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RESEARCH

Lower flexibility and range of motion in prepubertal soccer players: a pilot study

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Abstract

Purpose Even if sport practice is essential for children's health, in the last years, an increased number of studies recorded injuries from the age of 12 years. In the multifactorial nature of injuries, a reduction in flexibility and/or range of motion is hypothesized to play a role. Thus, the aim of this study is to analyze the flexibility and range of motion of soccer players in the prepubertal age.

Methods In this pilot transversal study, we investigated through various mobility tests (ankle wall test, sit and reach test, and active straight leg raise test) a population of 78 prepubertal soccer players (male, 12 ÷ 14 years old, BMI 18.472 ± 2.18 kg/m^2).

Results The results showed a significant reduction in their flexibility and range of motion compared to the reference values reported in clinical guidelines, and this decrement increased with the years of soccer history and age.

Conclusions The lower flexibility and range of motion confirmed the importance of planning an adequate training to prevent their limitation with repercussions on body growth.

Keywords Sport · Ankle wall test · Sit and reach test · Active straight leg raise test · Prevention

Introduction

Practicing sports and fitness regularly are basic prerequisites for children's health [1], as well as the participation in youth sports has been demonstrated to be positively associated with higher levels of physical activity in the adulthood [1]. Therefore, from both an individual and a health perspective, it is important to promote sufficient physical activity during childhood [2]. It is recommended that children engage in at least 60 min of moderate- or high-intensity physical activity per day [1]. In these terms, team sports can be a suitable context for children. Since football is the most popular sport in the world and most (22 of 38 million officially registered players) of the players are under the age of 18, it has a great potential to induce health benefits on children to help them to sustain a healthy lifestyle [3–7]. Football is considered a high-intensity sport, that involves frequent changes in speed and direction of movement, and many situations where players are involved in tackles to maintain possession or win the ball [3]. Especially the high-impact situations that occur, during contact between players, cutting maneuvers and falls, create a significant risk of injury, so it is necessary to implement preventive measures to reduce the risk, while still sustaining the health benefits associated with playing [3, 8, 9].

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The multifactorial nature of risk of injuries in football was evaluated by Anason et al. [10], that followed a population of 306 players with a mean age of 24 years. Also, flexibility, as predisposing factor, was investigated and results demonstrated that, for example, for groin strains, a predictor risk factor is the decreased range of motion in hip abduction. A considerable amount of literature describes injuries in football, and much of it comes from the analysis of adult professional players. However, only few research is available on injuries in young soccer players (YSP) [11]. The latter study includes players from under 9 up to under 23 years old. Most injuries in professional players and YSP are typically caused by soft tissue, and a large percentage occurs in non-contact situations [12, 13]. Ekstrand et al. [12] investigated a study population with a mean age of 25.7 years, Read et al. [13] studied a group in the range of 11–18 years old. Injuries involve mainly the lower extremities (reported for players with a mean age of 25.3 years) [14], as muscles of the thigh (reported for players in the range of 15–19 years old) [6], anyway ligament injuries are also frequent as well as contusions, haematomas, and tendinopathies that frequently occur in YSP [11]. Player's age is an important risk factor and a particular increase in injury incidence rates is observed in boys starting from the age of 12 [6]. A recent study showed that the incidence of the anterior cruciate ligament (ACL) injuries in the pediatric population has increased by 2.3% over the past 20 years. It was reported that very few injuries were found in patients younger than 10 years of age; however, the incidence of ACL injuries increased significantly among the ages of 10 and 14 years. This is the time when the game evolves from a short-field game to the standard of adult football, and the number, specificity, and intensity of training sessions increase, while most players start to grow rapidly. Surely, the increased training could be an excessive stress for a body that is still growing [9, 15], but it is not known what exactly the risk factors are for these traumas and how it is possible to prevent them. Rossler et al. [9] investigated players aged 7–12 years, and Koutures et al. [15] studied a population among 7 and 15 years old. Jones et al. [16] reported the results of a study (cohort with a mean age of 19 years) that demonstrated the ability of an increase in flexibility to reduce lower extremity overuse injuries. Witvrouw et al. [17] discussed that knee injuries are thought to be caused by reduced quadriceps femoris flexibility which induces sports disorders (among 17 and 21 years old). Azuma et al. [18] consider an improved flexibility, as though continuous stretching, to be related to a reduced incidence of muscle and tendon injuries (mean age 16.2 years). Moreover, Opplert el al and Behm et al. [19, 20] proved that an increased range of motion of the lower limbs led to positive effects in terms of sports performance. Really, the diffusion of information on anthropometric and growth-related risk factors is fundamental but is not always present in youth football research [21]. The hypothesis of this study is that in an asymptomatic population of prepubertal soccer players, especially in the areas of increased overuse, such as the inferior limbs, there could be a reduction in flexibility and/or range of motion. Therefore, the thesis of this study is to evaluate the flexibility and range of motion of this population cohort.

