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EVALUATION OF THE EFFECTS OF SOCCER PRACTICE AND OF A TARGETED TRAINING PROGRAM ON THE MOBILITY AND POSTURE OF THE ANKLE IN PLAYERS OF DIFFERENT AGES

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PREFACE

Soccer (football) is among the most practiced sports in many countries of the world and involves many young people as well as adults. [1-3] As for Italy, about a half of young males aged between 3- and 19-years old play soccer.[2-5] There are also many adults who play football, especially at an amateur level. Unfortunately, the effects of the SaR-CoV-2 pandemic have had a negative impact on the number of participants who, however, is still very high and should improve once the pandemic is over. [5,6]

Regarding health, it is known that practicing sport has many and important positive effects including physical, physiological, and social.[7-9] Unfortunately, some negative aspects have, however, been associated with the practice of football. [9,10] Among these, it is well known that the practice of football involves an intense, continuous, sometimes excessive effort of the muscles. Furthermore, soccer players are subjected to repeated and more or less significant injuries during sports practice.[10-14]

All of this leads to an increased risk of injury and overuse condition with possible effects, even not yet known, on the health of football players.[10,15,16] Among the joints, the ankle is one of those most involved in football and is particularly exposed to injury. Both traumatic injuries and overuse of the ankle could affect the integrity and the mobility of the joint. [10,17,18] Considering these possible effects it is important because the ankle plays a fundamental role in the quality of movement and posture.[19,20]

Approximately one-fifth of soccer injuries are ankle injuries. Specifically, ankle sprains are among the most frequent injuries and are regarded as approximately two-thirds of all ankle injuries.[10,15,16] It is also important to consider that while about two thirds of soccer injuries are traumatic (contact injuries and non-contact injuries) the remaining part are caused by overuse.[17,18,21] Furthermore, it has been verified that having suffered from previous injuries is an important risk factor for future ones.[10]

In addition to a history of ankle injuries, many factors have been associated with an increased risk of injury. Among these, age, competitive activity, type of footwear and playing surface used, with early sport specialization in addition to the growth period have been reported to be risk factors.[21-24]

Finally, regarding possible chronic effects, it has been reported that there is a risk of ankle pain and a high prevalence of ankle osteoarthritis among former players.[25,26]

All ankle structures can be affected by soccer practice and the presence of ankle stiffness. Inversion trauma is the most frequent mechanism of injury in soccer players. This type of injury can have consequences in particular for the anterior talofibular ligament.[18,26]

As regards the possible effects on the lateral ligament of the ankle, any injuries can have consequences on the joint stability of the ankle and the subtalar joint,[17,27] as well as being able to favor the same ankle osteoarthritis and sinus tarsi syndrome. [25,28,29]

A particular situation that affects the relationship between the ankle joint and the practice of soccer is the effects on the joint capsule. Indeed, while it is laterally reinforced by the presence of ligaments, the anterior insertion of the joint capsule on the tibia and talus is more subjected to the effects of trauma.[24,26,30] In particular, repetitive kicking action during soccer practice may involve repeated direct (micro)trauma to the edge of the articular cartilage at the level of the anterior insertion of the joint capsule. This condition is feared because it can cause inflammation, scar tissue development, calcification and, subsequently, reactive spur formation with possible long-term consequences.[26,31]

It is also important to consider that Achilles tendon disorders are more common among soccer players. The effect of soccer on Achilles tendon is important to study considering its possible effects on AJM and in particular for ankle dorsiflexion.[11,18,32]

In addition to the effects of specific sports movements, repeated traumas can lead to adaptations of the joint and periarticular structures which can cause ankle stiffness.[24,35,36] The risk of ankle joint stiffness in soccer players seems to be a paradox. In fact, the distinguishing feature of the game of football and its specific sports movements is the ball handling. On one hand, it is requested a high ability to move the foot with amplitude and precision in every direction. On the other hand, the results of some preliminary studies have verified the possible presence of a reduced ankle mobility (AJM) in footballers. The risk of ankle mobility impairment is considered important due to its numerous and feared consequences.[36-38]

Decreased ankle range of motion (ROM) is in itself a risk factor for injury such as repetitive ankle sprains, as well as affecting the quality of balance, posture, gait and running of players.[10,24,39,40] Furthermore, a reduction of ankle ROM can be itself a risk factor of overuse for articular and periarticular structures.[15,16,39]

In this sense, in footballers a vicious circle would be defined over time where the practice of sport involves the development of joint stiffness of the ankle which, in turn, increases the risk of injuries and overuse. All this can, therefore, negatively affect the same AJM.[36-38,41] It has also been reported that the negative effects associated with the presence of limited ankle ROM may persist in former players even some time after the interruption of the activity.[25,26,41]

In this sense, even if research activities have been aimed at understanding the extent and causes of the reduction of ankle range of motion in soccer players, many aspects related to the manifestation, extent, trend and effects as well as treatment of this alterations remain to be clarified. Unfortunately, to date there are no clear indications regarding the entity, and the trend over time of this parameter. Furthermore, there are still no clear indications regarding the effects of exercise protocols aimed at preventing or improving AJM deficits in these players. The pursuit of these objectives, which will be addressed in the present thesis, can also represent an opportunity to improve the performance of players and teams.

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STUDY 1

Lower limb posture and joint mobility in young Soccer players

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INTRODUCTION

The study of the effect of sport on young players is of noteworthy importance considering the large number of subjects involved and how sport can affect the development.[1-3]

Soccer is the most practiced sport, especially by males, in many countries around the world. The practice of Soccer in sports settings as well as in recreational and school ones can begin from the first years of life; therefore, even young subjects can have a history of a multiple years of sports practice.[4-8]

Basketball and Volleyball are also two of the most practiced sports by young subjects, but they differ from Soccer where the ball is managed with the feet, a condition that can induce muscle-connective adaptations at the level of the lower limb and expose the ankle to a greater number of traumas.[9-11]

The study of the effects of sport on ankle mobility is considered important because the ankle is a load-bearing joint of the body with fundamental biomechanical and postural functions.[10,12,13] The ankle is formed by a ginglymus of hinge-type synovial joint formed by the medial and lateral malleolus, which forms a mortise to receive the trochlear surface of the talus.[10,13,14] The anatomy of the articular surfaces of the talocrural joint together with other passive factors (e.g. capsuloligamentous structures surrounding the joint) and dynamic factors (e.g. muscle-action) determine joint mobility, by allowing and limiting it, in dorsiflexion and plantar flexion on the sagittal plane.[10,13,15]

Previous studies underlined that the practice of certain sports can significantly modify ankle mobility. In this sense, it has been reported that the practice of Soccer can induce a reduction in ankle joint mobility, while, this effect does not seem to occur in young Basketball and Volleyball players.[16-18] The levels of AJM reduction detected in Soccer players were such to be able to increase the risk of ankle sprain, and affect the quality of gait as well as the balance, also due to a partial deafferentiation from the articular and periarticular structures caused by repeated injuries.[12,14,19-24]

To date, there is no clear evidence regarding the effects that a reduced AJM can have on lower limb posture of young Soccer players.[25,26] The complexity of this condition can lead to a significant variation in ankle mobility, detectable in young Soccer players, suggesting that another parameter of great importance such as posture could be altered in these subjects.[12,27,28] The possible detection of postural anomalies is important because they could be studied and treated in order to prevent the same joint and postural abnormalities and injuries as well as to improve sports performance.[9,14,29]

The main aim of this study was to evaluate the possible effects of sport practice on lower limb posture and their relationships with the AJM.

MATERIALS AND METHODS

A total of 111 young male athletes, 61 Soccer, 20 Basketball, and 30 Volleyball players participated in this study. Data were collected on age, height, weight, years of sports practice, other sports practiced, number of weekly training sessions, lower limb-dominance, and history of injuries. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared (kg/m^2). Detailed characteristics of study participants are shown in Tables 1 and 2.

Before enrolment, subjects underwent a physical examination including inspection of lower limb to detect the presence of deformity, injuries, and trauma, that could affect ankle joint mobility, hamstring flexibility, or posture. Individuals with the presence of current foot and ankle problems at baseline, such as orthopaedic or surgical complications, congenital foot or leg deformity or who did not practice the same sport for at least six months continuously were not enrolled.

All young players and their parents or guardians were informed on the purpose of the study and its experimental procedures before obtaining their written informed consent and the enrolment in the study. The protocol and the consent forms were approved by the Paediatrics Ethics Committee of Meyer Children's Hospital in Florence. The study was performed according to the principles expressed in the Declaration of Helsinki.

Table 1. Main characteristic, ankle joint mobility and hamstring flexibility and comparison between Soccer vs controls composed of Volleyball and Basketball players.

	Soccer group	***Control group***	***p-value***	***Volleyball***	***Basketball***	***p-value***
Age (years)	11.6±1.9	11.9±1.6	*0.60**	12.7±1.3	10.7±1.2	*<0.001**
BMI (Kg/m²)	18.5±2.3	19.7±3.6	*0.115**	19.0±2.9	20.8±4.4	*0.178**
Years of activity	5.5±1.9	3.2±2.4	*<0.001**	3.5±2.7	2.7±1.8	*0.358**
Total AJM (°)	127.6±15.7	138.8±21.6	*0.002*	137.3±19.4	140.7±24.9	*0.552*
Plantar Flexion AJM (°)	24.7±7.4	31.4±7.4	*<0.001**	31.2±5.7	31.7±9.6	*0.843*
Dorsal Flexion AJM (°)	102.9±13.0	107.5±17.0	*0.113*	106.4±16.1	109.0±18.6	*0.231*
Right AJM (°)	65.6±8.4	69.5±10.5	*0.029*	69.3±10.1	70.0±11.4	*0.816*
Left AJM (°)	62.3±8.9	69.3±12.1	*<0.001*	68.4±10.8	70.7±14.0	*0.512*
Dominant AJM (°)	65.0±8.9	69.8±10.7	*0.011*	69.4±10.3	70.4±11.5	*0.539**
Non Dominant AJM (°)	62.3±8.6	69.1±11.9	*0.002*	68.3±10.6	70.2±13.9	*0.586*
Δ R/L AJM (°)	3.2±7.1	0.2±7.0	*0.025**	0.9±7.8	0.7±5.6	*0.434*
S/ R test (cm)	-5.2±7.5	-8.0±8.3	*0.091*	-8.4±9.1	-7.5±7.0	*0.627**

Values are means ± standard deviation. Comparisons were performed using T-test or Mann-Whitney test (*). Abbreviations: N.: number; AJM: ankle joint mobility; BMI: body mass index; R/L: right/left; S/R: Sit and Reach Δ: difference; °: degree; cm: centimeters.

Table 2. Soccer and Control players leg-foot inclination angles with vertex at the center of the lateral malleolus, one half-lines passing through head of the fibula and one through: head of fifth metatarsal bone (FP angle) or parallel to the ground (LP1 angle) or perpendicular to the ground (LP2 angle).

	Soccer	**Control**	***p-value***
FP angle			
Standing - left angle (°)	122.6±4.9	123.9±4.2	0.306*
Standing - right angle (°)	122.0±6.0	121.0±4.9	0.396
Standing Tot. angle (°)	244.6±8.9	244.7±6.9	0.93
Lying - left angle (°)	149.2±6.7	152.7±5.9	0.004
Lying - right angle (°)	148.8±6.7	152.9±6.0	<0.001
Lying Tot. angle (°)	298.0±12.6	305.6±10.9	0.002*
LP1 angle			
Standing - left angle (°)	87.6±3.1	86.5±3.2	0.095
Standing - right angle (°)	87.1±3.6	85.8±3.6	0.072
Standing Tot. angle (°)	174.7±5.8	172.2±6.3	0.049
LP2 angle			
Lying - left angle (°)	85.0±2.5	82.5±2.6	<0.001
Lying - right angle (°)	84.3±2.3	82.4±2.4	<0.001
Lying Tot angle (°)	169.2±4.3	164.9±4.5	<0.001

Values are means ± standard deviation. Comparisons were performed using T-test or Mann-Whitney U Test (*). Abbreviations: (°): degree; (Tot): right+left.

