed in either group regarding body fat percentage and calf circumference measurements ($p > 0.05$). Additionally, no statistically significant differences were found between experimental and control groups in the post-test ($p > 0.05$) (Table 1).

3.2 Field-Based performance tests and one repetition Maximum (1RM)

Pre and post-test values for maximal kicking speed, one-repetition maximum (1RM) strength, sprint, and agility performance were analyzed in both the experimental and control groups (Table 2). In the experimental group, significant improvements were observed in maximal kicking speed and 1RM strength in both the dominant and non-dominant legs ($p < 0.05$). Although slight increases were noted in sprint and agility test times, these changes were not statistically significant ($p > 0.05$).

In the control group, no significant changes were found in maximal kicking speed or agility performance ($p > 0.05$).

Table 1. Pre and post-test body composition measurements of the control group and experimental group.

	CG(n=21)			EG (n=18)		
	Pre-test	Post-test	*ES*	Pre-test	Post-test	*ES*
% Muscle	41.2±2.8	43.0±2.1*	0.8	40.6±2.6	43.7±2.0*	1.5
% Fat	11.9±5.3	12.2±5.1	0.1	11.9±4.1	11.3±3.8	0.2
Thigh Circumference (cm)	49.5±4.3	50.3±4.1*	0.6	49.4±4.6	51.9±4.6*	0.6
Calf Circumference (cm)	34.8±2.7	34.7±2.4	0.13	35.7±4.4	35.5±2.8	0.1

*Significant difference compared to pre-test (p < 0.05). *CG:* Control Group, *EG:* Experimental Group.

Table 2. Pre- and post-test results of maximal kicking speed, one-repetition maximum (1RM) strength, sprint, and agility performance in the control and experimental groups.

	CG (n=21)			EG (n=18)		
	Pre-test	Post-test	*ES*	Pre-test	Post-test	*ES*
Maximum speed kicking (Dominant Leg) (km/h)	89.2±6.0	89.8±7.6	*0.1*	91.3±6.2	99.3±6.2*#	*1. 4*
Maximum speed kicking (NonDominant Leg) (km/h)	72.2±7.1	70.0±9.2	*0.3*	77.5±6.7#	83.1±6.3*#	*1.2*
1RM (Dominant leg) (kg)	11.1±2.5	14.3±3.7*	*1.1*	11.4±2.6	28.3±3.7*#	*5.7*
1RM (Nondominant leg) (kg)	11.3±3.1	13.9±3.2*	*1.0*	11.0±2.9	26.0±3.0*#	*5.0*
Sprint 0–30m (sec)	4,3±0,3	4,4±0,2*	*1.1*	4,2±0,3	4,3±0,2	*0.4*
Agility (sec)	9,8±0,4	9,8±0,5	*0.0*	9,7±0,7	9,5±0,4	*0.4*

* Significant difference compared to pre-test (p < 0.05). # Significant difference between the groups (p < 0.05). Data are presented as Newton Meter per Body Weight (Nm/kg). Ext: Isometric extension strength; Flex: Isometric flexion strength. CG: Control Group, EG: Experimental Group.

However, while 1RM strength in both legs showed a statistically significant improvement ($p < 0.05$), sprint performance showed a statistically significant decrease ($p < 0.05$). Post-test comparisons between the groups revealed significant differences in favor of the experimental group in maximal kicking speed and 1RM strength for both legs ($p < 0.05$). No significant differences were observed between the groups in sprint and agility performance ($p > 0.05$).

3.3 Isometric and isokinetic strength performance

Pre- and post-test isometric strength values of the dominant and non-dominant legs are presented in Table 3. In the experimental group, a statistically significant increase was observed in both extension and flexion strength at all two angles (60° and 90°) for both the dominant and non-dominant legs ($p < 0.05$). In the control group, significant increases were found in 90° dominant leg extension strength ($p < 0.05$). No statistically significant changes were observed at the other angles in the control group ($p > 0.05$). Between-group comparisons revealed that post-test values for 90° flexion strength of the dominant leg, as well as both extension and flexion strength of the non-dominant leg at 90°, were statistically significantly higher in the experimental group than the control group ($p < 0.05$).

