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Decrease in muscle shortening and effect on strength and speed in adolescent soccer players (u-13)

Disminución del acortamiento muscular y efecto sobre la fuerza y la velocidad en futbolistas adolescentes (sub-13)

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Abstract

In soccer, the variables of strength, speed and flexibility are associated with the athletic performance capacity of athletes, being these determinants not only to adapt to the demands of the competition, but at the same time flexibility can help to reduce the risk of injury. The aim of the study was to determine the effect on strength and speed after reducing muscle shortening. This is a quantitative study with an observational-analytical cross-sectional design. The evaluated sample consisted of 22 under-13 category players with an average age of 13.40±0.66 years, a height of 156.95±9.27 cm, and a body mass of 44.54±7.29 kg. They were randomly divided into a control group (*n*=10) and an experimental group (*n*=12). The experimental group underwent an 8-week intervention involving static stretches, incorporating the Proprioceptive Neuromuscular Facilitation method in the fourth week to decrease muscle shortening before the post-test. Knee extension and dorsiflexion were assessed using a goniometer, and physical abilities were measured through the My Jump Lab app, including Squat Jump, Counter Movement Jump, Counter Movement Jump with Arms, the Nordics hamstring test, and speed in 10, 20, and 30 meters using the Runmatic app. Significant results (p<0.05) were observed for jump height in Squat Jump, jump height, flight time, and speed in Counter Movement Jump, torque in the Nordics test, and speed in 30 meters. According to the findings of the present study it seems that flexibility influences vertical jumping ability and speed.

Key Words: sport performance; physical abilities; soccer; flexibility, evaluation.

Resumen

En el fútbol, las variables de fuerza, velocidad y flexibilidad están asociadas a la capacidad de rendimiento deportivo de los atletas, siendo estos determinantes no sólo para adaptarse a las exigencias de la competición, sino que al mismo tiempo la flexibilidad puede ayudar a reducir el riesgo de lesiones. El objetivo del estudio fue determinar el efecto sobre la fuerza y la velocidad tras reducir el acortamiento muscular. Se trata de un estudio cuantitativo con un diseño transversal observacional-analítico. La muestra evaluada consistió en 22 jugadores de categoría sub-13 con una edad media de 13.40±0.66 años, una altura de 156.95±9.27 centímetros y una masa corporal de 44.54±7.29 kilogramos. Se dividieron aleatoriamente en un grupo de control (*n*=10), y un grupo experimental (*n*=12). El grupo experimental se sometió a una intervención de 8 semanas con estiramientos estáticos, incorporando el método de Facilitación Neuromuscular Propioceptiva en la cuarta semana para disminuir el acortamiento muscular antes de la prueba posterior. La extensión de rodilla y la dorsiflexión se evaluaron utilizando un goniómetro, y las habilidades físicas se midieron a través de la aplicación My Jump Lab, incluyendo Squat Jump, Counter Movement Jump, Counter Movement Jump with Arms, el test nórdico de isquiotibiales y la velocidad en 10, 20 y 30 metros utilizando la app Runmatic. Se observaron resultados significativos (p<0.05) para la altura de salto en Squat Jump, altura de salto, tiempo de vuelo y velocidad en Counter Movement Jump, torque en el test Nordics y velocidad en 30 metros. Según los resultados del presente estudio parece que la flexibilidad influye en la capacidad de salto vertical y en la velocidad.

Palabras clave: rendimiento deportivo; capacidades físicas; fútbol; flexibilidad, evaluación.

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Introduction

Soccer is a cooperative-oppositional sport where physical variables influence specific performance concerning positional play (Diana et al., 2017; Gómez-Carmona et al., Paraskevas et al., 2023). Similarly, performing specific actions in alignment with the player's position helps understand the nature of the sport and the athlete's characteristics to adapt to constant competition changes (Deprez et al., 2015). In youth soccer, there is inequality in anthropometric indicators such as height, body mass, and body composition (Nughes et al., 2020; Porta et al., 2023; Tereso et al., 2021). As well as physical characteristics determined by speed, agility, strength, power, and anaerobic endurance (Aquino et al., 2017; Becerra-Patiño, 2023; Emmonds et al., 2016; Ospina-León et al., 2023).