Ankle joint mobility

Ankle joint mobility (AJM) was evaluated using a standardized protocol.[30-32] The patient was lying supine with the feet over the edge of the outpatient examination table, and the ipsilateral knee was extended and put over a rigid support 5-cm high. The maximum range of dorsal and plantar flexion was determined after marking the fifth metatarsal bone with the dermographic pen and positioning the inclinometer (Fabrication EnterprisesInc, White Plains, NY) along the diaphysis of the bone, with one extremity placed on the distal condyle. The subtalar joint was in a neutral position while the ankle joint was in the resting position that it naturally takes on the sagittal plane.

In a recent paper, it has been reported that the mean standard deviation of three consecutive readings of the ankle range of motion (ROM) in young subjects, as carried out in this study, was very limited: 1.1±0.9 degrees of plantar flexion and 1.4±1.1 degrees of dorsiflexion.[33]

Flexibility

Flexibility was evaluated using the Sit and Reach test. Participants barefooted were asked to sit on the ground with their feet approximately hip-wide against the testing box. While keeping their knees extended, putting one hand on the other, and slowly reaching forward as far as they could. Once fully extended forward, the participant could touch a metric tape and this distance was recorded.[34] All measurements were performed by the same observer with more than 10 years of experience, recording the mean of 3 consecutive readings.

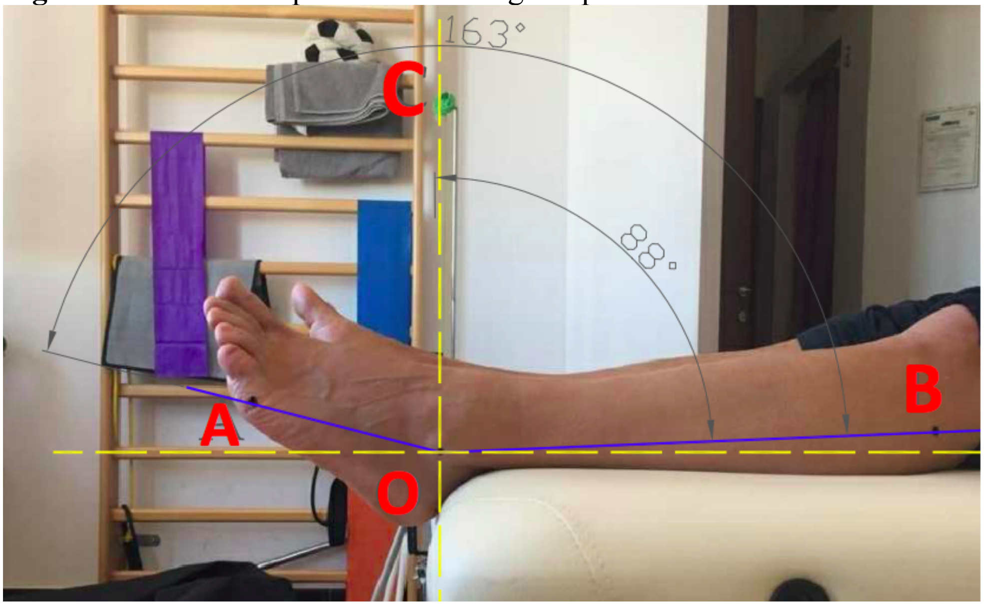
Angle of inclination of the foot and leg

Lower limb posture on the sagittal plane was assessed by photographic images of: a) Foot posture (FP), the angle with vertex at the center of the lateral malleolus and straight lines passing through the head of the fifth metatarsal bone and the second through the center of the head of the fibula; b) Leg posture (LP), the angle with vertex at the center of the lateral malleolus and straight lines passing through the head of the fibula and the second parallel to the ground (perpendicular in the case of subjects lying; Fig.1).

The analysis of the images was acquired in two different postures: in the upright position and lying supine on the examination table with the patient's feet over the limit, same posture maintained during the evaluation of the ankle ROM without knee rigid support. The angles were calculated from the photographic images using AutoCAD software.

When the results relating to the lower right and left limb were considered together, the description "tot", which stands for total, was used (i.e., right + left = tot.)

Figure 1. Lower limb posture on the sagittal plane.



Angles considered: FP angle: vertex at the center of the lateral malleolus (O) and straight lines passing through the head of the fifth metatarsal bone (A) and the second through the center of the head of the fibula (B); **LP angle:** the angle with vertex at the center of the lateral malleolus (O) and straight lines passing through the head of the fibula (B) and the second perpendicular to the ground (C).

Statistical analysis

Data were reported as mean±standard deviation (SD). ROM values were expressed in degrees (°). Statistical normality test was performed using Shapiro-Wilk tests. A multivariate analysis of variance (MANOVA) was conducted to assess if the practice of different sports affects the lower limb posture (i.e., Lying tot. FP angle; and Lying tot. LP angle; dependent variables). The assumption of multivariate normality (Doornik-Hansen test: p = 0.723) and homogeneity of the variance (Levene's F test: Lying tot. FP angle p = 0.332; Lying LP tot. angle p = 0.900) and covariance (Box's M test: p = 0.172) matrices were assessed and met.

When the different sports showed a significant multivariate effect on the lower limb posture, a univariate analysis of variance (ANOVA), followed by post-hoc Tukey's HSD pairwise comparisons, was performed for each dependent variable (Tab. 3). Basketball and Volleyball players were grouped because, as demonstrated previously[16] and in the present study, they showed a similar lower limb posture and AJM, whereas they differed from Soccer players (Tab. 1,2).

The comparisons between the two groups (Soccer vs. non-Soccer players) were made using the independent T-test or the nonparametric test: Mann-Whitney.

The association between the joint mobility and posture parameter has also been evaluated separately for soccer and non-soccer players as well as considering all subjects assessed using Pearsons or Spearman's correlation coefficients. The analyses were performed using Stata

(StataCorp, v.13) and SPSS Statistics (IBM, v.20) software. The α level of statistical significance was set at 0.05.

Table 3. Post-hoc pairwise comparison between groups of players considering leg-foot inclination angles in the lying position with vertex at the center of the lateral malleolus and half-lines passing through head of the fibula and through the FP angle (head of fifth metatarsal bone) or the LP2 angle (perpendicular to the ground).

			95% CI		
Dependent Variable	**Comparison**	**Mean Difference**	**CI_{INF}**	**CI_{SUP}**	***p-value***
Lying Tot. FP angle	Soccer vs Basketball	-9.68	-16.94	-2.43	0.006
Lying Tot. FP angle	Soccer vs Volleyball	-6.30	-12.58	-.02	0.049
Lying Tot. FP angle	Volleyball vs Basketball	-3.38	-11.51	4.75	0.585
Lying Tot. LP2 angle	Soccer vs Basketball	5.63	2.97	8.29	0.000
Lying Tot. LP2 angle	Soccer vs Volleyball	3.43	1.12	5.74	0.002
Lying Tot. LP2 angle	Volleyball vs Basketball	2.20	-.78	5.18	0.191

Pairwise comparisons were performed using post-hoc Tukey's HSD. CI inferior ($_{INF}$) and superior ($_{SUP}$) 95% confidence intervals of the mean difference. (Tot): right+left.

RESULTS

According to the inclusion criteria, age and BMI were fully comparable between groups (Tab. 1). The sport practiced showed a significant multivariate effect on the posture of the leg (Wilk's $\Lambda = 0.761$, $F_{(4, 214)} = 7.814$, $p < 0.001$). Follow up ANOVAs indicated that the sport practiced significantly affected both Lying tot. FP angle ($F_{(2, 108)} = 6.220$, $p = 0.003$, eta-squared (η^2) = 0.103) and Lying tot. LP angle ($F_{(2, 108)} = 15.013$, $p < 0.001$, $\eta^2 = 0.218$). Post-hoc pairwise comparisons showed that Lying tot. FP angle and Lying tot. LP angle were not different between the Basketball and Volleyball players. However, Soccer players showed greater Lying LP tot. angle and lesser Lying tot. FP angle than Basketball and Volleyball players (see Tab. 2).

Compared to the control group, the young Soccer players showed reduced plantar flexion AJM (p<0.001) and total AJM (p=0.002; Tab. 1). A significant difference in mobility was found in the group of young Soccer players by comparing left and right limbs (p<0.001) and non-dominant

dominant limb (p=0.035). This difference was not found in the control group. Basketball and Volleyball players showed no differences in the joint mobility of the ankle and about the angle between the leg and the foot calculated in non-weight-bearing condition (Tab. 1,2).

Considering all subjects assessed the total AJM and ankle dorsiflexion was found to be directly related to the Lying tot. FP supine position angle (respectively: $p < 0.005$ and $p < 0.001$) and inversely correlated with the Lying LP tot. angle (respectively $p = 0.015$ and $p = 0.009$).

The sit and reach test did not show any significant differences between Soccer players and controls.

DISCUSSION

In this study, we aim to verify whether the practice of Soccer could affect the posture of the leg and foot of young players as well as verifying the negative effect on ankle joint mobility.[4,6,7]

Regarding the analysis of the lower limb posture carried out, while, on one hand the evaluation of the young subjects in upright position did not show particular differences between the Soccer and non-Soccer groups, on the other hand the analysis of the images of the players in the lying position showed significant differences between the groups (Tab. 2).

The multivariate analysis showed a significant effect of the type of sport practiced on the lower limb posture. Instead Basketball and Volleyball players showed overlapping results.

In particular, the angle with the vertex at the center of the lateral malleolus and with half-lines passing through the distal extremity of the fifth metatarsal and through the head of the fibula was minor in Soccer players compared to controls (Tab. 2, FP angle). This result is evident, despite the analysis that considered the inclination of the leg in relation with the perpendicular line to the ground, which showed a lower inclination of the leg in Soccer players (Tab. 2, LP2 angle).

The results achieved suggest that, if on one hand, the modifications sport-related considered cannot prevail on postural needs in orthostatic condition, on the other hand, the foot, in young Soccer players, takes a posture in dorsal flexion if evaluated in non-weight-bearing condition (Tab. 2, LP2 angle).

Moreover, this result was only obtained in non-weight-bearing condition which suggests that the tests performed in this study may allow recognizing the early effects of Soccer practice on the posture of the lower limb in addition to those on AJM. Therefore, the posture's modifications detected could have negative consequences for young Soccer players.

One of the study results confirmed a significant reduction in AJM in young Soccer players (Tab. 1). Even if, the real causes of the limited AJM and the altered posture of the lower limb that can be shown by young Soccer players are not known, it is well known that the peculiarity of this sport is to directly manage the ball with the feet. In addition to a high risk of incurring in traumas, this activity, could involve, differently from other sports such as Basketball or Volleyball, the toning not only of the flexor muscles of the foot but more generally of the leg muscles.

In this sense, the results of this study could indicate that the main role in determining the variations of AJM could be played by the effects induced by repetitive hitting the ball with greater or lesser strength. Such activities may require high strength in both concentric (hitting) and isometric (stabilizing the joint) activity executed by the dorsal flexor muscles of the ankle involved.[35,36]

Moreover, the strengthening of these muscles in the anterior and lateral part of the leg would justify, at least in part, the difference between Soccer and non-Soccer groups investigated regarding the posture assumed by the foot if evaluated in a non-weight-bearing position.