The pre- and post-test values of isokinetic extension and flexion strength at 60°/s, 180°/s, and 240°/s angular velocities for the dominant and non-dominant legs were analyzed (Table 4). The experimental group observed a significant increase in isokinetic extension and flexion strength at all angles ($p < 0.05$). In contrast, the control group showed significant improvements only in flexion strength at specific angles (60°, 180°, and 240°), while no notable changes were detected in extension strength. Between-group comparisons revealed that the post-test values of the experimental group were statistically higher than those of the control group ($p < 0.05$).

The pre- and post-test values of isokinetic extension and flexion strength at 60°/s, 180°/s, and 240°/s angular velocities for the dominant and non-dominant hips were analyzed (Table 5). In the control group, no significant changes were observed in hip isokinetic extension and flexion strength values at any angular velocity for either hip ($p > 0.05$). In contrast, the experimental group exhibited a significant difference in both extension and flexion strength at all angular velocities ($p < 0.05$). A further comparison of the post-test values between the two groups revealed that the experimental group exhibited significantly higher levels of extension and flexion strength than the control group at all angular velocities ($p < 0.05$).

4 Discussion

The main findings of this study indicate significant improvements in lower extremity strength and kicking speed following a six-week session of LKE, a functional exercise specifically designed to improve hip and knee

Table 3. Pre- and post-test isometric strength values of the dominant and non-dominant legs.

		CG (n=21)						EG (n=18)					
		Dominant			Non-dominant			Dominant			Non-dominant		
		Pre	Post	*ES*	Pre	Post	*ES*	Pre	Post	*ES*	Pre	Post	*ES*
60°	Ext. (Nm/kg)	2.7±0.5	2.8±0.6	*0.6*	2.6±0.5	2.7±0.8	*0.5*	2.7±0.5	3.6±0.6*	1.6	2.5±0.4	3.1±0.5*	*1.5*
	Flex. (Nm/kg)	1.5±0.4	1.8±0.3	*0.8*	1.5±0.3	1.6±0.3	*0.3*	1.5±0.3	1.8±0.2*	1.1	1.5±0.2	1.8±0.3*	*1.2*
90°	Ext. (Nm g)	2.4±0.4	2.7±0.6*	*0.7*	2.5±0.4	2.6±0.4	*0.8*	2.5±0.4	3.1±0.6*	1.1	2.3±0.4	3.1±0.5*#	*1.9*
	Flex. (Nm/kg)	1.2±0.3	1.4±0.3	*0.7*	1.2±0.2	1.3±0.3	*0.4*	1.3±0.2	1.7±0.2*#	2.0	1.3±0.2	1.6±0.3*#	*1.2*

* Significant difference compared to pre-test ($p < 0.05$). # Significant difference compared between to the groups ($p < 0.05$). Data are presented as Newton Meter per Body Weight (Nm/kg). Ext: Isometric extension strength; Flex: Isometric flexion strength. CG: Control Group, EG: Experimental Group.

Table 4. Pre- and post-test values of isokinetic knee extension and flexion strength at 60°/s, 180°/s, and 240°/s angular velocities for the dominant and non-dominant sides.

		CG(n=21)						EG (n=18)					
		Dominant			Non-dominant			Dominant			Non-dominant		
		Pre	Post	*ES*	Pre	Post	*ES*	Pre	Post	*ES*	Pre	Post	*ES*
60°/sec	Ext. (Nm/kg)	2.4±0.4	2.3±0.3	0.3	2.2±0.4	2.3±0.4	0.3	2.5±0.2	2.9±0.4*#	1.2	2.5±0.3#	2.9±0.3*#	1.5
	Flex. (Nm/kg)	1.6±0.4	1.9±0.2*	0.9	1.5±0.3	1.8±0.3*	1.0	1.7±0.3	2.1±0.2*#	1.7	1.6±0.3	2.1±0.3*#	1.9
180°/sec	Ext. (Nm/kg)	1.7±0.2	1.7±0.2	0.0	1.7±0.2	1.8±0.2	0.5	1.8±0.2	2.0±0.2*#	1.1	1.8±0.2	1.9±0.2*#	0.6
	Flex. (Nm/kg)	1.3±0.3	1.5±0.2*	0.8	1.2±0.2	1.4±0.2*	1.0	1.4±0.3	1.8±0.2*#	1.7	1.3±0.3	1.7±0.3*#	1.5
240°/sec	Ext. (Nm/kg)	1.5±0.1	1.5±0.2	0.0	1.4±0.2	1.5±0.2	0.5	1.5±0.2	1.7±0.2*#	1.1	1.6±0.2#	1.7±0.1*#	0.6
	Flex. (Nm/kg)	1.2±0.2	1.4±0.2*	1.0	1.1±0.2	1.3±0.2*	1.0	1.2±0.2	1.6±0.2*#	2.2	1.2±0.3	1.6±0.2*#	1.7