These morphofunctional factors are crucial in the selection processes conducted by coaches to meet the sport's specific demands (Becerra-Patiño et al., 2023). Studies have explored the effects of stretching duration on sprinting ability in adolescent soccer players (Iatridou et al., 2018; Jordan et al., 2012; Santos et al., 2024). The specific physical demands are related to actions like sprints, accelerations, decelerations, direction changes, jumps, and collisions, where strength, speed, resistance to explosive efforts (Olsen et al., 2023), and flexibility play a significant role (Ayala & Sinz De Baranda, 2010; Fjerstad et al., 2018; Kendall, 2017). Some studies have described the effects of flexibility on athletic performance in soccer players (Alimoradi et al., 2023; Bogalho et al., 2022; Kendall, 2017). A study concluded that flexibility could influence vertical jump capacity, balance, and speed in adult soccer players, but further research is needed to confirm these findings in adolescent players (Bogalho et al., 2022).

During competition some variables such as strength are crucial for stabilizing the body (Bittmann et al., 2023). However, many intense and repeated actions not only serve as performance indicators but also pose injury risks (Bargueiras-Martínez et al., 2023). According to studies, muscular shortening increases due to growth, with the highest peaks around 14 and 15 years old (Ramos-Espada et al., 2007). This injury risk can negatively impact athletes' health, leading to future problems hindering their sports participation (Emery et al., 2015; Hernández-Beltrán et al., 2022), particularly arising from muscular shortening, which has mechanical, physiological, and electrical

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implications (Rodriguez-Falces et al., 2022). In this line, the coaching staff must consider the player's age during the training task development, because the number of injuries increases considering the category (Gamonales et al., 2024).

Understanding the relationship between physical abilities and an athlete's performance can provide a better understanding of the sport and the athlete, ensuring long-term development (Becerra-Patiño & Escorcia-Clavijo, 2023). However, while many studies focus on assessing athletes' physical development, a significant portion has concentrated on studying body composition (Emmonds et al., 2016), endurance (Izadi et al., 2020), strength (Hammami et al., 2018) and speed (Moran et al., 2020). Sports staff and coaches at competitive levels should incorporate specific lower-body explosive strength exercises to enhance players' long-term development towards the elite level (França et al., 2022). To our knowledge, among the various components of athlete's health and performance, there are limited studies focused on reducing muscular shortening and the effect of improved flexibility on strength and speed in adolescent soccer players. Hence, this study aimed to determine the effect on strength and speed after reducing muscular shortening to assess the impact of an 8-week training plan with three sessions per week on young soccer players. In this line, some specific aims were determined to evaluate and clarify the information regarding different tests: i) to analyse the knee extension; ii) to evaluate the dorsiflexion; iii) to identify the jump height, time of flight, force, speed and power in different jump test; iv) to determine the Torque and Angle of Rupture through the use of Nordic Test, and v) to analyse the speed in 10, 20 and 30 meters.

Materials and method

Design

This is a quantitative study with an observational-analytical cross-sectional design (O'Donoghue, 2010). For the sample selection, a random method was used. The study was classified as low risk according to Colombian regulations based on non-invasive research standards and guidelines.

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Participants

The sample was made up of 22 young soccer athletes from Bogotá, part of the U-13 category participated in the investigation (Table 1). To respect the specific characteristics of eligible participants, the following inclusion criteria were considered: i) having muscular shortening in the pretest; ii) performing the post-test; iii) belonging to the U-13 category; iv) being present for 90% of the training plan v) not having lower or upper limb injuries affecting test performance; vi) having a minimum of two years of soccer playing experience. Exclusion criteria were established as follows: i) suffering from any health condition one week before the evaluation; ii) experiencing physical discomfort during the evaluation; iii) resuming fieldwork with a duration of less than two months.

Table 1.

General descriptive characteristics of the sample (n = 22).

Characteristics	Mean ± SD
Age (years)	13.40±0.66
Height (cm)	156.9±9.27
Weight (kg)	44.54±7.29
Leg length (cm)	97.34±6.90
Squat at 90° (cm)	72.15±5.63
Lever (cm)	114.5±6.55
Training experience (yrs)	2.56±0.41

Note. cm: centimeters; kg: kilograms

Instruments

Angles were assessed using the universal goniometer with a measurement range of 360º (model XTGM01, Xonit, Mexico). Weight was evaluated using an Omron scale (Hbf-514C, Kyoto, Japan) with a precision of 0.1 kg and a portable stadiometer (Seca, 213), to determine height.

The selected method for assessing Squat Jump (SJ), Counter Movement Jump (CMJ) and Countermovement Jump with Arms (CMJA), strength was the mobile application utilizing video recording through My Jump 2, with an intraclass correlation coefficient of 0.997, *p*< 0.001; Bland-Altman bias = 1.1±0.5 cm, *p*< 0.001, and validity for height r = 0.995, *p*< 0.001 (Balsalobre-Fernández et al., 2015). The iPhone app

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Runmatic was used to measure running mechanics (r = 0.94-0.99, *p*< 0.001) (Balsalobre-Fernández et al., 2017).