This condition could also justify the apparent paradox detected in the group of young Soccer players and related to the presence of a condition of leg extension associated with a reduced total angle between leg and foot in addition to a reduced AJM in plantar flexion. The latter is often associated with rigidity of the triceps of the sura; this stiffness would hinder an extension of the leg and the dorsiflexion of the foot.

It can therefore be hypothesized that the reduced AJM and modified posture of the lower limb found in this study share the same causal factors. In fact, the results achieved on AJM and the posture evaluated in lying supine position were correlated.

According to the data reported in literature, the AJM assessed in the Volleyball and Basketball players is similar and resulted to be in line with the reference values reported for subjects matched for age.[15,35,37-39] Similarly, the posture evaluated resulted similar in Volleyball players and Basketball players in both the positions examined.

Numerous studies showed that the reduced AJM is a risk factor for several dreadful adverse events and this relationship could also concern the postural anomalies detected. For this reason, it would be important not only monitoring these parameters but also verifying the effect on the performance and history of injuries in addition to study the effectiveness of exercise protocols aimed at recovering AJM.[11,22,28]

CONCLUSIONS

The results of this study confirm that young Soccer players can show a reduced ankle joint mobility and an altered posture of the leg and the foot that can be seen in non-weight-bearing position. The alterations of these parameters seem to be a consequence of the Soccer practice. While the possible negative effects induced by a limited AJM are known, the possible short and long term effects that an altered posture of the lower limb can have on young subjects are unknown. Considering the importance of the parameters investigated, further studies aimed at clarifying this relationship seem necessary.

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STUDY 2

THE TREND OF ANKLE JOINT MOBILITY IN ADULT AND YOUNG SOCCER PLAYERS AND ITS ASSOCIATION WITH MUSCLE STRENGTH: AN EVER-PRESENT AND WORRYING ALTERATION.

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INTRODUCTION

It has long been suggested that soccer players (SP) may show a significant reduction in ankle mobility (AJM).[1,2] This result seems paradoxical considering that soccer requires the best possible ability to control the ball with the feet while a limited AJM may adversely affect this ability.[3-5]

Many reasons contribute to the importance of the study of AJM in SP. In this sense, it is known how the presence of stiff ankles could represent a risk factor for injuries, have long-term ankle consequences[6-10] as well as negatively affect the same posture and quality of movement. Moreover, it is important to consider that soccer is the most practiced sport, especially by young males, in many countries around the world.[11-13] At the same time soccer is played by a large number of adults mostly involved in amateur soccer leagues.[14-15]

In order to properly manage AJM, the complexity of the ankle should be considered.[16,17] In particular, the ankle is a hinge joint formed by the medial and lateral malleolus respectively of the tibia and fibula which form a mortise to receive the trochlear surface of talus. The stability of the joint, as well as being guaranteed by the same geometry of the joint, is mainly related to the action of the muscles for dynamic stability, however, the periarticular structures would have a major role in maintaining static stability. Movements allowed by the ankle joint are mainly dorsiflexion and plantarflexion of the foot on the sagittal plane.[17-19]

The role of injuries with regard to the causes of limited AJM in SP has been hypothesized.[17,20] For SP, injuries of the ankle can be either traumatic or resulting from repeated sports-specific microtrauma, that can lead to the occurrence of an overuse condition. In particular, physical contact among players, the high intensity movements that can be performed and the same kicking of a soccer ball can cause direct trauma on the ankle joint.[21,22] All ankle ligaments and joint capsule in addition to other periarticular structures can be subjected to injuries and alterations due to sport practice.[2,6,19]

Some authors have speculated that in order to protect the ankle from continuous micro-traumatic or traumatic events, SP can instinctively seek greater ankle joint stability.[2,4,5,22] This stability of the ankle could be ensured by an increased co-contraction of the agonist and antagonist muscles involved in joint movements.[23-25] In this sense, the muscle strength level and tightness of the leg muscles can affect this sport-specific adaptation.[17,20,26] Moreover, over time the practice of soccer can cause an important increase of the stiffness of the periarticular soft tissues and muscle-tendon structures.[4,19,25,27] This adaptation can also play a role in increasing the stability of the ankle.

Dorsiflexion has usually been evaluated in SP,[2,28,29] however, it has to be considered that the evaluation of plantar flexion could promote a better understanding of the altered AJM in SP.[1,10,30] In this sense, some large cohort studies have reported the values of both the plantar and dorsal flexion of the ankle of young and adult subjects.[31-34]

Although the performance seems in some cases to be the only goal of sports the evaluation of important parameters such as ankle ROM, which can significantly affect the health of SP as well as their performance, could also be important.[2,6,10,17,19] The aim of this study was to describe the trend of ankle mobility during the whole period of sports activity and its relationship with muscle strength.

MATERIALS AND METHODS

In 204 male Soccer Players [range: 6.7-45.1 years] and in 87 male controls [range: 7.5-45.2 years] the ankle joint mobility in both plantar and dorsiflexion in addition to hand grip strength were examined. Detailed characteristics of the study participants are shown in Table 1.

The control group consisted of sedentary subjects or practiced sports for which no significant effects on ankle ROM are known such as basketball, volleyball, athletics.[1,35] For some evaluations, SP and controls were assigned to two different groups: Young (<16 years) and Adults

(>16 years). The age of 16 was chosen because previous studies showed that puberty can positively affect AJM, whereas in adolescence AJM can decrease significantly.[5] Two subjects aged 15.9 and 15.7 were included in the adult group because they trained and played with a team participating in the Under 17 championship (Fig. 1).

Data were collected on age, weight, height, dominant kicking leg, sport practiced, years of activity, number of weekly training sessions and years of sport practice. Moreover, the type of footwear used, the playing surface where the training sessions took place, the duration of the training sessions, the injuries suffered in addition to the job activity of SP were considered.[16,17] Body mass index (BMI) was calculated as body weight in kilograms divided by height in squared meters (kg/m^2).

The physical examination included foot inspection and the presence of deformity, injuries and traumas such as affect ankle joint mobility. Exclusion criteria were: age less than 6 years and greater than 50, presence of diabetes, other diseases as well as orthopedic and/or surgical complications at baseline that can affect AJM, and, for the Soccer Players, soccer practice for less than 6 months continuously. The measurements were taken at least one month after the start of the championship and immediately before the first weekly training session. All participants, parents or legal guardians were informed on the purpose of the study and its experimental procedures before obtaining their written informed consent and the enrolment in the study.

The study protocol and the consent forms were approved by the Paediatrics Ethics Committee of Meyer Children's Hospital in Florence (protocol number: 161/2016 on September 29, 2016) and by Ethics Committee of University of Urbino Carlo Bo (cod. CESU20221118VER37 November 2020). The study was carried out according to the principles expressed in the Declaration of Helsinki.

Determination of joint mobility

The method used for the assessment of ankle mobility has been described in previous studies, in brief: active range of motion (ROM) of the ankle joint in plantar flexion (APF) and dorsiflexion (ADF) was measured by an inclinometer.[16,35,36] Players were asked to lie in the supine position on a fixed treatment table with the ankle rested in line with the edge and the feet across the border of the table, the ipsilateral knee was extended and put over a rigid support 5-cm high.

The inclinometer (Fabrication Enterprises Inc., White Plains, New York, USA) was positioned along the diaphysis of the bone, with one extremity on the distal condyle, after marking the fifth metatarsal bone with a dermographic pen. The subtalar joint was in a neutral position while the ankle joint was in the resting position that it naturally takes on the sagittal plane. The greater angle of the active APF and ADF was measured and the mean of three consecutive readings was reported, while the Total Ankle Mobility (ATOT) was the sum of the two values (APF+ADF). In a previous study concerning the use of this method,[37] it was reported that the mean standard deviation of three consecutive readings of the ankle ROM, as reported in this study, was very limited: 1.1±0.9 degrees of plantar flexion and 1.4±1.1 degrees of dorsiflexion. The ankle ROM was measured by the same operator that had more than 10 years of experience. The dominant lower limb was identified by asking the players which was the preferred limb for kicking the soccer ball. The test operator who evaluated AJM did not know the dominant limb of the players.[30]

Determination of hand grip strength

Hand grip strength was evaluated by the Jamar hydraulic hand dynamometer (model 5030J1) 0-90 Kg. The dominant upper limb was identified by asking the players which hand was used for writing.[38] Before the test the examiner gave explanations, showed the posture to be maintained, how to hold the dynamometer and how to perform the test. In particular, hand grip was evaluated with subjects in the standing position, arms by the side of the body, shoulder adducted in a neutral position, elbow 90° flexed with the forearm parallel to the ground and pronated in order to maintain the display of the dynamometer on the frontal plane.[39] Only the dominant hand was tested. A trial test was allowed to become familiar with the device. The SP were asked to maintain the same posture and dynamometer handle during the three tests and to squeeze with maximum strength for three seconds without moving the rest of the body. The peak-hold needle automatically recorded the highest strength exerted. The test had to be stopped in case of pain. No verbal encouragements were offered during the test even if the examiner counted the seconds and gave the command to stop. The scheduled rest between repetitions was 15 seconds. Three tests were performed consecutively, and the average of the values achieved was reported.[38,40] The adjustable dynamometer handle was placed on the second grip position (4.76 cm), while for younger subjects, it could be moved to the first position (3.5 cm) to allow them to handle the device properly and with an adequate provision for the fingers. In order to calibrate the device, we used a new tool and checked the "zero" position of the needle in absence of load. We then positioned the device on a rigid surface and applied a weight of 10 kg and then of 20kg to check the accuracy of the needle indications. In this study, the Jamar hydraulic hand dynamometer has been used since it is a well-validated device for the quantitative measurements of the maximum isometric MS of the hand with widespread use in clinical practice. Moreover, this dynamometer has a high test-retest and inter-rater reliability in addition to high reproducibility when used by children and adults.[26,39,41-43]

Statistical analysis

Data were reported as mean ± standard deviation (SD) or Range [maximum and minimum values]. ROM values were expressed in degrees (°). A statistical normality test was performed using Shapiro-Wilk tests. The comparisons between the two groups were carried out using the independent T-test or the nonparametric test: Mann-Whitney. The association between the joint mobility and age, BMI and hand strength has also been evaluated in controls and separately in young and adult SP as well as considering all subjects assessed using Pearson or Spearman's correlation coefficients. Multiple linear regression analysis was carried out considering dorsiflexion (ADF), plantar flexion (AFP) and total AJM (ATOT) (expressed in degrees) as dependent variables and Age, BMI, and Hand Strength as independent variables in Adult SP or in Young SP. The analyses were performed using Stata (StataCorp, v.13) and SPSS Statistics (IBM, v.25) software. The α level of statistical significance was set at 0.05.

RESULTS

A total of 291 subjects, 204 soccer players (SP) and 87 controls matched for age, gender, and BMI were evaluated in this study (Table 1). SP and Control groups had a similar distribution among young and adults (data not shown). The AJM of SP was lower than that of controls ($p<0.001$). A similar result was obtained by considering young people ($p<0.001$) and adults ($p<0.001$) separately (Table 1).

As regards the two movements considered, both the APF and the ADF were significantly lower in the SP group than in controls ($p<0.001$; Table 1).

Table 1. Main characteristic, ankle joint mobility and muscle strength of all, young and adult soccer players (SP) and Controls.