Methods

Study design

In this pilot transversal study, all the assessments were made at the end of two sporting seasons (2022 and 2023, the last weeks) by the same operator (D.P.). The sample size included 78 volunteers, all recruited from two professional football soccer societies of Padua (Italy). Each player and the relative caregiver have been both informed of the testing protocol and a written informed consent was signed before starting the study. The Helsinki Declaration and human experimentation rules [22] were considered and the Ethics Committee of the University of Padua approved the research. All participant information and test results were collected anonymously in a database and then statistically analyzed according to subgroups specified in Table 1. The subgroups thresholds were established by considering the total range of values (for Subgroup 1 and 2) and the mean value (for Subgroup 3 and 4).

Participants

This study included a total of 78 young soccer players. The participants were all males and taken from different ages: 12, 13, and 14 years old (y/o). Moreover, they were all members of the Italian Football Federation. The age of the athletes was in line with the scientific literature which considers these ages to be the apex of musculoskeletal development. Each athlete was recruited by the two sports clubs that authorized the transmission of athletes' personal data and contacts for the study. Our study inclusion criteria were (1)

Table 1 The overall study population was subdivided, and the participants were grouped into several subsets based on the criteria reported for the statistical comparison

Subset	Criteria (no. subjects)
Group 1	Left lower limb test (78)
Group 2	Right lower limb test (78)
Subgroup 1	1–5 years soccer history (25)
Subgroup 2	6–10 years soccer history (53)
Subgroup 3	12–13 years old (46)
Subgroup 4	14 years old (32)

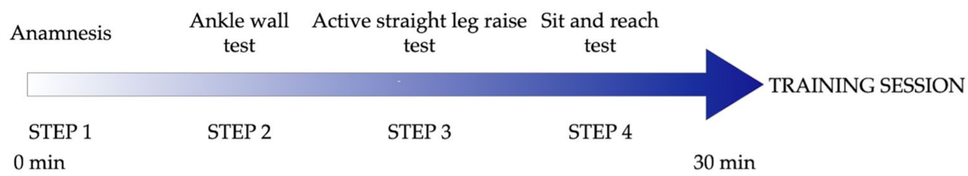

Fig. 1 Evaluation pipeline for each participant included in the study

teams registered in the local soccer association and undergoing regular training and (2) children aged 12–14 years and registered in the team. Participants and/or their guardians/parents were also asked to complete a health declaration form. Participants were excluded from the study if they had a history of upper and lower limb injury requiring medical attention in the past 2 years, systemic diseases, cardiovascular disease, neurological disorders, bone fractures, and/or surgery. Furthermore, participants in the role of goalkeepers (different training from the other players) were excluded. A survey was designed to collect the personal and the morphological data of the athletes and their training frequency. In general, their workouts were scheduled on average three times a week. The athletes underwent mobility tests three times (three trials) with 2 min of rest period (sitting position) between each trial, and all the tests were performed before one of their training sessions (the last week of their sporting season), before warming up.

Procedures

All the evaluations were performed before the athletes training session, after a demonstrative session performed by the operator. The study protocol duration was approximately 30 min in total. Each player was undergone to the specific evaluations in the same order. Each step consists as follows: (STEP 1) anamnesis as medical history survey, (STEP 2) ankle wall test, (STEP 3) active straight leg raise test, (STEP 4) sit and reach test, Fig. 1.