Protocol

After the study's objective, scope, and procedures were explained to the athletes and coaching staff, each sportsman provided assent, and parents or guardians provided informed consent for voluntary participation. Each procedure adhered to the principles outlined in the Helsinki Declaration (2013) and received approval from the National Pedagogical University's ethics committee (340ETIC-2024). Similarly, this study was conducted under the sports science ethics premises (Harris et al., 2022).

All data collection took place during the pre-competitive period. For the training plan design, a review of various studies focused on reducing muscular shortening and improving Range of Movement (RoM) (Ayala & De Baranda, 2008; Bohajar-Lax et al., 2015; Cipriani et al., 2003), was conducted, targeting male soccer players. We relied on three documents: firstly, focusing on improving muscular shortening through flexibility in adolescent male soccer players (Iatridou et al., 2018). Secondly, two documents characterize muscular shortening in sports, specifically in the hamstrings and gastrocnemius muscles (Vidal et al., 2011).

The training plan proposed has the following characteristics:

- It has three sessions per week for 8 weeks in the final phase of training.
- Active and passive stretching methods will be used; "*active static for learning stretches*" and "*passive during adolescence with caution*" (Weineck, 2005).
- Each shortened muscle group will be stretched for 180 seconds, fragmented into series ranging between 6 and 9 until reaching the specified time. The stretching intensity was determined using the perceived effort scale of flexibility, working within the range of "61 to 80 – Discomfort" (Martin-Dantas et al., 2008). Additionally, flexibility evaluation provides higher-quality information when recorded in degrees (°) rather than centimetres (cm), and goniometry facilitates assessment (Milanese et al., 2014). Before data collection, a pilot test was

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conducted to establish warm-up protocols, determine the duration of each test, and gain expertise in using the My Jump Lab application.

Table 2.

Intervention protocol of the experimental group.

Pre test (week 1)	Day 1 (Height, weight, leg length, flexion 90°, lever)	Day 2 (muscle length of knee extension and dorsiflexion, SJ, CMJ, CMJA)	Day 3 (Nordics and speed in 10, 20 and 30 meters)
Training plan considerations (week 2-9	- 10 weeks. - 8 weeks of intervention. - 3 sessions per week - Last 20 minutes of training..	- Active and passive stretching. - Perceived Flexibility Perceived Stress Scale, "Discomfort" (PERFLEX).	- Bibliographic review for the elaboration of the training plan. - Validation of the training plan by the judgment of two experts.
Post test (week 10)	Day 1 (Height, weight, leg length, flexion 90°, lever).	Day 2 (muscle length of knee extension and dorsiflexion, SJ, CMJ, CMJA)	Day 3 (Nordics and speed in 10, 20 and 30 meters).

The data collection was conducted under the next structure (Table 3).

Table 3.

Structure of the data collection.

Variable	**Indicators**		
	Position	**Goniometer placement**	**Measurement**
Knee Extension	Supine with hips and knees flexed at 90°.	Fulcrum located at the outer femoral condyle, fixed arm directed proximally on the outer thigh, movable arm directed distally parallel to the outer malleolus.	The subject performs knee extension while maintaining hip flexion, and the achieved range in degrees is the test result
Dorsi flexion	Supine with legs extended and ankle at 90°.	Fulcrum located at the outer malleolus, fixed arm directed proximally with the fibula head as a reference, movable arm parallel to the fifth metatarsal.	The subject performs dorsiflexion, and the achieved range in degrees is the test result.
	Description		**Data**
SJ	The athlete faces the device, flexes their knees to 90°, places hands on their waist throughout the test, holds the flexion, and upon receiving the signal, jumps vertically as high as possible from that position.		Jump height (cm), flight time (ms), force (N), average speed (m/s), and power (W).
CMJ	The athlete faces the device, places their hands on their waist throughout the test, and upon receiving the signal, jumps vertically as high as possible by flexing their knees.		Jump height (cm), flight time (ms), force (N), average speed (m/s), and power (W).
CMJA	The athlete faces the device and, as soon as the signal is received, jumps vertically as high as possible by flexing their knees and using their arms as additional impetus.		Jump height (cm), flight time (ms), force (N), average speed (m/s), and power (W).