	All SP (n=204)	All Controls (n=87)	**p value**	Adult SP (n=61)	Adult Controls (n=23)	**p value**	Young SP (n=143)	Young Controls (n=64)	**p value**
Age (yrs)	15.5±7.5	15.9±9.9	**0.962***	25.2±6.9	28.0±8.7	**0.204***	11.3±1.9	11.6±1.8	**0.594***
BMI (kg/m^2)	19.9±2.9	20.1±3.7	**0.427***	22.5±2.1	23.4±2.3	**0.108**	18.6±2.4	19.3±3.6	**0.380***
HGS (kg)	27.8±12.9	27.9±11.4	**0.182***	44.2±7.5	47.5±8.8	**0.125**	20.7±6.7	23.8±7.3	**0.005***
APF (degrees)	26.3±7.2	32.6±7.4	**<0.001**	26.0±5.7	33.5±7.0	**<0.001**	26.4±7.8	32.5±7.7	**<0.001**
ADF (degrees)	95.5±15.6	105.5±15.8	**<0.001***	89.0±10.5	104.2±13.1	**<0.001**	98.3±16.6	106.4±16.5	**0.003***
ATOT (degrees)	121.8±18.0	138.1±19.2	**<0.001***	115.0±12.9	137.8±13.9	**<0.001***	124.7±19.1	138.9±20.5	**<0.001***
Δ R-L (degrees)	5.3±4.6	5.6±5.0	**0.655***	4.4±3.5	5.4±5.2	**0.252***	5.7±4.9	5.6±5.0	**0.789***

Note: Values are mean±SD. Comparisons among groups were performed using *t*-test for independent samples or Mann-Whitney test (*). AJM: ankle joint mobility; APF: ankle plantar flexion; ADF: ankle dorsiflexion; ATOT: Ankle total; BMI: Body Mass Index; R-L: right/left; S/R; Δ: difference.

Regarding the comparison between the Adult and Young groups, AJM was significantly higher in Young SP compared to the Adult SP (p <0.001; Tab. 2). Conversely, AJM was similar in Adult controls compared to Young controls (138.9±20.5° vs 135.7±14.7°; Table 1).

From the comparison of the Under 17 SP (adults A) with those of the Senior soccer division (adults B) only the ADF was significantly lower in Adults B (p<0.006; Table 3; Figure 1). The difference in BMI between the two groups was linked to the lower weight of the Under 17 players (Table 3).

Table 2. Main characteristic, ankle joint mobility and muscle strength of all, young and adult soccer players (SP) and Controls.

	Young SP (n=143)	Adults SP (n=61)	p value
Age (yrs)	11.3±1.9	25.2±6.9	<0.001*
BMI (kg/m^2)	18.6±2.4	22.5±2.1	<0.001*
Years of SP (yrs)	4.9±2.0	15.3±6.2	<0.001*
HGS (kg)	20.7±6.7	44.2±7.5	<0.001*
APF (degrees)	26.4±7.8	26.0±5.7	0.899
ADF (degrees)	98.3±16.6	89.0±10.5	<0.001*
ATOT (degrees)	124.7±19.1	115.0±12.9	<0.001*
Δ R-L (degrees)	5.7±4.9	4.4±3.5	0.081*
Right AJM (degrees)	63.1±10.0	57.6±6.5	<0.001*
Left AJM (degrees)	61.6±10.5	57.4±7.6	<0.001*

Note: Values are mean±SD. Comparisons among groups were performed using *t*-test for independent samples or Mann-Whitney test (*). AJM: ankle joint mobility; APF: ankle plantar flexion; ADF: ankle dorsiflexion; ATOT: Ankle total; BMI: Body Mass Index; R-L: right/left; S/R; Δ: difference.

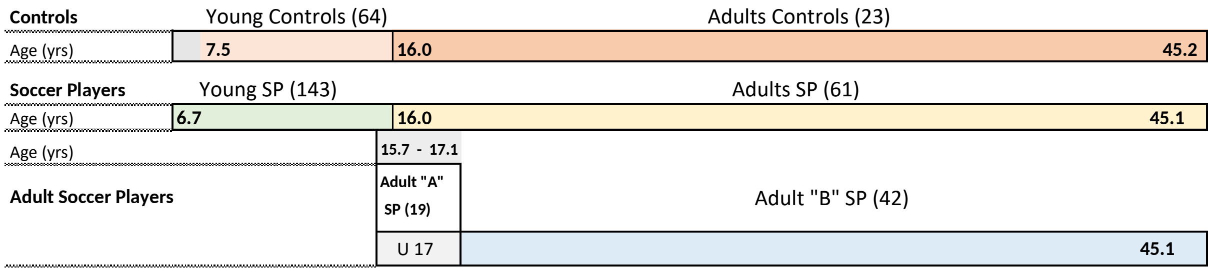
Table 3. Main characteristic, ankle joint mobility and muscle strength of Under 17 and Over 17 soccer players.

	Adult A (Under 17; n=19)	Adults (other Adults; n=42)	p-value
Age (yrs)	16.6±0.4	29.0±4.5	<0.001
BMI (kg/m^2)	21.2±1.5	23.1±2.0	<0.001
HGS (kg)	42.9±5.9	44.7±8.1	0.381

APF (degrees)	27.1±6.3	25.5±5.5	0.322
ADF (degrees)	83.6±9.0	91.4±10.3	0.006
ATOT (degrees)	110.7±12.6	116.9±12.7	0.080
Δ R-L (degrees)	4.2±3.4	4.5±3.6	0.803*

Note: Values are mean±SD. Comparisons among groups were performed using *t*-test for independent samples or Mann-Whitney test (*). AJM: ankle joint mobility; APF: ankle plantar flexion; ADF: ankle dorsiflexion; ATOT: Ankle total; BMI: Body Mass Index; R-L: right/left; S/R; Δ: difference.

Figure 1. Range of age for groups: Soccer Players (204), Controls (87) and Under 17 (19)



Abbreviations: (SP): Soccer Players; (U 17): Under 17.

Considering all SP investigated, ATOT was inversely correlated with age ($p<0.015$). This relationship was particularly evident for ADF ($p<0.005$). Ankle dorsiflexion and ATOT also showed a significant inverse relationship with BMI and HGS.

The difference in mobility between the two ankles (right-left) of players was also inversely correlated with age and muscle strength ($p<0.022$) These relationships between the parameters considered were not found in the control group (Table 4).

Table 4. Correlation matrix for all subjects, soccer group (SP) and Controls between Ankle Plantar Flexion, Ankle Dorsiflexion, Total AJM, difference right-left and Age, BMI and HGS

	APF		ADF		ATOT		ΔR-L	
	r	p-value	r	p-value	r	p-value	r	p-value
ALL (291)								
Age	0.00	0.950	-0.17	0.003	-0.14	0.014	-0.11	0.072
BMI	-0.12	0.056	-0.22	<0.001	-0.22	<0.001	-0.11	0.064
HGS	0.04	0.514	-0.21	<0.001	-0.16	0.009	-0.13	0.026
SP (204)								
Age	0.03	0.674	-0.20	0.005	-0.17	0.015	-0.16	0.022
BMI	-0.16	0.029^	-0.29	<0.001	-0.30	<0.001	-0.09	0.213
HGS	0.05	0.452	-0.27	<0.001	-0.22	0.002	-0.16	0.022
Controls (87)								
Age	-0.11	0.328	-0.12	0.282	-0.16	0.129	0.01	0.950

BMI	-0.11	0.333	-0.18	0.100	-0.22	0.039	-0.15	0.163
HGS	-0.05	0.667	-0.12	0.282	-0.15	0.196	-0.05	0.666

Note: Test of normality was performed using Shapiro-Wilk tests. Comparisons were performed using Spearman's rho test (r). Abbreviations: AJM: ankle joint mobility; BMI: body mass index; APF: Ankle Plantar Flexion; ADF: Ankle Dorsiflexion; ATOT: Total AJM; ΔR-L: difference right-left.

Considering separately the Adults and Young groups, no significant correlations were found between AJM and the other parameters investigated (Age, BMI, hand strength, years of activity; data not shown).

Since age, body weight and muscle strength had a role in the reduction of AJM in SP, we performed a Multiple linear regression analysis with ankle joint mobility as dependent variable and age, BMI and HGS test as covariates considering adults and Young SP separately. From this analysis, BMI remained significantly associated with ATOT reduction in Young SP (Table 5).

Table 5. Multiple linear regression analysis considering dorsiflexion (ADF), plantar flexion (AFP) and total AJM (ATOT) (expressed as degrees) as dependent variables and age, BMI, and Hand strength as independent variables in Adult SP or in Young SP.

	Adult SP (61)			**Young SP (143)**		
	ß-Reg. coef.	**p-Value**	**p-Model**	**ß -Reg. coef.**	**p-Value**	**p-Model**
APF						
			0.284			0.266
Intercept	36.846	<.0001		34.326	<0.001	
BMI	-0.614	0.139		-0.558	0.091	
AGE	-0.072	0.532		-0.076	0.903	
Hand Strength	0.106	0.317		0.170	0.288	
ADF						
			0.101			0.469
Intercept	73.130	<.0001		115.736	<.0001	
BMI	-0.156	0.831		-0.974	0.131	
AGE	0.429	0.040		-0.138	0.910	
Hand Strength	0.200	0.290		0.150	0.631	
ATOT						
			0.3330			0.158
Intercept	109.976	<.0001		150.062	<.0001	
BMI	-0.770	0.412		-1.531	0.034	
AGE	0.357	0.177		-0.215	0.875	
Hand Strength	0.306	0.207		0.320	0.360	

Note: ß-Reg. Coef.: Unstandardized coefficients. They are produced by the linear regression model after its training using the independent variables. Unstandardized coefficients, keeping the other variables constant, indicate the variation of dependent variable associated with a one-unit change in the corresponding independent variable.

DISCUSSION

The trend of the AJM of SP for the whole sporting period was investigated in this study, from children up to adults. In addition, the relationship between AJM and muscle strength was considered. This objective was also pursued thanks to the comparison with a control group. According to what was reported in previous articles, the control group consisted of sedentary subjects or those practicing sports activities not involving modifications in AJM.[1,35] In this study, we decided to evaluate two senior male soccer teams because they represent the large part of Adult SP.[14,15]

The comparison between SP and controls allowed us to confirm how the practice of soccer involves a significant reduction in AJM. Furthermore, considering the AJM values reported in large cohort studies,[31-34] it showed similar values to those found in the control group and confirmed how soccer practice involves reduced ankle ROM. The difference in AJM between SP and controls was also confirmed by considering Young subjects and Adults separately (Table 1). As a whole, the results achieved confirmed the presence of a significant inverse relationship between AJM and age in SP. Therefore, the AJM of the SP, in addition to reducing early and significantly, continues to decrease over time.