* Significant difference compared to pre-test ($p < 0.05$). # Significant difference compared between to the groups ($p < 0.05$). Data are presented as Newton Meter per Body Weight (Nm/kg). Ext: Isokinetic extension strength; Flex: Isokinetic flexion strength. CG: Control Group, EG: Experimental Group.

Table 5. Pre- and post-test values of isokinetic hip extension and flexion strength at 60°/s, 180°/s, and 240°/s angular velocities for the dominant and non-dominant sides.

		CG (n=21)						EG(n=18)					
		Dominant			Non-dominant			Dominant			Non-dominant		
		Pre	Post	*ES*	Pre	Post	*ES*	Pre	Post	*ES*	Pre	Post	*ES*
60°/sec	Ext. (Nm/kg)	2.6±0.8	2.4±0.7	0.9	2.5±0.7	2.3±0.6	1.0	2.8±0.7	3.7±0.5*#	1.6	2.6±0.5	3.4±0.8*#	1.2
	Flex. (Nm/kg)	1.6±0.3	1.6±0.4	0.0	1.5±0.3	1.5±0.4	0.0	1.7±0.3	2.0±0.3*#	1.1	1.5±0.3	1.9±0.3*#	1.5
180°/sec	Ext. (Nm/kg)	2.1±0.7	1.8±0.5	1.6	2.0±0.5	1.9±0.6	0.6	2.1±0.6	2.8±0.7*#	1.2	2.0±0.5	2.7±0.5*#	1.6
	Flex. (Nm/kg)	1.2±0.2	1.2±0.3	0.0	1.2±0.2	1.3±0.3	1.3	1.2±0.3	1.4±0.2*#	0.8	1.2±0.3	1.6±0.2*#	1.7
240°/sec	Ext. (Nm/kg)	1.8±0.7	1.7±0.5	0.5	1.7±0.6	1.7±0.6	0.0	2.0±0.5	2.3±0.5*#	0.7	1.8±0.5	2.4±0.6*#	1.2
	Flex. (Nm/kg)	1.0±0.2	1.1±0.3	1.3	1.0±0.2	1.0±0.3	0.0	1.1±0.2	1.3±0.2*#	1.1	1.0±0.3	1.2±0.2*#	0.8

* Significant difference compared to pre-test ($p < 0.05$). # Significant difference compared between to the groups ($p < 0.05$). Data are presented as Newton Meter per Body Weight (Nm/kg). Ext: Isokinetic extension strength; Flex: Isokinetic flexion strength. CG: Control Group, EG: Experimental Group.

joint strength. Multiple muscle groups train simultaneously with LKE, which may enhance muscle mass. These adaptive changes may improve muscular strength and kicking performance. The ease with which this exercise can be integrated into existing training sessions without disrupting traditional routines further highlights its practical value. Therefore, LKE can be recommended as an effective training method for optimizing lower extremity function in young soccer players.

A key empirical insight generated through this research was that LKE significantly increased kick velocity in the experimental group, with improvements of 8.4 ± 3.1% in the dominant leg and 7.4 ± 4.5% in the non-dominant leg. Numerous studies in the literature have investigated the effects of different resistance training models on soccer kicking performance at different ages and performance levels. These studies reported increases in kicking velocity of approximately 4–12%, with training protocols typically conducted three times per week for periods ranging from 5 to 12 weeks, and these findings are consistent with our data.[12,1330–33] The aforementioned studies have contributed positively to kicking performance by employing multiple exercise modalities to train various muscle groups. The plyometric exercises that include the SSC activity pattern may be another training model to improve kicking performance.[34] Careful planning of intensity and volume, along with professional supervision, is critical to minimize injury risk and support performance development, yet its management can be particularly delicate in youth athletes during this type of training method.[35] Previous studies have demonstrated that combining kicking motion-simulated exercises with traditional strength or coordination training can effectively enhance kicking performance.[17,18] However, in those studies, it was not possible to isolate the specific effects of the leg-kicking exercise due to the simultaneous implementation of multiple training modalities. Since no additional training components were included in our study, performance improvements may be attributed specifically to isolated applications.