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Nordics	With the help of external support located on their calves, the athlete kneels and initiates a controlled descent with hands on the chest without increasing the number of segments. When they feel they can no longer control the descent, they separate their hands from the chest to cushion the fall	Break angle (°) and torque (Nm).
Speed	The athlete in a bipedal position runs 30 meters in a straight line in the shortest time possible upon receiving the signal.	Partial times at 10, 20, and 30 meters and total time (s).

After the test application, a randomization of the sample was carried out to obtain the control group (10 athletes) and the experimental group (12 athletes). Initially, the group was composed of 24 players. There, it was randomly determined that 12 players would be in the experimental group and 12 in the control group. However, two players in the control group did not meet the criteria and did not perform the post-test. Therefore, they were not considered. The experimental group participated in the training plan for 8 weeks during the final stretching phase, while the control group continued with the dynamics proposed by the category coach. Subsequently, the post-test was executed over two days under the same conditions and with the same tools as the pretest. On the first day, muscular length tests, SJ, CMJ, and CMJA were conducted, and on the second day, hamstring force tests (Nordics) and speed at 10, 20, and 30 meters.

Statistical analysis

For the type of sample under the described experimental design and taking a type I error of 5% and a nominal power of 80%, the sample size was determined by means of the partial eta-squared (ηp^2) statistic, taking as reference the detection of strong differences between groups and times in a significant way ($\eta p^2 > 0.3$) (Ateş et al., 2019). Below is the detail of the sample size for different values of ηp^2. According to the given conditions, at least a sample size of 21 participants was required for the study. Finally, the sample was made up of 22 athletes.

For the statistical analysis, a characterization of each variable was performed based on its type. Nominal scale variables were assessed using central tendency measures (mode), as well as dispersion measures (frequencies). Regarding quantitative variables, the mean and median were used as measures of central tendency, with

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standard deviation as a measure of dispersion and position measures. To identify the sample distribution, the Shapiro-Wilk test was carried out, and parametric tests were used for the inferential analysis (Shapiro & Wilk, 1965). In the inferential phase, repeated measures analysis of variance (ANOVA), was employed (Field, 2013).

Differences between groups, times, and group-time interactions were assessed. Effect size estimates for main effects were calculated using ηp^2 and interpreted as follows: 0.01 = small, 0.06 = medium, and ≥ 0.14 = large (Lakens, 2013). The analysis was conducted using statistical software ®Studio version 4.1.0 (RStudio, INC, Boston, 2016). The level of signification was established in $p < 0.05$.

Results

Table 4 presents the knee extension results; significant differences can be observed for the right knee in both time and group time ($p = 0.00$). Similar significant values were observed for the left knee, both in time and between groups ($p = 0.00$).

Table 4.

Knee Extension Goniometry Results.

Right knee extension (°)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	224.251	1.683	0.07	0.07	0.20
Time	1	20	2.866	296.934	0.93	0.15	0.00***
Group-Time	1	20	2.866	367.970	0.94	0.18	0.00***
Left knee extension (°)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	154.625	2.050	0.09	0.09	0.16
Time	1	20	4.935	219.198	0.91	0.25	0.00***
Group-Time	1	20	4.935	197.739	0.90	0.23	0.00***

*****$p < 0.00$**
Note: num.DF = degrees of freedom in the numerator, den.DF = degrees of freedom in the denominator, MSE = mean squared error, F = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, pes = is the partial eta squared effect size, ges = is the generalized eta squared effect size, Pr. F = p-value determined with the distribution F.

Regarding dorsiflexion, significant differences were observed for the right leg concerning time ($p = 0.00$) and group time ($p = 0.00$), both with a large effect size. Similarly, for the left leg, similar results were observed with significant differences and large effect sizes for time ($p = 0.00$) and group time ($p = 0.00$).

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Table 5.

Results of dorsiflexion goniometry.

Right dorsiflexion (°)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	3.691	1.020.	0.04	0.04	0.32
Time	1	20	146.625	123.548	0.86	0.19	0.00***
Group-Time	1	20	146.625	100.483	0.83	0.16	0.00**
Left dorsiflexion (°)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	23.675	2.332	0.10	0.09	0.14
Time	1	20	1.660	115.925	0.85	0.27	0.00***
Group-Time	1	20	1.660	94.895	0.82	0.23	0.00***

****$p < 0.01$; ***$p < 0.00$**

Note: num.DF = degrees of freedom in the numerator, den.DF = degrees of freedom in the denominator, MSE = mean squared error, F = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, pes = is the partial eta squared effect size, ges = is the generalized eta squared effect size, Pr. F = p-value determined with the distribution F.