As suggested in previous studies, part of the difference of AJM between Young and Adult SP may be associated with the effects of puberty on AJM. In particular, it is known that children show a tendentially linear growth in muscle strength at an early stage, while from 13-14 years of age this growth accelerates during the remainder of adolescence.[25,44,45] In particular, the trend of development of muscle strength is not fully superimposable to that of bone tissue and height. In fact, the peak height velocity is about a year before peak growth velocity of body mass.[23,25] This time lag can determine a period in which the same leg muscles may be less effective in stabilizing the ankle while promoting its ROM in SP. Subsequently, the increased muscle strength may lead to an increased stabilizing action capacity although it can negatively affect the AJM. In this sense, it is known that the increase in muscle-tendon stiffness reaches adult levels by late adolescence (16-18 years old).[25,46,57]

The results obtained with this study seem to confirm that the period of temporary improvement of the AJM in SP appears to be overcome in SP of the Under 17 team. In this sense, in the comparison between the players of the Under 17 team (Adult A) and those of the Senior soccer division (Adult B) there were no significant differences in the parameters investigated. These results indicate, once again, that the effects of soccer practice on AJM occur precociously in children and it is almost fully present in late adolescence. In particular, as regards the sample of SP investigated in this study, the lowest AJM values were observed in SP of the Under 17 team (Adult A). In this sense, it must be considered that the players of the Under 17 team trained once a week more than adult SP of the Senior soccer division (3 vs 2) and used a different playing field (grass vs synthetic). These factors could justify, at least in part, the AJM trend found in the Adult soccer group. These results are only partially in agreement with those reported in some previous studies. As for the senior male SP, almost forty years ago, Hattori and Ohta (1987) measured the range of motion of the ankle joint in 68 male footballers (18-22 years) and 66 non-athletic male student controls. The results of the study showed a significant difference in AJM between the two groups. This difference was about 20 degrees considering plantar and dorsiflexion together.[4] This difference is similar to that found in our study (Tab. 1).

Regarding the effect of growth on AJM, in 2019 Cejudo et al. evaluated ankle dorsiflexion ROM in 72 young SP 8-19 years. In particular, it was reported that despite having found higher mean values in younger subjects (under 10 years), no fully significant differences were found among SP of different ages. However, the AJM showed a lower value passing from the Under 10 players to the Under 12 players, re-increasing in the Under 14 SP and then decreasing again in the Under 19 players.[28]

The results for a larger sample of football players were published even more recently by the same authors. In this study, Robles-Palazòn and colleagues (2022) studied the mobility of the ankle and other joints of the lower limb in 286 male soccer players (age range: 10-19 years). The study results showed no significant changes in AJM in players of different ages.[29]

Regarding these studies, it is important to consider how in these studies only dorsiflexion of the ankle was considered. This may, at least in part, explain the non-matching of the differences in AJM among adolescent soccer players of different ages as noted in our study.

Previous studies reported that there is no difference in mobility between the two ankles of the players.[2,30] This could indicate that the role of cyclic and symmetrical movements such as walking and running are more prevalent than the effects of specific sports movements such as hitting the ball.[30,48] The results of this study indicate that the difference in mobility between the two ankles, although not significant, was inversely correlated to age and muscle strength as assessed by the HGS test. In this sense, growth and adulthood seem to have a corrective effect with this parameter.[16,30]

As a whole, in accordance with what has been reported in previous articles,[48-50] the results obtained with this study suggest the need to organize activities aimed at the emergence and / or management of a limited AJM would be timely, taking them into account from the beginning of the soccer activity and maintained over time.

The results obtained can be particularly useful in defining activities aimed at the appropriate management of AJM also considering age and other parameters related to the development such as muscle strength. In this sense, studies aimed at verifying how training protocols targeted at increasing AJM affect the performance and risk of injuries of players of different ages are recommended.

CONCLUSIONS

The results of this study confirm that the practice of soccer involves a significant reduction in ankle ROM in both plantar and dorsiflexion. This reduction is already present in younger players. Considering soccer players of different ages, from children up to adults, the AJM was inversely related to the age of the players. Moreover, ankle ROM was also inversely correlated with BMI and muscle strength. Unlike non-soccer controls, Adult SP showed a significantly lower AJM than the Young SP group. Unfortunately, the U17 footballers already showed a very reduced ankle ROM that was similar to the value of players participating in the senior soccer division. The difference in AJM between right and left ankles of soccer players was not significant and inversely correlated with age and muscle strength. As a whole, the results of this study confirm that the assessment, monitoring and management of the AJM in SP is necessary. In this sense, the results of this study may be useful for athletic trainers to define appropriate training protocols.

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STUDY 3

The effect of an adapted training protocol on ankle joint mobility in young soccer players

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INTRODUCTION

For young people, sports practice is a significant source of physical activity, and it has many positive health benefits that are considered important for their development.[1-3]

In many western countries, the majority of young people, starting from the first years of life, regularly perform structured sports activities in sports clubs or at school.[4-7] Soccer with variations in its practice according to each country, is often the sport preferred by males.[6-8]

Sports practice, as such, significantly involves the musculoskeletal system together with the joints.[1,2,9,10] The ankle is the joint mostly involved in sports practice because of its anatomical and functional features as a joint connection between the leg and the foot. Moreover, it plays a fundamental biomechanical and postural role.[11-13]

The ankle is a load-bearing joint formed by the medial and lateral malleolus, which form a mortise to receive the trochlear surface of the talus.[10,12,13] In addition to the morphology of the articular surfaces of talocrural joint that forms an angular ginglymus with a single axis of movement (bimalleolar axis), other passive factors (e.g., capsuloligamentous structures surrounding the joint) and dynamic factors (i.e., muscle action) provide both active and passive tension, allowing and limiting the range of motion (ROM) of ankle joint in dorsiflexion and plantar flexion (sagittal plane).[12-14]

It has also been reported that the practice of soccer can modify the same joints ROM.[11,13,15,16] This condition should be timely studied considering the possible negative effects induced by altered ankle joint mobility (AJM) on young athletes.[17-19]

In this sense, it has been reported that reduced AJM may significantly increase the risk of ankle sprains, affect the quality of gait, the dynamic balance and the plantar pressure distribution.[10,19-22] All this can also be due to partial deafferentation from articular and periarticular structures caused by repeated injuries.[11,15,23,24] Furthermore, a reduction of ankle ROM can be a risk factor of overuse for articular and periarticular structures.[11,22,25]

In the light of these considerations, analysing the effects of soccer practice on ankle mobility could provide useful information on actions aimed at the prevention or functional recovery of AJM alterations[10,16,26] also through a different organization of training sessions with the inclusion of specific *exercises.*

To date there is not yet any clear scientific evidence, as to whether the practice of soccer may affect the posture of soccer players. In this regard, the relationship between an altered AJM and the posture assumed by the legs of young players is unknown and it should be studied in order to avoid negative short and long term consequences.

The main aim of this study was to verify the effects of a two months adapted training protocol (TP) on AJM. Moreover, the relationship between AJM and the leg and foot posture on the sagittal plane has also been considered.

MATERIALS AND METHODS

A total of 62 young male athletes, 31 soccer players and 31 volleyball players were enrolled. The subjects observed were recruited in sports clubs from Tuscany who had positively replied to the invitation to participate in the study and they have been evaluated from May 2017 to May 2018.

Data were collected on age, sex, body mass index (BMI), lower limb-dominance, other sports practiced, number of weekly training sessions, history of injuries, and years of sports practice. BMI was expressed as body weight in kilograms divided by height in meters squared (kg/m^2). Detailed characteristics of study participants are shown in Table 1.

Ankle joint mobility in plantar and dorsal flexion, hamstring flexibility (Sit and Reach test) in addition to the leg and foot inclination angle on the sagittal plane were evaluated.

The physical examination included the inspection of the lower limbs for the injuries and trauma that could affect ankle joint mobility, hamstring flexibility, or lower limb posture.

Individuals with the presence of current foot and ankle problems at baseline, as well as orthopaedic and/or surgical complications, congenital foot or leg deformity in addition to a history of the practice of the same sport for less than six months continuously were excluded.

All young players and their parents or legal guardians were informed on the purpose of the study and its experimental procedures before obtaining their written informed consent and the enrolment in the study. The protocol and the consent forms were approved by the Pediatrics Ethics Committee of Meyer Children's Hospital in Florence. The study was performed according to the principles expressed in the Declaration of Helsinki.

Evaluation of ankle joint mobility

AJM was evaluated using a standardized protocol.[27-29] The patients were lying supine with the feet over the edge of the outpatients examination table, the ipsilateral knee of the ankle assessed was extended and put over a rigid support 5-cm high. The maximum range of dorsal and plantar flexion was determined after marking the fifth metatarsal bone with the dermographic pen and positioning the inclinometer (Fabrication Enterprises Inc, White Plains, NY) along the diaphysis of the bone, with one extremity placed on the distal condyle. The subtalar joint was in a neutral position while the ankle joint was in the resting position that it naturally takes on the sagittal plane.

In a recent paper, it has been reported that with this evaluation procedure the standard deviation of three consecutive readings of the ankle ROM in young subjects was minimal: 1.1±0.9 degrees of plantar flexion and 1.4±1.1 degrees of dorsiflexion.[30]

Evaluation of flexibility

Flexibility was evaluated using the Sit and Reach test. Young athletes were asked to remove the shoes, sit on the ground with their feet approximately hip-wide against the testing box while keeping their knees extended. Then, they were asked to put one hand on the other and slowly reach forward as far as they could.[31]

All measurements were performed by the same observer with more than 10 years of experience, recording the mean of 3 consecutive readings.

Evaluation of the angle of inclination of the leg

Lower limbs posture on the sagittal plane was assessed by images of: a) the angle with vertex at the centre of the lateral malleolus and straight lines passing through the head of the fifth metatarsal bone and the second through the centre of the head of the fibula; b) the angle with vertex at the centre of the lateral malleolus and straight lines passing through the head of the fibula and the second parallel to the ground (perpendicular in the case of subjects lying).

The analysis of the images were acquired in two different postures: in the upright position and lying supine on the examination table with the patient's feet over the limit, the same posture was maintained during the evaluation of the ankle Rom without rigid knee support.

Training protocol

Soccer players performed 10-weeks (10 sessions) of adapted training protocol, including 4 exercises aimed at improving AJM.

The exercises performed consisted of: 1) Players were requested to stand with both hands against the wall, put one foot forward, keeping the feet pointing straight forward and the heel touching on the ground, lean forward onto the front leg to feel the stretching of the calf muscle (3 repetitions of 30 seconds for each side); 2) Players were seated so as not to touch the ground with their feet, and used one foot at a time and then both feet to draw in the air the widest imaginaries letters of the alphabet using the hallux (for example “W” - 1 repetition for each side); 3) Players were seated with extended knees trying to touch their feet in dorsiflexion; players could help themselves to lean forward by using elastic bands to be placed at the level of the plantar surface of the metatarsal heads (3 repetitions of 30 seconds); 4) Players with one knee resting on the ground with the ipsilateral foot pointed backward and maintained in plantar flexion with the contralateral foot positioned anteriorly, trying to achieve the maximum plantar flexion of the corresponding foot maintained in plantar flexion by moving the pelvis backward and the maximum dorsiflexion of the other ankle moving the pelvis forward (3 repetitions of 30 seconds for each side).

The training protocol was performed with one minute of rest between exercises and in the presence of a trainer to monitor the correct execution of the exercises.

Statistical analysis

Data were reported as means±standard deviation (SD). ROM values were expressed in degrees (°). A two-way factorial repeated-measures ANOVA was conducted to assess the effect of the TP, the limb (dominant-nondominant), and their interaction (independent repeated measures variables) on each study outcome (i.e., ROM plantar flexion and ROM dorsal flexion – dependent variables). The α level of statistical significance for the two two-way factorial repeated-measures ANOVAs was set at 0.025 in order to control for type I error inflation due to multiple testing. Statistical normality test was performed using Shapiro-Wilk tests. The comparisons between the two groups were analysed by T-test (independent or paired samples) or nonparametric test: Mann-Whitney, Wilcoxon rank. The strength of the association between two variables has been evaluated by Pearsons or Spearman's correlation coefficients test. SPSS Statistics (IBM, v.20) software was used for all analyses.