As the strength and speed of thigh and hip muscle contractions are key factors in kicking performance,[3036–39] our findings suggest that LKE contributed to improvements in kicking performance. The LKE model was implemented to strengthen muscle groups that influence kicking performance. Another possible explanation for kicking speed enhancement is the biomechanical overlap between the movement patterns involved in the LKE exercise and those required during instep kicking. Kicking activity consists of preparation, backswing, limb cocking, acceleration, and follow-through.[40] The applied resistance during LKE caused the hip, knee, and ankle joints in the backswing, limb cocking, and follow-through phases occur at narrow angles than in an actual kick. However, the general pattern of muscular activation during LKE exhibited a high degree of similarity to improve neuromuscular coordination, as observed in an instep kick. Therefore, the high degree of muscle activation similarity during LKE may induce improvement in neuromuscular coordination, which may be a possible explanation for performance enhancement.

Our isokinetic strength evaluation data showed that LKE increased moment production at low, moderate, and high angular velocities in the hip and knee muscle groups. Hip extension and flexion strength improved in both the dominant and non-dominant legs across all three angular velocities, and in each case, hip strength was significantly higher in the experimental group compared to the control group. Similarly, knee extension and flexion strength increased in the experimental group following the intervention. Based on previous studies published in this journal, including our own, isokinetic knee strength values reported for male soccer players aged between 15 and 18.5 years indicate that at 60°/s angular velocity, extensor strength ranges from 2.1 to 3.2 Nm/kg and flexor strength from 1.4 to 2.2 Nm/kg; at 180°/s, extensor strength ranges from 2.2 to 2.3 Nm/kg and flexor strength from 1.2 to 2.3 Nm/kg; and at 240°/s, extensor strength ranges from 1.5 to 1.7 Nm/kg and flexor strength from 0.9 to 1.5 Nm/kg.[2441–43] The strength values observed in our study fall within these ranges, suggesting that our participants reflect a typical lower-limb strength profile for youth soccer players. This alignment with the existing literature supports the representativeness of our sample in terms of knee muscle strength characteristics.

The effect of different resistance training exercises on isokinetic knee strength in soccer players has been previously investigated,[44,45] and it is widely accepted that the velocity of movement during resistance exercises is a key determinant of muscular strength gains.[46,47] Indeed, resistance training performed at slower velocities tends to yield greater improvements in strength compared to training performed at higher speeds.[44] In line with this, the consecutive moderate concentric and slow eccentric contractions employed in our training protocol appear to have effectively enhanced isokinetic strength.

During kicking activity, it is important to contract the core and support leg muscles to maintain body stability. The support leg plays a fundamental role in maintaining postural stability by counteracting external forces, carrying the body's weight, and ensuring efficient force transmission throughout the kicking action.[33,48,49] The exercised leg is activated as if kicking the ball, and the support leg has to contract for hip and knee stability while LKE. The significant increase in the isometric strength of the knee muscles observed in our study may indicate improved core stability and enhanced force transmission to the ball during the moment of contact by the kicking leg. Supporting this, a moderate positive correlation was found between the change in knee extension isometric strength at 90° and the change in ball velocity ($r = 0.571$, $p < 0.05$), suggesting that improvements in isometric strength at this angle may contribute to increased kicking performance. This 90-degree knee flexion position may reflect a brief isometric contraction phase due to the nature of the leg kicking movement pattern, particularly during the transition from backswing to forward swing. This point has also been identified as a critical moment for maximal energy transfer and hip deceleration during the kicking motion.[50]