The results related to the SJ show no significant differences between groups. However, significant differences were found over time for jump height (p = 0.01) and speed (p = 0.02). Finally, significant differences were also found over time regarding power (p = 0.46), and regarding group time, significant differences were observed only for the jump height variable (p = 0.04).

Table 6.

SJ results.

Jump height (cm)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	55.096	2.834	0.12	0.11	0.10
Time	1	20	3.909	16.460	0.45	0.05	0.00***
Group-Time	1	20	3.909	4.786	0.19	0.01	0.04*
Time of flight (ms)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**Pes**	**Ges**	**Pr. F**
Group	1	20	12.703	1.462	0.06	0.03	0.24
Time	1	20	11.365	4.099	0.17	0.08	0.05
Group-Time	1	20	11.365	0.0064	0.00	0.00	0.93
Force (N)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**Pes**	**Ges**	**Pr. F**
Group	1	20	126.612	39.103	0.16	0.14	0.06
Time	1	20	14.400	34.694	0.14	0.01	0.07
Group-Time	1	20	14.400	0.2262	0.01	0.00	0.63
Speed (m/s)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**Pes**	**ges**	**Pr. F**
Group	1	20	0.026	2.436	0.10	0.10	0.13
Time	1	20	0.0016	12.252	0.37	0.03	0.00***
Group-Time	1	20	0.001	2.485	0.11	0.00	0.13

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Power (W)							
Source	num. Df	den. Df	MSE	F	pes	ges	Pr. F
Group	1	20	266.644	3.690	0.15	0.10	0.06
Time	1	20	146.871	4.513	0.18	0.07	0.04*
Group-Time	1	20	146.871	0.0071	0.00	0.00	0.93

*$p < 0.05$; ***$p < 0.00$

Note: num.DF = degrees of freedom in the numerator, den.DF = degrees of freedom in the denominator, MSE = mean squared error, F = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, pes = is the partial eta squared effect size, ges = is the generalized eta squared effect size, Pr. F = p-value determined with the distribution F.

For the CMJ test, significant results were found for groups about jump height ($p = 0.04$), flight time ($p= 0.04$), speed ($p = 0.04$), and power ($p = 0.04$), all with a large effect size. Similarly, for time, significant differences were found in jump height ($p = 0.00$), flight time ($p = 0.00$), speed ($p = 0.00$), and power ($p = 0.04$). Finally, for group time, significant differences were found in jump height ($p = 0.01$), flight time ($p = 0.02$), and speed ($p = 0.01$).

Table 7.

CMJ results.

Jump height (cm)							
Source	num. Df	den. Df	MSE	F	Pes	Ges	Pr. F
Group	1	20	48.606	4.737	0.19	0.18	0.04*
Time	1	20	3.759	13.608	0.40	0.04	0.00***
Group-Time	1	20	3.759	7.040	0.26	0.02	0.01**
Time of flight (ms)							
Source	num. Df	den. Df	MSE	F	Pes	Ges	Pr. F
Group	1	20	3.418	4.699	0.19	0.17	0.04*
Time	1	20	242.255	14.142	0.41	0.04	0.00***
Group-Time	1	20	242.255	6.329	0.24	0.02	0.02*
Force (N)							
Source	num. Df	den. Df	MSE	F	Pes	Ges	Pr. F
Group	1	20	159.059	33.133	0.14	0.11	0.08
Time	1	20	36.198	26.759	0.11	0.02	0.11
Group-Time	1	20	36.198	0.1347	0.00	0.00	0.71
Speed (m/s)							
Source	num. Df	den. Df	MSE	F	Pes	Ges	Pr. F
Group	1	20	0.0209	4.579	0.18	0.17	0.04*
Time	1	20	0.0014	15.865	0.44	0.04	0.00***
Group-Time	1	20	0.0014	6.669	0.25	0.02	0.01**
Power (W)							
Source	num. Df	den. Df	MSE	F	Pes	Ges	Pr. F
Group	1	20	354.856	43.785	0.17	0.15	0.04*
Time	1	20	63.461	46.216	0.18	0.03	0.04*
Group-Time	1	20	63.461	0.71809	0.03	0.00	0.40

***$p < 0.05$, **$p < 0.01$, ***$p < 0.00$**

Note: num.DF = degrees of freedom in the numerator, den.DF = degrees of freedom in the denominator, MSE = mean squared error, F = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, pes = is the partial eta squared effect size, ges = is the generalized eta squared effect size, Pr. F = p-value determined with the distribution F.