RESULTS

According to the inclusion criteria, age, sex, and BMI were fully comparable between groups (Tab. 1). Among the 62 subjects evaluated at the baseline, 1 soccer player has been excluded because of a history of minor amputation of the foot. Six soccer players did not come for the evaluations after training protocol: two subjects changed team or interrupted practicing sports, one was sick, three had school or family commitments.

The results of two-way factorial repeated-measures ANOVAs indicate that TP showed a significant positive effect on ankle ROM in plantar flexion ($F_{(1, 24)}$ = 13.300, p = 0.001, partial eta-squared (η_p^2) = 0.357) but not in dorsiflexion ($F_{(1, 24)}$ = 0.672, p = 0.420, η_p^2 = 0.027). Ankle ROM in plantar flexion was significantly improved after the TP (15.3 ± 3.4°) compared to the pre-TP values (12.4 ± 4.5°), with a mean improvement between the post and pre training of 2.8 ± 4.8° (Tab. 2).

Table 1. Main characteristic, ankle joint mobility, and hamstring flexibility of subjects who practiced different sports and comparison between groups.

	Soccer	**Volleyball**	***p-value***
Age (years)	13.2±0.5	12.7±1.3	0.051
BMI (kg/m²)	19.2±2.5	18.9±3.2	0.679
Years of activity	6.9±1.1	3.4±2.8	0.001*
Training sessions per week	3.0±0.0	2.6±0.5	0.017*
Total AJM (°)	127.6±15.3	141.0±20.5	0.008
Right AJM (°)	64.1±7.7	70.5±10.6	0.019
Left AJM (°)	62.1±9.1	70.5±11.3	0.010
Plantar Flexion (°)	24.6±7.8	31.9±6.2	0.001*
Dorsal Flexion (°)	101.5±11.9	109.1±16.7	0.451
Δ R/L AJM (°)	5.3±4.5	5.7±5.3	0.510*
S/R test (cm)	-6.6±6.0	-8.1±9.9	0.014

Values are means ± standard deviation. Comparisons among groups were performed using T-test for independent samples or Mann-Whitney test (*). Abbreviations: AJM: ankle joint mobility; BMI: body mass index; R/L: right/left; S/R: Sit and Reach; Δ: difference; °: degree; cm: centimeters.

Table 2. Comparison of the results obtained by the soccer players before and after the adapted training protocol and between the soccer and the volleyball players.

	Soccer before ATP	**Soccer after ATP**	***p-value***	**Soccer after ATP**	**Volleyball**	***p-value***
Total AJM (°)	127.6±15.3	131.0±11.9	0.024	131.0±11.9	141.0±20.5	0.093
Right AJM (°)	64.1±7.7	66.5±6.6	0.044	66.5±6.6	70.5±10.6	0.183
Left AJM (°)	62.1±9.1	64.4±7.2	0.183	64.4±7.2	70.5±11.3	0.083
Plantar Flexion (°)	24.6±7.8	30.6±5.5	0.001	30.6±5.5	31.9±6.2	0.553
Dorsal Flexion (°)	101.5±11.9	100.4±9.8	0.420	100.4±9.8	109.1±16.7	0.073
Δ R/L AJM (°)	5.3±4.5	5.2±5.1	0.584	5.2±5.1	5.7±5.3	0.458*
S/R test (cm)	-6.6±6.0	-2.7±7.1	0.001^	-2.7±7.1	-8.1±9.9	0.008*

Comparisons among groups were performed using T-test (paired samples or *independent*) or nonparametric test Mann-Whitney (*), Wilcoxon rank (^). Abbreviations: AJM: ankle joint mobility; R/L: right/left; S/R: Sit and Reach; Δ: difference; °: degree; TP: training protocol.

Limb of measurement (dominant-nondominant) did not affect ankle ROM in plantar flexion ($F_{(1, 24)} = 0.777$, $p = 0.387$, $\eta_p^2 = 0.031$) or in dorsiflexion ($F_{(1, 24)} = 1.620$, $p = 0.215$, $\eta_p^2 = 0.063$).

The interaction effect of time and limb of measurement (dominant-nondominant) was not statistically significant in either plantar and dorsiflexion.

Compared to the volleyball players, at baseline, the young soccer players showed reduced plantar flexion (p<0.001) and total AJM (p<0.008; Tab. 1). When assessed in the supine position, soccer players showed a minor angle between foot and leg than that assessed in controls (p<0.001; Tab. 3, next page).

DISCUSSION

In this study, two of the most practiced sports in the world, which in several countries are practiced by over 50% of young subjects,[6,8] have been considered. Consequently, the knowledge of the effects that the practice of such sports activities can have on young subjects has been considered of great social, sports, and health interest.[1-3]

The results of the initial assessments carried out allowed to verify that soccer players showed a significantly reduced AJM compared to the young volleyball players to be similar to that shown by elderly people.[32-34] In particular, the plantar flexion was strongly impaired instead of the dorsiflexion (Tab. 1).

Table 3. Soccer and Volleyball players' leg - foot inclination angles with half-lines passing through the head of the fibula (F) and through: A) the head of fifth metatarsal bone; B1) parallel to the ground; B2) perpendicular to the ground.

	Soccer	Volleyball	*p-value*
Angle (F-A)			
Standing - left angle (°)	122.8±5.3	123.5±4.3	0.574
Standing - right angle (°)	121.4±5.3	120.8±3.5	0.634
Standing right+left angle (°)	244.2±8.8	244.3±5.8	0.889*
Lying - left angle (°)	147.8±7.5	152.6±5.9	0.009
Lying - right angle (°)	146.7±6.6	151.7±4.8	0.002
Lying – right+left angle (°)	294.4±13.2	304.3±9.8	0.002
Angle (F-B1)			
Standing - left angle (°)	86.8±2.8	87.0±3.1	0.766
Standing - right angle (°)	86.8±3.6	86.0±3.5	0.370
Standing right+left angle (°)	173.5±5.1	172.9±6.1	0.689
Angle (F-B2)			
Lying - left angle (°)	85.8±2.6	83.4±2.5	<0.001
Lying - right angle (°)	84.8±2.2	82.4±2.3	<0.001
Lying – right+left angle (°)	170.6±4.3	165.8±4.3	<0.001

Values are means ± standard deviation. Comparisons among groups were performed using T-test for independent samples or Mann-Whitney Test (*). Abbreviations: °: degree.

These reduced AJM values found in the soccer group could be considered worrying for the possible consequences that this deficit can cause over time.[11,20,22] Therefore, a specific prevention program, using TP, can be considered worthy of attention.[10,16,21,23,26]

After a short period of a tailored training, consisting of only a weekly session for 10 weeks, AJM of young soccer players and particular the plantar flexion improved significantly even though remaining lower than that recorded in the control group (Tab. 2).

The real cause of a limited AJM condition in young soccer players and its role is still unknown. Soccer practice can affect the structural integrity of the ankle.[13,16,18,35] The same intense movements that can be performed such as high-intensity jumps and movements with continuous changes in speed and direction, typical of soccer, can cause ankle injuries and affect AJM.[9,14,16,35,36] Moreover, it has been reported that these injuries could be increased by the use of artificial surfaces in addition to inappropriate footwear.[16,37,38]

However, the AJM assessed in the volleyball group resulted to be in line with the reference values reported in scientific literature for subjects matched for age.[32,33] This sport is also characterized by a high incidence of ankle injuries and trauma and direct contact caused by high-intensity movements.[39,40] All of this suggests that other factors may contribute to cause limited joint mobility in soccer players.

The results of this study seem to indicate that the major role in determining the variations of AJM could be played by the effects induced by repetitive hitting the ball with greater or lesser strength.

Such activities may require a high strength in both concentric (hitting) and isometric (stabilizing the joint) activity by the dorsal flexor muscles of the ankle involved.[41,42]

The strengthening of the muscle-connective tissue in the anterior and lateral part of the leg could justify, at least in part, the significant effect of the training protocol proposed on AJM in plantar flexion (Tab.2) and could also justify the differences between the two groups studied regarding the posture assumed by the foot if evaluated in non-weight-bearing position.

Regarding the analysis of the images carried out in this study, while on one hand the evaluation of the young subjects in upright position did not show particular differences between the two groups studied, on the other hand the analysis of the images of the players in the lying position showed significant differences between the two groups (Tab. 3).

In particular, the angle with the vertex at the centre of the lateral malleolus and with half-lines passing through the distal extremity of the fifth metatarsal and for the head of the fibula was lower in the soccer players (Tab. 3, A). This result is evident despite the analysis that considered the inclination of the leg in relation to the perpendicular line to the ground that showed a lower leg's inclination in soccer players (Tab. 3, B2).

On the whole, these results suggest that in young soccer players, the foot assumes a posture in dorsal flexion if evaluated in non-weight-bearing conditions. The fact that this result was only obtained in the non-weight-bearing condition suggests that the tests performed in this study may allow recognizing the early effects of soccer practice on the posture of the lower limb in addition to those on AJM

With regard to the prevention and treatment of such alterations, the possibility of modifying the training program may not be easy due to the dreadful negative effects on sports performance.

In these respect, in order not to hinder the soccer training program, in this study, only 4 exercises were added for a limited number of sessions. This could justify the limited improvements of AJM achieved by the TP.

CONCLUSIONS

The practice of soccer seems to cause a marked reduction of AJM characterized by an increased activity of ankle dorsal flexor muscles. The same posture of the lower limb could modify over time. All this suggests that the stiffness induced at the ankle level by the soccer practice is a complex condition with the possibility of medium-long term consequences. A short-term training program, as proposed in this study, may lead to an only limited but significant increase of AJM. Further studies are needed to evaluate the usefulness of avoiding the AJM reduction in young soccer players.

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STUDY 4

A six-month unsupervised Training Program Does Not Improve Ankle Joint Mobility in Soccer Players

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INTRODUCTION

Soccer is often the sport preferred by young males and a large number of adults in many countries.[1-4] It is well known that soccer practice is a significant source of physical activity, and it has many positive effects on health.[5-7] However, continued soccer practice has also been associated with some negative consequences.[5,8,9] Among these, those affecting the joint mobility of the ankles are particularly feared and studied.[10-12]

The anatomy and physiology of the ankle are very complex because, at the same time, the mobility and stability of the joint must be maintained at the same time. The ankle or talocrural joints is a load-bearing joint and it is one of the most congruous joint in the body. The talocrural joint is formed by the articular surfaces of the tibial (medial malleolus and tibial plafond), fibular distal epiphyses (medial surface of the lateral malleolus) and the superior, lateral, and medial aspects of the talus.[11,13] In particular, the medial and lateral malleolus concur to form a mortise to receive the articular surface of the talus.[11,13]

In addition to the morphology of the articular surfaces of the talocrural joint that forms an angular ginglymus with a single axis of movement (bimalleolar axis), other passive factors (e.g., capsuloligamentous structures surrounding the joint) and dynamic factors (i.e., muscle action) provide both active and passive tension, allowing and limiting the range of motion (ROM) of the ankle joint in dorsiflexion and plantar flexion.[11,13,14]

In addition to the ankle joint all periarticular structures can be affected by the practice of this sport and lead to ever greater problems even after the end of sports activity

(Ekstrand&Gillquist, 1982; Tol et al, 2002; Golanó et al, 2014; Azuma&Someya, 2020).[11,15-17] This condition is much feared for its possible consequences on the quality of balance, posture and movement as well as representing, in turn, an important risk factor for injuries in addition to being able to negatively affect performance.[18-22]