STEP 1—Anamnesis: a specific questionnaire was used to record data on the subject's sports history. The following information was collected: gender, age, weight and height, dominance of the foot with which to kick, weekly workouts, and years of attendance of the sport (soccer).

STEP 2—Ankle wall test (AW) to evaluate the dorsiflexion flexibility of the ankle. This test was performed against a wall, and it was measured with a meter (flexometer, precision class 1). The maximum distance from the wall to the knee was recorded by the operator (see Fig. 2). Participants were asked to place their big toe aligned with a tape sign (yellow line), on the floor. The tape line was fixed 15 cm from the wall. They were asked to keep going until their knee was as close to the wall as possible. The heel should always remain in contact with the floor, placing the ankle joint in maximum dorsiflexion. The untested leg rested on the floor and the participants were allowed to hold on to the wall for support if needed. Next, the operator measured the distance between the knee and the wall (pink line). Then, that distance was subtracted from 15 cm to calculate the total foot–knee distance. Three measurements were taken and averaged. The subject was asked to report any sensations during the test. According to the literature, a person who exceeds a distance (foot-knee) of at least 10 cm could be considered in a normal range [23] (Table 2).

Fig. 2 AW test

Table 2 Normal values from the literature

Test	Reference value	References
AW test	> 10 cm	[23]
Active straight leg raise test	> 80°	[24]
Sit and reach test	> 0 cm	[25, 26]

STEP 3—Active straight leg raise test (FA) to evaluate the flexibility of the hamstrings. The measurements in relation to the maximum elevation of the limb were recorded by the operator (Fig. 3). Participants were asked to lie on their backs on the floor. At this point, it was necessary to actively lift the thigh, keeping the sacrum and pelvis still, avoiding twisting and extending the knee; the elevated foot remained in a neutral position to prevent gastrocnemius involvement. The operator measured the angle between the greater trochanter and the horizontal

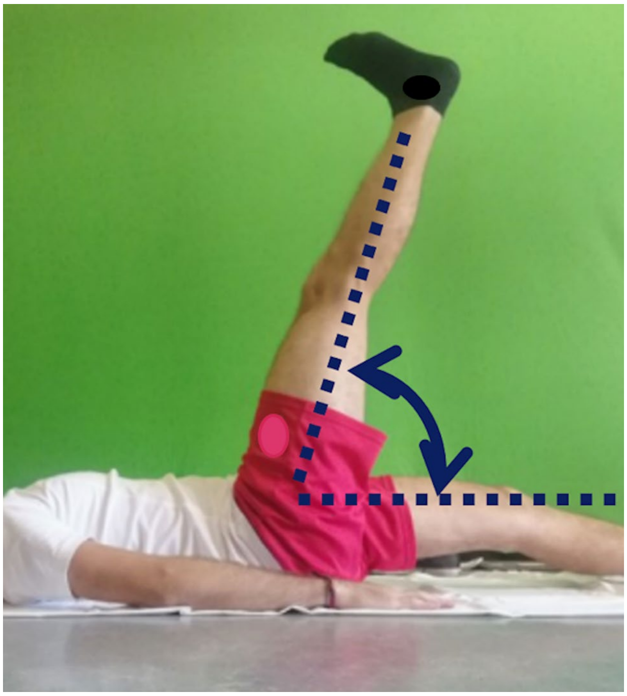

Fig. 3 FA test

line (blue line). To establish a standard procedure, it was necessary that the knees of the athlete both extended and that the back and the pelvis were stabilized in way to avoid an excessive pelvic inclination. A total of three measurements were made for each limb (with a protractor) and then averaged. The normal value of hamstring flexibility was reached if the angle between the raised thigh and the horizontal plane was at least 80° (Table 2).