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In Table number 8 regarding the CMJA, significant differences were observed for groups with large effect sizes for jump height (*p* = 0.03), flight time (*p* = 0.03), and speed (*p* = 0.03). Similarly, statistically significant differences were found for time in jump height (*p* = 0.00), flight time (*p* = 0.00), and speed (*p* = 0.00). Finally, no significant differences were found for group-time.

Table 8.

Results CMJA.

Jump height (cm)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	68.353	51.429	0.20	0.19	0.03*
Time	1	20	3.155	385.376	0.65	0.07	0.00***
Group-Time	1	20	3.155	0.5032	0.02	0.00	0.48
Time of flight (ms)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	4.411	50.579	0.20	0.19	0.03*
Time	1	20	1.822	401.043	0.66	0.07	0.00***
Group-Time	1	20	1.822	0.2008	0.00	0.00	0.65
Force (N)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	241.165	23.875	0.10	0.08	0.13
Time	1	20	89.385	12.630	0.05	0.01	0.27
Group-Time	1	20	89.385	0.7148	0.03	0.00	0.40
Speed (m/s)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	0.0271	49.664	0.19	0.19	0.03*
Time	1	20	0.0011	399.317	0.66	0.07	0.00***
Group-Time	1	20	0.0011	0.3509	0.01	0.00	0.56
Power (W)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**Ges**	**Pr. F**
Group	1	20	607.240	34.985	0.14	0.12	0.07
Time	1	20	171.655	30.691	0.13	0.03	0.09
Group-Time	1	20	171.655	0.9877	0.04	0.01	0.33

***p < 0.05, ***p < 0.00**

Note: num.DF = degrees of freedom in the numerator, den.DF = degrees of freedom in the denominator, MSE = mean squared error, F = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, pes = is the partial eta squared effect size, ges = is the generalized eta squared effect size, Pr. F = p-value determined with the distribution F.

Regarding the results presented in Table 9, it was observed that there were no significant differences for the variable groups. However, significant differences were found regarding the time for torque (*p* = 0.00), and breaking angle (*p* = 0.01).

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Meanwhile, for the variable group time, significant differences were only observed about torque ($p = 0.02$).

Table 9.

Nordics results.

Torque (Nm)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**ges**	**Pr..F**
Group	1	20	3.961	2.202	0.09	0.09	0.15
Time	1	20	3.956	27.073	0.57	0.10	0.00***
Group-Time	1	20	3.956	5.838	0.22	0.02	0.02*
Angle of rupture (°)							
Source	**num. Df**	**den. Df**	**MSE**		**pes**	**ges**	**Pr..F**
Group	1	20	1.086	10.203	0.04	0.04	0.32
Time	1	20	9.303	69.998	0.25	0.02	0.01**
Group-Time	1	20	9.303	0.441	0.02	0.00	0.51

*$p < 0.05$, **$p < 0.01$, ***$p < 0.00$

Note: num.DF = degrees of freedom in the numerator, den.DF = degrees of freedom in the denominator, MSE = mean squared error, F = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, pes = is the partial eta squared effect size, ges = is the generalized eta squared effect size, Pr. F = p-value determined with the distribution F.

Finally, according to Table 10, significant results and a large effect size between groups ($p = 0.02$), and time ($p = 0.00$), can be observed about 10 m, and for 20 m, a large effect size between groups ($p = 0.01$). For 30 m, only significant differences were found for time ($p = 0.00$). Finally, for total time, differences were found between groups ($p = 0.03$), and time ($p = 0.00$), and no statistically significant differences were found for group-time in any variable.

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Table 10.

Speed results.

10 meters (s)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**ges**	**Pr. F**
Group	1	20	0.02	60.184	0.23	0.17	0.02*
Time	1	20	0.00	129.757	0.39	0.15	0.00***
Group-Time	1	20	0.00	0.0454	0.00	0.00	0.83
20 meters (s)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**ges**	**Pr. F**
Group	1	20	0.02	78.998	0.28	0.27	0.01**
Time	1	20	0.00	52.190	0.20	0.00	0.03*
Group-Time	1	20	0.00	0.5323	0.02	0.00	0.47
30 meters (s)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**ges**	**Pr. F**
Group	1	20	0.02	0.7094	0.03	0.03	0.41
Time	1	20	0.00	130.470	0.39	0.06	0.00***
Group-Time	1	20	0.00	32.106	0.13	0.01	0.08
Total time (s)							
Source	**num. Df**	**den. Df**	**MSE**	**F**	**pes**	**ges**	**Pr. F**
Group	1	20	0.15	54.176	0.21	0.19	0.03*
Time	1	20	0.01	182.746	0.47	0.08	0.00***
Group-Time	1	20	0.01	0.7847	0.03	0.00	0.38