In line with the literature, hypertrophic adaptations are optimally stimulated by loading intensities ranging between 70–85% of one-repetition maximum (1RM), with a minimum of 16 training sessions consisting of 3–6 sets of 6–12 repetitions per exercise.[51–53] The training model implemented in this study was structured based on these principles. For players with no prior resistance training experience, performing exercises at 12RM is more appropriate than using heavier loads such as 8–10RM, as it allows for better control and safety especially in unilateral tasks like the leg-kicking exercise used in this study. Similar protocols within the 8–15RM range have been effectively applied in adolescent populations.[54] Furthermore, the "1–4 tempo" (4 s eccentric, 1 s concentric), regulated by a metronome, was selected to reflect the biomechanical demands of the movement. This slower eccentric duration is consistent with previous findings indicating that increased mechanical tension and time under tension can enhance hypertrophic adaptations.[55] The increase in muscle mass observed in the experimental group suggests that the LKE training protocol may activate hypertrophic signaling pathways. Potential structural adaptations in muscle mass resulting from strength gains may also play a role in the improvement of kicking performance. However, the strength improvements observed in our study appear to surpass those reported in previous research conducted on soccer players,[56,57] suggesting a potentially more effective adaptation response under the applied training conditions. It should be noted that the experimental and control groups have not previously performed any resistance training with extra weights. This situation can explain why the improvement in the experimental group players' 1RM strength (ES: 5.71–6.1, dominant and non-dominant leg) values was more significant than in other literature studies. This pronounced increase may be attributed to participants' untrained status, the task-specific nature of the unilateral kicking exercise, and potential motor learning effects. Although such large effect sizes are relatively uncommon, they are not unprecedented; similar magnitudes have been observed in studies involving untrained youth athletes under comparable training conditions.[58]

The initial gains observed during the early phase of resistance training may be attributable to neural adaptations rather than intrinsic muscular changes.[59] Considering the LKE training plan and movement pattern, it can be anticipated that resistance training will stimulate both protein synthesis and motor pathway activation in the muscle. Repeated execution of similar movement patterns throughout the training period may have enhanced motor learning and contributed to neural mechanisms such as increased motor unit activation and improved neuromuscular coordination.[60] The increased kicking velocity may be due to a combination of neural and muscular adaptations.[61] The age of participants and lack of prior resistance training experience may partially explain the magnitude of the strength gains observed. Previous research has demonstrated that, with proper supervision and age-appropriate programming, weightlifting can be both safe and effective for children and adolescents.[62] Although the literature reports significant improvements in strength following various training approaches in similar age groups,[63] direct comparisons are limited due to the unique nature of the LKE protocol.

Nevertheless, a key methodological limitation of the present study is the absence of more objective and advanced assessment techniques-such as muscle cross-sectional area (CSA) imaging or molecular analysis of hypertrophic signaling pathways (e.g., mTOR, Akt), which would provide stronger evidence regarding the validity and biological mechanisms underlying the observed hypertrophic responses.[64] The absence of direct physiological assessments such as neural activation and CSA or molecular markers of hypertrophy remains a key limitation in interpreting the underlying mechanisms.

The LKE did not improve the 30-meter sprint or agility performance. The activity pattern of the LKE exercise may explain this finding. The sprint performance is highly dependent on the ability to generate force rapidly, and agility, involves rapid acceleration, deceleration, direction changes in response to external stimuli.[65] The relatively slow contraction speed during our LKE intervention may have limited adaptations related to explosive strength and speed, which likely failed to stimulate the adaptations necessary for sprint performance and agility development.[47,66]

5 Conclusion

In conclusion, the results of the present study indicated that a 6-week LKE, in addition to a regular soccer training program, may improve the kicking speed of young soccer players in the season period. The LKE, which is sport-specific and time-efficient implementation, maybe a practical and effective alternative to conventional strength training. It can be suggested that this training method may be a preferred model by soccer players and coaches to increase muscle strength as well as improve kicking performance.

Ethical approval and informed consent statements

This study was approved by the Cukurova University Faculty of Medicine Non-Invasive Clinical Research Ethics Committee (Approval No: [66], Date: [07.07.2017]). Written informed consent was obtained from all participants prior to their inclusion in the study.

Consent to participate

Written informed consent was obtained from all participants prior to their inclusion in the study.

Author contributions

Conceptualization: AK, SSK, SKE; Methodology: ÖCB, ÇSK, MEK, ET, ÇÖP, ÖG; Data Curation: AK, ÖCB, MEK, ÇSK, ET, SKE, KTÖ, SSK; Writing – Original Draft: AK; Writing – Review & Editing: SKE, KTÖ, ÇÖP, ÖG; Supervision: SSK. All authors have read and approved the final manuscript.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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