STEP 4—Sit and reach test (SR) to evaluate the flexibility of the lower lumbar region and of the hamstrings. The operator carried out the measurement (with a meter, the same instrument held by the operator in Fig. 2) between the 0 point (beginning of the case) and the tip of the hands in relation to the maximum trunk flexion, while keeping the extension of knee (Fig. 4). The participant was asked to sit on the floor, placing the feet perpendicular to the chest, with the knees extended. He was asked with his hands to reach and to pass his toes. The result was given by the position of maximum flexion that the subject was able to maintain for at least 2 s, to allow the examiner to read the results correctly. In these photos, the subject reached a negative score for this test (yellow line), from different perspectives: (a) lateral and (b) top view. Three measurements were made, and the average was calculated. A normal trunk flexion was confirmed by the number of centimeters reached on the scale (> 0 cm) (Table 2).

Statistical analysis

The statistical analysis performed on the sample. Descriptive statistics have been described with mean ± standard deviation (SD). Inferential statistics were performed with paired, one-sample and two-sample *t* test. The paired test was used to compare the body sides (left vs right lower limb) within the same group of subjects. The one-sample test was used to compare the population mean with a claimed value (in this case, the reference values are specified in Table 2). The two-sample test was used to compare the means of different subgroups (i.e., divided in accordance with years of soccer history or age), among different subjects. The assumptions were that the populations have been assumed to have a normal distribution according to the central limit theorem. For all these tests, the confidence interval was assumed to be 95% ($\alpha = 0.05$). See Table 3 for hypothesis tests summary. The analysis was performed with Minitab Statistical Software (Software, Minitab, State College, Pennsylvania 2010 Minitab, Inc.).

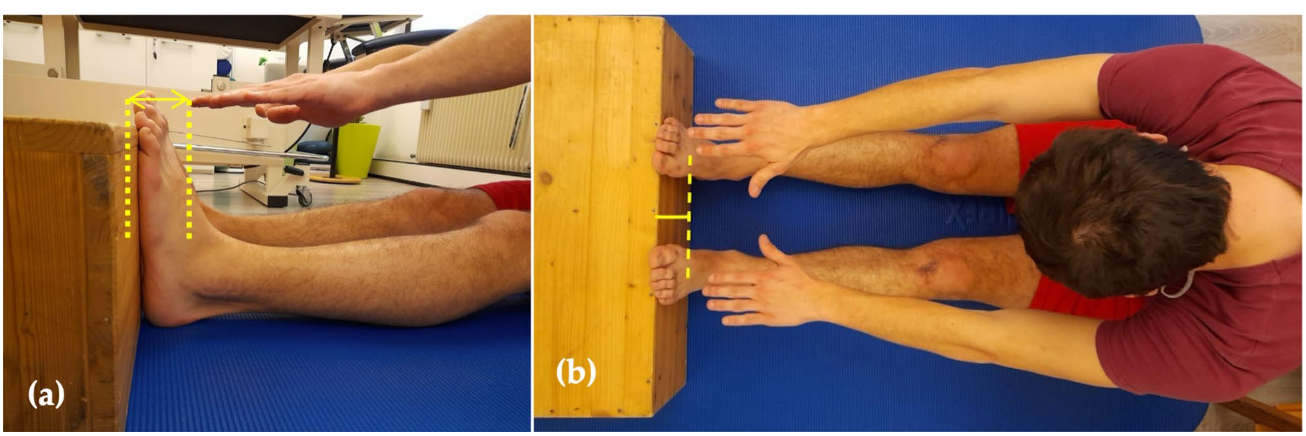

Fig. 4 SR test

Table 3 The overall population subsets were compared with different tests in accordance with specific grouping criteria

Hypothesis test (t test)	H_1 if accepted, p value < α
Paired Two-tailed	Population mean Group 1 ≠ Group 2
One-sample Left-tail	Population mean < reference value
Two-sample Right-tail	Population mean Subgroup 1 > Subgroup 2 and population mean Subgroup 3 > Subgroup 4