It was hypothesized, that several factors contribute to the occurrence and development of limited AJM in SP. In addition to physical contact between the players, during sports practice, different types of high intensity movements such as jumping or running with frequent and rapid changes of speed and direction, twisting and turning, overtaking and landing, can cause joint microtrauma and concur to induce a condition of overuse.[23,24] Other factors such as the soccer field surface or the type of soccer shoes used may affect the risk of injury or ROM of the ankles.[15,25]

The limited range of motion (ROM) of the ankle in soccer players (SP) can therefore be considered as a sport induced adaptation. It was suggested, that on the one hand this adaptation involves greater joint stability associated with a reduced risk of injury but, on the other hand, it induces a limitation of the ankle range of motion.[10,23,26] In this sense, several studies suggested the importance of the prevention or treatment of limited AJM in SP.[15,17,27,28]

In 1985 Moller et al. studied how stretching exercises performed before or after a training session modified the joint mobility of the lower limbs of the adult male SP. In particular, the authors reported how this type of treatment had positive effects on joint mobility and injury prevention.[29] More recently, Zakas and colleagues (2006) evaluated the significant positive effect of a stretching exercise protocol, whether or not associated with a warming-up phase, on the ankle dorsiflexion of a team of adolescent soccer players.[30]

The improvement in AJM obtained by Zakas et al. is similar to those of our more recent study on a three-month supervised stretching training program with 4 specific exercises involving soccer players.[27,30] In our study, a control group of non-soccer players was also considered. The results of the study showed that the proposed training protocol significantly increased the ankle ROM even though it was significantly lower than that of the non-SP controls.[27]

Recently, Azuma and colleagues published an article on the evaluation of the effects of a supervised physical therapy intervention on muscle tightness for the injury prevention in adolescent male SP.[17] In this study, significant increases in ankle dorsiflexion were obtained using a supervised intervention performed for 12 weeks (three times a week, 20-30 minutes of stretching sessions). Moreover, additional exercise instructions were provided during the cool-down period and the voluntary training session. The authors reported also that in the 40 weeks following the training period, the injuries suffered by the SP were lower than those of the controls.[17] Other studies evaluated the effect of different types and duration of stretching exercises on injuries prevention,[31-33] kicking speed and range of motion (ROM) in SP of different ages.[33]

Unfortunately, to date there are still no clear indications on the protocols to be used for the recovery of AJM in adult SP.[8,9,23,28,34] The main aim of this study was to verify the effects of a six months stretching training protocol (STP) on AJM of male soccer players.

METHODS

A total of 58 adult male subjects, 34 amateur soccer players (SP) and 24 non-soccer player controls were enrolled in this study. Detailed characteristics of the study participants are shown in Table 1.

Table 1 Detailed characteristics, AJM and Muscle strength of the study participants.

	SP at baseline vs Controls			**SP at baseline vs SP after STP**		**SP after STP vs Controls**	
	SP at baseline (n=34)	**Controls (n=24)**	**P value**	**SP after STP (n=28)**	**P value**	**Controls (n=24)**	**P value**
Age (yrs)	29.0±4.6	28,2±8,9	0.464*	29.7±4.8	----	28,2±8,9	0.293*
BMI (Kg/m^2)	23.2±2.1	23,3±2,3	0.755	23.2±2.2	----	23,3±2,3	0.816
Yrs of Soccer Practice	18.3±5.8	----	----	18.8±5.9	----	----	----
HGS (Kg)	45.0±7.5	48.0±8,9	0.198	44.1±7.2	----	48.0±8,9	0.106
APF (°)	25.4±5.1	33,4±6.9	<0.001	28.0±6.3	0.090	33,4±6.9	0.005
ADF (°)	91.4±10.4	104,3±12.8	<0.001	88.2±12.4	0.050	104,3±12.8	<0.001
ATOT (°)	116.8±13.1	137,7±13,6	<0.001	116.1±15.1	0.540	137,7±13,6	<0.001
Dominant AJM (°)	58.2±6.8	68.6±8.1	<0.001	57.9±7.5	0.456	68.6±8.1	<0.001*
Non-dominant AJM (°)	58.6±7.7	68.7±8.4	<0.001	58.3±9.0	0.833	68.7±8.4	<0.001
Right AJM (°)	58.5±6.7	68.2±7.8	<0.001	58.5±7.5	0.560	68.2±7.8	<0.001
Left AJM (°)	58.3±7.8	69.2±8.6	<0.001	57.7±9.0	0.740	69.2±8.6	<0.001
Δ R/L – D/non-D (°)	5.0±3.7	5,4±5,2	0.510*	3.7±4.8	0.877	5,4±5,2	0.270*

Values are mean±SD. Comparisons among groups were performed using *t*-test (paired samples or independent) or non-parametric Mann- Whitney (*) or Wilcoxon rank (^) test. BMI: body mass index; HGS: hand grip strength; AJM: ankle joint mobility; R/L: right/left; D/non-D: Dominant/non-Dominant; Δ: difference; TP: training protocol; (°) degrees.

All subjects were recruited in sports clubs from Marche, Tuscany, and Emilia Romagna who had positively replied to the invitation to participate in the study and they were evaluated from September 2021 to June 2022. The 34 SP were players of 2 teams: Team A (18) and Team B (16). While the players of Team A trained on a dirt soccer field, Team B used an artificial turf soccer field. The control group was composed of sedentary subjects, people attending a fitness center or people who regularly engage in athletics i.e. conditions that do not have a known effect on AJM.[22,35]

Data were collected on age, weight, height, dominant kicking leg, sport practiced, years of activity, number of weekly training sessions and years of practice of different sports. Moreover, the type of shoes used, soccer playing surface, duration of training, injuries suffered and kind of job were considered. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared (kg/m2).

The physical examination included foot inspection and the presence of deformity, injuries and traumas such as to affect ankle joint mobility. Exclusion criteria were: age greater than 16 years and less than 50 years old, presence of diabetes, other diseases as well as orthopedic and/or surgical complications at baseline that can affect AJM. Soccer practice for less than 6 months continuously was an additional exclusion criteria per the SP group.

All participants and parents were informed of the purpose of the study and its experimental procedures before obtaining their written informed consent and the enrolment in the study. The study protocol and the consent forms were approved by the Paediatrics Ethics Committee of University of Urbino Carlo Bo (cod. CESU20221118VER37 November 2020). The study was performed according to the principles expressed in the Declaration of Helsinki.

Determination of joint mobility

The method used for the assessment of ankle mobility has been described in previous studies.[22,36] In brief, the active range of motion (ROM) of the ankle joint in plantar flexion (APF) and dorsiflexion (ADF) was measured by an inclinometer.

Players were asked to lie in the supine position on a fixed treatment table with the ankle resting in line with the edge and the feet across the edge of the table, the ipsilateral knee of the assessed ankle was put over a rigid support 5-cm high. The greater angle of the active APF and ADF was measured and the mean of three consecutive readings was reported, while the total ankle mobility (ATOT) was the sum of the two values (APF+ADF). In a previous study, it was reported that the mean standard deviation of three consecutive readings of the ankle ROM, as reported in this study, was very limited: 1.1±0.9 degrees of plantar flexion and 1.4±1.1 degrees of dorsiflexion. The ankle ROM was measured by the same operator who had more than 10 years of experience.[27]

The dominant lower limb was identified by asking the players which was the preferred limb for kicking the soccer ball. The test operator who evaluated AJM did not know the dominant limb of the players.[34,37]

Determination of hand grip strength

The method used for assessing muscle strength has also been described in previous studies.[26] In brief, Hand Grip Strength (HGS) was evaluated by the Jamar hydraulic hand dynamometer (model 5030J1) 0-90 Kg. Before the test, the examiner gave explanations, showed the posture to be maintained, how to hold the dynamometer and how to perform the test. In particular, hand grip was evaluated with subjects in the standing position, arms by the side of the body, shoulder adducted in a neutral position, elbow 90° flexed with the forearm parallel to the ground and pronated in order to maintain the display of the dynamometer on the frontal plane.[38] The players were asked to maintain the same posture and the dynamometer handle during the three tests and to squeeze with the maximum strength for three seconds without moving the rest of the body.[39,40] Only the dominant hand was tested. A trial test was allowed to become familiar with the device. The dominant upper limb was identified by asking the players which hand was used for writing.[39]

In this study, the Jamar hydraulic hand dynamometer was used since it was a well-validated device for the quantitative measurements of the maximum isometric MS of the hand and it was widely used in clinical practice. Moreover, this dynamometer has a high test-retest and inter-rater reliability in addition to a high reproducibility.[38,41-44]

Training protocol

Soccer players performed 6 months (twice a week) of stretching training protocol (STP) from 2021 November to 2022 April, including 4 exercises aimed at improving AJM. Due to the Christmas period and Covid-19 pandemic, training was suspended for 7 weeks, from 18 December 2021 to 9 February 2022. The exercises performed during the initial (warming-up) phase of each soccer training session are described below: — exercise 1: players were requested to stand and put one foot forward, keeping the feet pointing straight forward and the heel on the ground, then to lean forward onto the front leg to feel the stretching of the calf muscle (3 repetitions of 20 seconds for each side);

— exercise 2: standing with feet facing in front, one foot forward while the rear foot rested on the dorsal surface of the foot (toes) keeping the ipsilateral knee extended; weight was gradually shifted to the lower limb in front of the ankle with the lengthening of the extensor muscles of the ankle (3 repetitions of 20 seconds for each side); — exercise 3: players sat with extended knees trying to touch their feet in dorsiflexion; they could help themselves to lean forward by using elastic bands placed at the level of the plantar surface of the metatarsal heads (3 repetitions of 20 seconds); — exercise 4: players rested with one knee on the ground, the ipsilateral foot pointed backward and maintained in plantar flexion with the contralateral foot positioned anteriorly, trying to achieve the maximum plantar flexion of the corresponding foot maintained in plantar flexion by moving the pelvis backward and the maximum dorsiflexion of the other ankle moving the pelvis forward (3 repetitions of 20 seconds for each side). The correct execution of each exercise was shown to all the SP together immediately after the initial assessments and before the start of the adapted training period. Subsequently, the coach was contacted by telephone on a monthly basis to verify compliance with the protocol. The training protocol was performed with one minute of rest between exercises. The training sessions were carried out without the presence of an athletic trainer. The STP was conducted by the coach.

Statistical analysis

Data were reported as mean ± standard deviation (SD). ROM values were expressed in degrees (°). Statistical normality was assessed using Shapiro-Wilk tests. The comparisons between two groups were made using T-test (paired samples or independent) or the nonparametric tests (Wilcoxon rank or Mann-Whitney). The association between the joint mobility and hand strength was evaluated using Pearson or Spearman's correlation coefficients. Multiple linear regression analyses were carried out considering ankle dorsiflexion (ADF), plantar flexion (AFP) and the total AJM (ATOT) as dependent variables and Age, BMI, Years of Activity and Hand Strength as independent variables in SP. The analyses were performed using Stata (StataCorp, v.13) and SPSS Statistics (IBM, v.20) software. The α level of statistical significance was set at 0.05.

RESULTS

The two groups considered (soccer players and controls) were found fully comparable for age, sex and BMI (Table 1). Among the 34 players evaluated at baseline, 28 participated in the follow-up 6 months later. At baseline and after the training period, SP group showed a reduced AJM compared to controls ($p<0.001$) in both ADF and APF ($p<0.001$; Table 1).

The results related to muscle strength (Hand Grip Strength Test) were similar between the two groups considered (SP vs controls). The STP period did not induce changes in the AJM of SP group (Table 2).

Table 2: Detailed characteristics, Ankle joint mobility and Muscle Strength of Team A and Team B soccer players before and after stretching training program.