*$p < 0.05$, **$p < 0.01$, ***$p < 0.00$
Note: **num.DF =** degrees of freedom in the numerator**, den.DF =** degrees of freedom in the denominator, **MSE** = mean squared error, **F** = is the F statistic with an F distribution with degrees of freedom num.DF and den.DF, **pes** = is the partial eta squared effect size, **ges** = is the generalized eta squared effect size, **Pr.F** = p-value determined with the distribution F.

Discussion

The study successfully demonstrated that an 8-week training plan aimed at reducing muscular tightness revealed significant improvements in factors such as right and left knee extension, and right and left dorsiflexion. Additionally, there are positive improvements in the SJ component, specifically in jump height. In the CMJ component, there are positive enhancements in jump height, flight time, and speed. However, there were no notable improvements in flight time, speed, force, and power of SJ components. Similarly, there were no significant improvements in force and power for the CMJ. In the Nordic test, an improvement was evident in the torque component. Post-test evaluations revealed no significant changes in certain variables, indicating that in the evaluated population, the reduction of muscular tightness did not affect CMJA

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height, flight time, speed, force, and power, Nordic test rupture angle, and speed at 10, 20, and 30 meters.

A study confirmed that most of the evaluated youth presented muscular tightness, which seemed to be a frequent indicator in those engaged in sports (Ramos-Espada et al., 2007), aligning with the findings of this research where all 22 evaluated young footballers exhibited muscular tightness. Positive results in increasing RoM are attributed to the total stimulus time, with 180 seconds being the optimal duration regardless of the number of series performed (Ayala & De Baranda, 2008, Warneke et al., 2023). These findings align with those in the present study, where players varied the amount of series from week 1 to week 8, obtaining statistically significant results with the same total duration of 180 seconds. Additionally, static-active and static-passive stretches contributed to the improvement of RoM (Ayala & De Baranda, 2008; 2010). The study by Sánchez-Rivas et al. (2014), and Mayorga-Vega et al. (2016), affirm that both methods are effective and can be combined.

Moreover, it states that this stimulus time is relevant for the hamstrings, like the findings of this study, where a significant improvement was found for the experimental group in torque (Nm), and rupture angle. Static stretches also led to knee extension and dorsiflexion improvements. It is noteworthy that the use of passive stretches from the fifth week performed optimally, considering the maturity level of the athletes facing the demands of this type of stretching that are not recommended at earlier ages due to potential injury risk when perceived as "playful" (Weineck, 2005). These recommendations in the present study resulted in significant improvements in physical force variables in SJ and CMJ, as well as in speed and hamstring force.

Another study proved that hamstring stretching in soccer players during the final phase of stretching contributed to restoring the muscle length of these muscles (Vaquero et al., 2012). This aligns with the current study, where the training plan was carried out in the cool-down phase and had positive effects on reducing muscular tightness in adolescent soccer players. Static stretches generate improvements in the hip, knee, and ankle regardless of the stimulus duration; however, the duration did affect 20-meter sprint speed, with 40 or 60-second stimuli showing the best results for this physical variable (Iatridou et al., 2018). Nevertheless, the sub-14 player group performed

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stretches with a maximum stimulus time of 30 seconds (week 7 and week 8), still resulting in statistically significant improvements in the 20-meter speed of the experimental group over the control group.

The flexibility of the hip flexors has a slight correlation with speed and a null correlation with vertical jump height. Thus, considering the nature of sports like football that demand jumps in the shortest time and at great height, the stiffness of this muscle area can be beneficial. However, evidence supporting this is lacking (Bogalho et al., 2022). Nevertheless, in this study, it was evident that after increasing the RoM of the knee flexors, statistically significant increases occurred in the CMJ and CMJA heights, jumps that involve the elastic-explosive tension crucial in football for accelerating, decelerating, changing direction, and sprinting. The evaluation of performance through vertical jump (SJ and CMJ), and speed at 5, 10, and 20 meters in male football players aged 14 to 18 reveals that limited hamstring flexibility is related to the ability to perform various specific football actions such as running, jumping, changing direction, accelerating, and sprinting. Thus, muscular flexibility is a relevant factor to consider in training plans from an early age (García-Pinillos et al., 2015). These findings are related to the present study, as flexibility has effects on reducing muscular tightness, and this improvement in RoM, in turn, led to improvements in specific performance in the CMJ and speed, actions necessary to adapt to the demands of the sport.