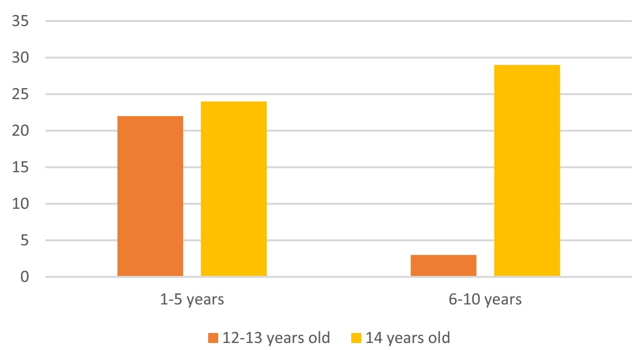

Fig. 5 Distribution of participants into subgroups (years old vs. years of soccer history)

Results

Descriptive statistics

This study included a total sample size of 78 male soccer players. The mean age was 13.10 ± 0.85 y/o; the mean height was 1.61 ± 0.10 m; the mean weight was 48.35 ± 9.33 kg; the mean BMI was 18.472 ± 2.18 kg/m^2; the mean of soccer history years was 6.59 ± 2.01 year; the 68/78 of participants had a 'right' dominance of the foot with which to kick. More information about distribution of participants among subgroups (years old vs. years of soccer history) is reported in Fig. 5.

The results from the tests considering on the overall population are reported in Table 4. The results from tests performed on the overall population but divided into subsets in relation to years of soccer history are reported in Table 5 and divided into subsets in relation to age are reported in Table 6.

Table 4 Results from mobility tests—overall population

Test	Body sides	Mean	SD
AW test (cm)	Left	9.20	3.22
	Right	9.37	3.22
FA test (°)	Left	76.78	8.38
	Right	74.38	11.68
SR test (cm)	–	− 3.21	7.58

Table 5 Results from mobility tests—Subgroup 1 vs Subgroup 2

Soccer history (years)	Test	Body sides	Mean	SD
1–5	AW test (cm)	Left	10.84	3.43
		Right	10.90	3.31
1–5	FA test (°)	Left	80.08	9.14
		Right	77.60	9.06
1–5	SR test (cm)	–	− 5.40	8.09
6–10	AW test (cm)	Left	8.42	2.99
		Right	8.65	2.95
6–10	FA test (°)	Left	75.23	7.59
		Right	72.87	12.53
6–10	SR test (cm)	–	− 2.17	7.17

Table 6 Results from mobility tests—Subgroup 3 vs. Subgroup 4

Age (y/o)	Test	Body sides	Mean	SD
12–13	AW test (cm)	Left	9.99	3.50
		Right	9.93	3.44
12–13	FA test (°)	Left	78.04	9.33
		Right	76.37	9.41
12–13	SR test (cm)	–	− 4.33	8.82
14	AW test (cm)	Left	8.06	2.68
		Right	8.56	2.73
14	FA test (°)	Left	74.97	6.50
		Right	71.53	14.01
14	SR test (cm)	–	− 1.59	5.07

AW test

There was a non-significant difference of AW test values between body sides: right (9.37 ± 3.22 cm) vs left (9.20 ± 3.32 cm). Descriptive statistic results computed on the overall population are reported in Table 4. Inferential statistic results that compare the body sides are reported in Table 7. Anyway, the test showed a significant difference between outcomes values and the reference value (10 cm) as reported from literature (see Table 2), for both left and right sides (see Table 8).

FA test

There was a significant difference of FA test values between body sides: right (74.38 ± 11.68°) vs left (76.78 ± 8.38°).

Table 7 Results from paired *t* test that compared the body sides

Test	Body sides	*p* value
AW test (cm)	Left	0.325
	Right	
FA test (°)	Left	0.025*
	Right	
SR test (cm)	–	–

*Significative difference (*p* value < α).

Table 8 Results from one-sample *t* test (left-tail) that compared population mean with a reference value

Test	Body sides	*p* value
AW test (cm)	Left	0.018*
	Right	0.044*
FA test (°)	Left	0.001*
	Right	0.000*
SR test (cm)	–	0.000*

*Significative difference.