	Baseline			**After STP**			**Baseline vs After STP**	
	Team A (18)	Team B (16)	P value	Team A (16)	Team B (12)	P value	Team A P value	Team B P value

Age (yrs)	29.4±5.6	28.5±3.2	0.782*	-----	-----	-----	-----	-----
BMI (Kg/m^2)	23.2±2.4	23.0±1.8	0.788	-----	-----	-----	-----	-----
Yrs of Soccer Practice	19.5±6.5	16.9±4.8	0.279*	-----	-----	-----	-----	-----
Hand strength (Kg)	43.8±7.1	46.3±7.9	0.369*	-----	-----	-----	-----	-----
ATOT (°)	117,4±12.2	116,0±14.3	0.756*	119.5+11.2	111.7+18.8	0.185	0.118	0.197^
APF (°)	26.0±5.2	24.8±5.0	0.506	28.3+4.8	27.6+8.1	0.757	0.659	0.004
ADF (°)	91.4±10.5	91.3±10.7	0.968	91.1+11.7	84.2+12.8	0.146	0.160	0.027
Δ D/non-D (°)	5,6±4,4	4.4±2.8	0.356	4.2+5.3	5.5+4.2	0.236*	0.499	0.344

Values are mean±SD. Comparisons among groups were performed using *t*-test (paired samples or independent) or non-parametric Mann-Whitney (*) or Wilcoxon rank (^) test. BMI: body mass index; HGS: hand grip strength; AJM: ankle joint mobility; D/non-D: dominant/non-Dominant; Δ: difference; STP: Stretching training protocol; (°) degrees.

The two teams considered in this study (Team A and B) performed the same number of weekly training sessions (twice a week) with the same duration (90 minutes). Only the soccer field surface used for training (dirt surface vs artificial turf) and, therefore, the soccer shoes used were different in the two soccer teams considered. The comparison between the two teams (Team A vs Team B; Table 2) showed a very similar ATOT with a difference of 1.4° (1.2%). Even considering the two Teams separately, ATOT values did not change after the training period. Considering the role of the players, the defenders of Team A (n = 6) and Team B (n=5) showed a higher AJM than the other players considered (n=23) (124.4±17.2° vs 113.1±8.8°; p = 0.015). Otherwise, the midfielders (n=13) showed lower muscle strength values (42.9±7.4 kg) even if the differences between the groups considered (n=21; 46.3±7.5 kg) did not reach full significance (data not shown).

The multiple linear regression analysis did not show any significant effects of age, BMI, duration of soccer practice or hand grip strength on ankle ROM (Table 3).

Table 3. Multiple linear regression analysis considering dorsiflexion (ADF), plantar flexion (AFP) and total AJM (ATOT) (expressed as degrees) as dependent variables and age, BMI, years of activity and Hand grip strength as independent variables in Adult SP (n=34).

	Soccer Players (34)		
	ß-Reg. coef.	p-Value	p-Model
APF			
			0.687
Intercept	37.72	0.002	
BMI	-0.51	0.279	
Age	-0.03	0.910	
Years of activity	-0.14	0.526	
Hand Grip Strength	0.07	0.628	
ADF			
Intercept	107.51	<0.001	0.343
BMI	-1.26	0.178	
Age	0.29	0.594	
Years of activity	-0.54	0.204	

Hand Grip Strength	0.33	0.221	
ATOT			
			0.282
Intercept	145.22	<0.001	
BMI	-1.78	0.129	
Age	0.26	0.701	
Years of activity	-0.68	0.200	
Hand Grip Strength	0.39	0.237	

Note: ß-Reg. Coef.: Unstandardized coefficients

DISCUSSION

The highly interesting topic of the alteration of the ankle joint mobility in soccer players was addressed in this study. This topic is of great interest considering the key role played by ankle mobility for the quality of movement, performance, and injury prevention in SP.[9,10,15,28,45] According to the literature considered,[23,37,46] the amateur soccer players included in this study showed an AJM of about 15.2% lower than that of the non-SP controls (Tab. 1). The AJM values found in the control group were similar to those reported in large cohort studies and aimed at defining reference values for this parameter.[47-50] The lower AJM found in SP group was in agreement with what was reported in our previous study on young SP. In particular, in young SP, the reduction in AJM was 9.5%.[27] Unlike the results obtained with the study conducted on young SP, the results of the present study showed that the proposed STP did not improve the AJM of the amateur SP considered. As a whole, these results suggest that the effects of soccer practice on AJM are even more evident in adults than in younger SP and difficult to recover. In this sense, in addition to the long history of soccer practice several other factors can contribute to explaining this result, which seems to disagree with what was reported in previous studies. Among these, it is important to consider that the activity proposed in this study was suspended for over a month due to the Christmas period and Covid-19 pandemic. Furthermore, the absence of an athletic trainer in both the teams considered in this study seems to justify the differences in the results achieved compared with those obtained with a similar protocol followed by young SP.[27] The same absence of an athletic trainer could also justify the differences between the results obtained from those reported in other previous studies aimed at studying how stretching exercises modified the joint mobility of the lower limbs of SP.[8,17,27,33] In fact, in these articles the proposed STP period resulted in an improvement of the ankle ROM. Unfortunately, teams of amateur soccer players, are not always able to cover the costs of collaborating with an exercise science expert. The difference in mobility between the two ankles of the SP was also considered in this study. In particular, since soccer is a sport that can lead to an asymmetry in the execution of the sporting gesture, such as kicking the ball, a different mobility

between the dominant and non-dominant limb can be expected.[15,16,37] In this sense, the results obtained did not show a significant difference in AJM between the dominant and non-dominant limb as well as between the right and the left in SP. The same comparison of the two soccer teams considered showed an overlap of the results obtained. Although the two teams trained on very different playing surfaces using therefore different soccer shoes, the results of this study seem to indicate that these parameters affected AJM to a lesser degree. The results obtained showed that only the defenders showed a higher AJM than the players in other roles. The analysis of the factors considered in this study does not provide a possible explanation of the result obtained.[51] Overall, while on the one hand the results obtained indicate the importance of the treatment of AJM in SP, on the other hand they highlight the importance of organizing supervised training programs in order to verify the correct execution of exercises as well as the compliance with the STP proposed. The organization of supervised STP would allow, as reported in previous studies, the modification of the proposed exercises according to the needs of each SP. In this sense, further studies aimed at evaluating the effect of different stretching exercise protocols aimed at improving AJM in SP appear necessary.
exercises according to the needs of each SP. In this sense, further studies aimed at evaluating the further studies aimed at evaluating the effect of different stretching exercise protocols aimed at improving AJM in SP appear necessary.

CONCLUSIONS

The practice of soccer causes a marked reduction of AJM in amateur male SP. All this suggests that the stiffness induced at the ankle level by the soccer practice is a complex condition with possible medium and long-term consequences. The unsupervised stretching training program proposed in this study does not lead to an improvement in the joint mobility of the ankle of SP. The interruptions of sport activity due to the Covid-19 pandemic and the absence of Athletic trainers in the sports clubs involved, in addition to the long history of soccer practice could justify, at least in part, the lack of improvement on the ankle ROM. The different playing surfaces considered, as well as age, years of sports practice, muscle strength and BMI did not show an effect on AJM. Further studies are needed to evaluate the usefulness of avoiding the AJM reduction in soccer players

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Overall conclusions

The aim of my PhD thesis was to delve deeply into the research topic of the effect of soccer practice in subjects of different age. In particular, the purpose of this study was to investigate the research topic of the trend and alteration of the ankle joint mobility in soccer players of different ages.

Considering the high number of subjects who practice football in the world, the study of the different effects of its practice is necessary. In this sense, knowing the effect of soccer practice in players can allow the definition of targeted training protocols in order to maximize the positive returns and prevent negative ones.

Four studies have followed this preparatory phase. In these research activities, players of some youth and amateur clubs were investigated as well as sedentary subjects or those who practice sports that do not affect joint mobility itself.

The first two studies aimed to evaluate the joint mobility of the ankle in young subjects and adults considering the main factors that can affect the mobility of the joint. In particular, with the first study we verified the presence of reduced joint mobility in young soccer players and how this is associated with some postural values. To the best of our knowledge, this is the first study that highlights this relationship and can represent an important reference for future studies in this area as well as being a starting point for the definition of targeted training programs. Since the study was aimed at young football players, it was possible to demonstrate the rapid and significant effect of football practice on ankle ROM. This alteration of the ankle rom tends to decrease during growth even if puberty could attenuate the impact of football practice on ankle mobility. The fact that the posture of the lower limb can also be affected by ankle stiffness or, more generally, by the practice of football indicates the strong need to monitor the effects of the practice of this sport. In this sense, the assessment of ankle rom and lower limb posture as proposed in this study are easy, cheap and quick to perform and interpret. These characteristics make the same tests an appropriate solution with respect to a wide and systematic use in the football field.

In the second study, the trend of ankle mobility was further studied by studying adults as well. Furthermore, the possible relationship between ankle ROM and muscle strength was studied. Also in this case evaluation tools and protocols were used which can be carried out quickly and with low costs. The results of the study confirmed that, in adolescents, there is a very significant reduction in joint mobility and that this is also affected by the trend in strength. Furthermore, the values of ankle mobility, albeit less evidently, decrease in adults. These results also confirm that playing football causes ankle stiffness, a feared effect because it is associated with an increased risk of injury and instability of the joint itself. The finding of the relationship between ankle mobility and muscle strength provided further confirmation of the effect of growth and puberty on ankle stiffness. at the same time the results obtained indicate that for the entire period of football practice the effects on ankle ROM should be considered and appropriately managed.

Study number three investigated the effect of an adapted training protocol on the ankle rom of young players. The results of the study show how the inclusion of some exercises aimed at improving ankle mobility lead to a partial but significant increase in ankle rom without affecting the risk of injury and participation in training sessions.

In the fourth study, the adapted training protocol as proposed to young players was replicated with two teams of amateur soccer players. In this case, the training period, which included the execution of some simple exercises aimed at improving the ankle rom, did not lead to improvements with respect to the investigated parameter. This result was attributed to the absence of the athletic trainer in the clubs of amateurs compared to those of young players. In this sense, the absence of specialized personnel and a lesser organization of training can, at least in part, explain why the unsupervised stretching training program proposed with amateurs can repeat the results obtained with young players by improving ankle ROM. Furthermore, the interruptions of sport activity due to the Covid-19 pandemic, in addition to the long history of soccer practice could justify, at least in part, the lack of improvement on the ankle ROM.

The results of this project, together with those of further future studies, will contribute to increasing the accuracy and effectiveness of the proposed training protocols, allowing us to increase the benefit/risk ratio of the proposed sporting activity.

List of abbreviations

List of the abbreviations and acronyms used in the text

Abbreviation	Description
ACSM	American College of Sports Medicine
ADF	Ankle dorsiflexion
ANOVA	Univariate analysis of variance
AJM	Ankle Joint Mobility
APF	Ankle plantar flexion
ATOT	Total AJM
BFP	Body Fat Percentage
BMI	Body Mass Index
CI	Confidence Intervals
CIAFEL	Centro de Investigacao am Actividade Fisica
ES	Effect size
FINAL model	Model with the highest
FP	Foot posture
HGS	Hand grip strength
LP	Leg posture
MANOVA	Multivariate analysis of variance
η_p^2	partial eta-squared
ROM	Range of motion
R/L	Right/left
SD	Standard deviation
S/R	Sit and Reach test
SP	Soccer players
STP	Stretching training protocol
TP	Training protocol