It is contended that static stretches allow flexibility improvement without interfering with sports performance, especially in dynamic muscular performance actions (Medeiros, 2016; Medeiros & Martini, 2018). Improvements in flexibility through this type of stretch suggest statistically significant correlations with vertical jumps and 10-meter sprints (Vích, 2015). As reiterated in this discussion, the link between flexibility and the vertical jump has been substantiated. Additionally, static stretches at the end of the training, in line with the mentioned study (Vích, 2015), allowed flexibility improvements. Statistically significant differences were observed regarding 10-meter speed.

Furthermore, the effects of seven weeks of static stretching of the hamstrings on flexibility and speed performance in young soccer players determined that flexibility and speed at 30 meters improved significantly in the experimental group. It was

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concluded that implementing stretches at the end of the training session helps attenuate the negative effect of the load on the hamstrings and, in turn, promotes performance improvements (Rodriguez-Fernandez et al., 2015). These findings are somewhat related to the present study, where statistically significant improvements were found in force and speed variables, and a reduction in muscular tightness as a preventive measure in sports training after eight weeks of using static passive and active stretches in young soccer players.

Based on the previously stated objective, it was possible to demonstrate that through a training plan of 8 weeks, significant improvements were evidenced in the study group in the factors: right and left knee extension, right and left dorsal flexion, in addition to this, positive improvements were evidenced in the SJ component in jump height, in the CMJ component, positive improvements were found in jump height, flight time and speed, and no notable improvements were found in the components flight time, speed, strength, and power of the SJ. After the evaluations were performed, it was found that there was no relationship of change within the study group in any of the components of the CMJA and in the angle of rupture for the Nordics test, demonstrating that the decrease in muscle shortening does not generate any effect on these strength variables in the population studied.

Limitations

A limitation was found in the sample size, in the number of individuals analyzed to have a higher value of statistical significance, it is recommended to perform this study with a larger sample. Similarly, a limitation of the study was that the results could not be extrapolated to other disciplines, as only football was analysed in this study. Therefore, it is recommended that this study be extended to other sports to be able to compare the data and extract relevant conclusions.

In the same line, according to the time in which it is recommended to perform evaluations such as muscle asymmetry test, and stride length measurement added to those performed in this research project to identify their relationship with the problem posed.

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Another limitation is not being able to evaluate the study group a few months later to identify if the adaptations generated by the training plan were lost and to evaluate the strength and speed to identify whether or not the levels of this are maintained, given this it is recommended to evaluate the post-test to identify whether or not it returns to the initial condition before starting the intervention process.

Conclusions

It is concluded that a training plan of 8 weeks of static stretching shows significant improvements in the reduction of muscle shortening and positive changes in the strength component measured from the SJ, CMJ, CMJA and Nordics, as well as in the Speed in 10, 20 and 30 meters.

The importance of flexibility for the improvement of strength and speed in the study group is identified. In short, according to the findings of the present study, it seems that flexibility influences vertical jumping ability and speed.

The findings of the present study establish relationships between variables that are immersed in the sports training process, as well as the particularities of the flexibility processes and their relationship with the sports performance of adolescent soccer players. In view of this, a possible line of research suggests the analysis of the variables of the present study to determine differences between players and the effect of a training plan. There, it would be necessary to incorporate more and more rigorously the inclusion of flexibility, not only to favour sports performance but, at the same time, to contribute to the reduction of injury risks caused by muscle shortening, mainly in a sport with high neuromuscular demands such as soccer.

Future prospects

For future research related to muscle shortening it is suggested:

- It is recommended through pedagogical experience to work on flexibility given that it is a very important capacity that influences performance in terms of jumping and speed, in addition to this it also reduces the risk of injury. Flexible muscles and joints absorb impact better and can adapt to unexpected

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movements, which decreases the likelihood of sprains, strains, and other exercise-related injuries.

- It is recommended to perform the study with a larger population size to determine a larger effect size, and to have control of different variables not considered in the study.
- To have greater control of different contaminating variables to obtain a greater effect size in the population.
- It is recommended to associate muscle asymmetry tests to evaluate different findings and the influence of muscle shortening on them.
- Contemplate the possible scenarios for the development of the sessions throughout the weeks of intervention, avoiding that the climate and climatic factors affect the correct development of the sessions.
- It is recommended that coaches in charge of the different soccer categories include flexibility work in their planning.

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