Descriptive statistic results computed on the overall population are reported in Table 4. Inferential statistic results that compare the body sides are reported in Table 7. The outcomes showed a statistically significant difference between FA test collected values and the reference value (80°) as reported from literature (see Table 2), for both left and right sides (see Table 8).

SR test

The results showed a statistically significant difference between SR test values (− 3.21 ± 7.58 cm) and reference value (0 cm) taken from the literature (see Table 2). More details are reported in Table 8.

Association between years of playing football and mobility tests

The results showed a difference of flexibility between players in relation to the different subgroups (1–5 years of soccer history vs. 6–10 years of soccer history). Descriptive statistics outcomes are reported in Table 5. The decrement of flexibility increased with the years of soccer history, excepting for the SR test.

Association between age and mobility tests

The results showed a difference of flexibility between players in relation to the different subgroups (12–13 y/o vs. 14 y/o). Descriptive statistic outcomes are reported in Table 6. The decrement of flexibility increased with the age, excepting for SR test.

Inferential statistics

The outcomes from the inferential statistics analysis have been collected and reported in accordance with hypothesis tests and population subsets. Table 7 reports the *p* values from paired *t* tests that compared the body sides (defined in Table 1 as Group 1 and Group 2) and in Table 8 are reported the *p* values from one-sample *t* test (left-tail) that compared population mean with a reference value (see Table 2). Table 9 reports the *p* values from two-sample *t* test (right-tail) that compared population means between subgroups with different years of soccer history (defined in Table 1 as Subgroup 1 and Subgroup 2). Table 10 reports the *p* values from two-sample *t* test (right-tail) that compared population means between subgroups with different age (defined in Table 1 as Subgroup 3 and Subgroup 4).

Discussion

The objective of this study was to evaluate the prevalence of an impaired flexibility and reduced range of motion in an asymptomatic population of prepubertal soccer players, especially in the areas of increased overuse, such as the inferior limbs. Robles et al. [27] also reported how to test flexibility and range of motion in younger players (10–19 years old), finally reporting that a decrement occurred with aging.

Table 9 Results from two-sample *t* test (right-tail) that compared population mean between subgroups with different years of soccer history

Body sides	Test	Soccer history	*p* value
Left	AW test (cm)	1–5 years	0.002*
		6–10 years	
Right	AW test (cm)	1–5 years	0.003*
		6–10 years	
Left	FA test (°)	1–5 years	0.013*
		6–10 years	
Right	FA test (°)	1–5 years	0.031*
		6–10 years	
–	SR test (cm)	1–5 years	0.952
		6–10 years	

*Significative difference.

Table 10 Results from two-sample t test (right-tail) that compared population mean between subgroups with different age

Body sides	Test	Years old	p value
Left	AW test (cm)	12–13 y/o 14 y/o	0.004*
Right	AW test (cm)	12–13 y/o 14 y/o	0.027*
Left	FA test (°)	12–13 y/o 14 y/o	0.045*
Right	FA test (°)	12–13 y/o 14 y/o	0.047*
–	SR test (cm)	12–13 y/o 14 y/o	0.957

*Significative difference.

Moreover, Cejudo et al. [28] also investigated young soccer players (under 19 years old), demonstrating with mobility tests a decrement of flexibility in the group 16–19 years old if compared to the group 10–12 years old. In fact, the reduced flexibility and range of motion could be potential risk factors for injuries in young football players [10].

The results of the present study demonstrated for the first time the presence of a significant reduction in flexibility and range of motion for prepubertal soccer players in all tests, when compared with the reference values in the literature, even if asymptomatic. See Table 2 for reference values and Table 4 and 8 for statistics. According to the literature, a deficit in flexibility is one of the factors predisposing to injuries [16–18, 29, 30]. Ribeiro-Alvares demonstrated that a reduction of the active knee extension is risk factor for hamstrings strain [31]. Besides, in a population of adult soccer players, it has been demonstrated that a limited extension of the hip increases the rigidity and shortens the ileo-psoas muscle [32, 33], and that is a risk factor for subsequent musculoskeletal injuries [34]. Additionally, a limited range of motion, in this case, reduces the hip extension during gait, thus decreasing the speed and increasing the pelvic movement [35]. In these terms, another association between hamstrings injury and flexibility has been found by Gabbe et al. 2005 [36]. Low values of hip flexors/quadriceps flexibility, measured by the modified Thomas test, were found to be significantly related to hamstrings injury [37]**.** The mechanism by which hip flexors and quadriceps tightness would increase hamstrings injury risk has not been elucidated, but it has been proposed that it might adversely affect the movement mechanics, particularly sprinting and overloading the hamstring muscles, thereby increasing susceptibility to excessive strain. To reduce the incidence of hamstring injuries, a widely used practice to improve hamstring flexibility is stretching [10, 38], but this practice is scarcely applied in young soccer players for lack of time [39]. Therefore, the result of such study strongly suggests that introducing exercises for the flexibility in the routine training of the young soccer players is key to maintain a correct flexibility of the body. In the future, dynamic flexibility test of hamstring might offer a more precise evaluation of the injury risks [40]. Besides, other authors suggest that an increment of lower limbs range of motion and flexibility could lead to an improvement of the strength and performance [19, 20]. Specifically, Yamaguchi et al. [41] explained that a higher range of motion gained by a dynamic stretching protocol improved the leg extension power of 10%.

Our data also showed an association between the years of soccer history, the age of participants, and mobility test results. In both cases, the flexibility and range of motion decreased with the years of soccer history (from 1–5 to 6–10 years) and age (from 12–13 to 14y/o), excepting for SR test. See Tables 9 and 10 for inferential statistics outcomes.

Moreover, in our study, a difference between body sides have been found only for straight leg raise and not for AW tests (more details in Table 7). In the literature, the opinions about the role of the difference between right and left ankle flexibility are different. A study showed that in asymptomatic population (adult), there may be some differences between the mobility of the right and left ankle, but up to 3 cm, this difference is not a clinically significant [42]. At the contrary, Ribero-Alvares [31] affirmed that, even if a mobility difference between left/right legs of > 15% is usually considered acceptable, it can increase the risk of injury.

The relationship between foot dominance and mobility test results could be better investigated as future direction. A limitation of the current study is the sample size that in the future should be enlarged (with more equally distributed classes, expanding the context including participants' previous and complementary activities analysis) as further proof of the concept. Moreover, the tests were performed before warming up, so the tests could be repeated later. Furthermore, as this is a cross-sectional study, there is no evidence of a real increase in injuries over time in the studied cohort.

Conclusions

The evidence of the present study demonstrated that in asymptomatic young soccer players, there is already a reduction in the flexibility and range of motion of the back and of the lower limbs. This reduction in flexibility and range of motion could be related to the years of football history and the age of the athletes. These outcomes suggested the importance to plan a prospective study to evaluate the real risk of injury in these subjects and what could be the role of different trainings for flexibility and range of motions improvement as corrective and preventive action. Practical applications of study results could be the implementation of specific warming up and training protocols to prevent and improve reduction of flexibility and/or range of motion, as well as the implementation of pre-season evaluations tests/procedures.

Author contributions Conceptualization: DP and CS. Methodology: DP. Formal analysis: DP and LB. Investigation: DP. Resources: DP. Data curation: DP and LB. Writing—original draft preparation: DP and LB. Writing—review and editing: DP, LB, CP, CGF, and CS. Visualization: CS, CP, and CGF. Supervision: CS, CP, and LB. Project administration: CS. All authors have read and agreed to the published version of the manuscript.

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Data Availability Data available upon request.

Declarations

Conflict of interest The authors have no relevant conflict of interest to declare that are relevant to the content of this article.

Ethical Approval According to Italian law, the Ethical committee does not release numbers not being a practice that puts volunteers' health at risk and being an observational study without treatment and only involving volunteers. This study was completed in accordance with the Helsinki Declaration.

Human and animal rights The study was conducted in accordance with the Declaration of Helsinki.

Informed consent Informed consent was obtained from all subjects involved in the study. Patients signed informed consent regarding publishing their data and photographs.

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