Original Article

The effect of different sports specialization on ankle joint mobility of young players

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ABSTRACT

The aim of the study was to investigate the effects of practicing different sports on ankle joint mobility (AJM) in young subjects. In 344 players of 5 different sports (soccer, classical ballet, gymnastics, volleyball and basketball), mean age 12.0 ± 2.4 years, sex (male/female: 237/107), BMI 19.0 ± 2.8 (Kg/m^2), AJM was evaluated by using an inclinometer while the trunk flexibility was evaluated by the Sit and Reach test. Compared to all other groups, soccer players showed a significant reduction of AJM ($p < .005$) that is already present in younger subjects and that tends to worsen with aging ($p < .04$). On the contrary, the young dancers of classic ballet showed a significant increase in the AJM ($p < .002$). Basketball, volleyball and gymnastics groups showed a similar AJM. The higher AJM showed by females compared to males (128.5 ± 21.0° vs 144.6 ± 18.5°; $p < .001$) was not significant when the group of soccer players and dancers were excluded from the calculation. All groups investigated did not show a different mobility between the two ankles or the dominant and non-dominant limb. The age of the subjects investigated was not correlated with AJM. The group of gymnasts showed a significant increase in trunk flexibility ($p < .001$) compared to all other groups. Sport practice can significantly modify AJM both by increasing and reducing it. Such process should be timely assessed in order to prevent these alterations along with the related possible negative effects in the short and long term.
Keywords: Ankle joint mobility; Youth sports; Early specialization; Flexibility; Overuse injuries; Prevention.

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INTRODUCTION

For young people, sport practice is a significant source of physical activity and has many positive health benefits that are considered important for their development (Bergeron et al., 2015; Merkel, 2013; Strong et al., 2005).

In many western countries the majority of youths, starting from the first years of life, perform structured sport activities in sport clubs or at school. Sports such as basketball, volleyball and gymnastics are among the most practiced involving millions of children in the world (Statistics Canada, 2014; Study Center FIGC, 2017; Department for Digital, Culture, Media & Sport - England, 2018). Football, even if practiced differently according to country, is often the sport preferred by males involving also an increasing number of females (Statistics Canada, 2014; Study Center FIGC, 2017; FIFA Communications Division, 2007; National Physical Activity Plan Alliance, 2018). Even in Italy about a half of young males aged between 3- and 19-years old play football while about 10% of them play basketball. Regarding young females, about 23% practice gymnastics or similar sport activities and about 30% do ballet or dance. 10.6% of young subjects aged between 3 and 10 years play volleyball, a percentage that rises up to 22.3% of subjects in the 11-19 age range (Study Center FIGC, 2017).

Sports practice as such significantly involves the musculoskeletal system together with the joints. The ankle is the joint mostly involved in the practice of many popular sports (Kaueyer & Malone, 1980; Merkel, 2013; Golanò et al., 2014). This is also because, the anatomical and functional features of the ankle, as a joint connection between the leg and the foot, give it a fundamental, biomechanical and postural role, in addition to being important for the correct execution of many sport gestures (Russell et al., 2008; Basnett et al., 2013; Golanò et al., 2014).

The ankle is a load-bearing joint formed by the medial and lateral malleolus respectively of tibia and fibula, which form a mortise to receive the trochlear surface of talus (Kaueyer & Malone, 1980; Russell et al., 2008; Golanò et al., 2014). In addition to the morphology of the articular surfaces, other passive factors (i.e. capsuloligaments 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 on the sagittal plane (Russell et al., 2008; Golanò et al., 2014).

Sport practice can negatively affect the anatomical and functional integrity of the ankle. All ankle ligaments and joint capsule in addition to the others periarticular structures (i.e. Achilles tendon and plantar fascia), can be subjected to injury and alterations due to sport practice (Bahr & Bahr, 1997; McKay, et al., 2001, Faude et al., 2013; Golanò et al., 2014).

It has been documented that sport practice can modify ankle ROM and increase the risk of being subjected to injuries, leg pain, and musculoskeletal overload with possible negative long-term effects (Kaueyer & Malone, 1980; Bennell et al., 1999; de Noronha, 2006; Russell et al., 2008; Basnett et al., 2013; Golanò et al., 2014).

Analysing the effects of practicing different sports on ankle mobility of young players could provide useful information on actions aimed at the prevention of AJM alterations and its negative consequences (Kaueyer & Malone, 1980; Basnett et al., 2013; McKay et al., 2001; de Noronha, 2006; Faude et al., 2013; Terada et al., 2013). The aim of this study was to verify the effects of different kinds of sport practiced by young subjects on ankle joint mobility.

METHOD

Ankle joint mobility in plantar and dorsal flexion was evaluated in a total of 344 young athletes aged from 7.4 to 17.9 years old practicing different sport continuously (soccer, volleyball, basketball, classical ballet and artistic gymnastics) for at least the previous 6 months. Data were collected on age, sex, body mass index (BMI), lower limb-dominance, sport practiced, number of weekly training sessions, and years of sport practice. BMI was expressed as body weight in kilograms divided by height in meters squared (kg/m^2). Detailed characteristics of the study participants are shown in Table 1.

Table 1. Main characteristic and joint mobility of all subjects investigated.

	All groups (344)	All subjects less Soccer and Dance groups (139)
Gender (M/F) [a]	237/107	62/77
Age (yrs.)	12.0 ± 2.4	12.2 ± 2.0
BMI (Kg/m^2)	19.0 ± 2.8	19.1 ± 3.1
Plantar Flexion (°)	29.8 ± 8.6	32.9 ± 7.8
Dorsal Flexion (°)	103.7 ± 17.7	108.6 ± 14.4
Total AJM (°)	133.5 ± 21.5	141.5 ± 17.3
Right AJM (°)	67.2 ± 10.9	71.1 ± 8.6
Left AJM (°)	66.3 ± 11.6	70.4 ± 9.7
Δ R/L AJM (°)	5.1 ± 4.4	4.7 ± 4.2
S/R test (cm)	-1.1 ± 9.2	0.2 ± 11.0

Values are mean ± SD. Abbreviations: AJM: ankle joint mobility; BMI: body mass index; R/L: right/left; S/R: Sit and Reach; Δ: difference; °: degree; yrs.: years; cm: centimetres.

Exclusion criteria were aged less than 7 years and greater than 18, 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 practice of the same sport for less than 6 months continuously. The physical examination included foot inspection and the presence of deformity, injuries and trauma such as to affect ankle joint mobility and trunk flexibility. If subjects were practicing more sports at the same time, the subject was assigned to the sport group which had the most numerous weekly sessions, or that had been practiced for the longer time, otherwise they were excluded from the calculations.

Determination of joint mobility

AJM was evaluated using an inclinometer as previously reported (Clarkson, 2013; Francia et al., 2015; Francia et al., 2017): the patient was lying supine with the feet over the edge of the hospital bed, 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 drawing with the dermographic pen the fifth metatarsal bone and positioning the inclinometer along the diaphysis of the bone, with one extremity put 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 our recent paper (Francia, 2019), it has been reported that the mean standard deviation of three consecutive readings of the ankle ROM in young subjects, as reported in this study, was very limited: 1.1 ± 0.9 degrees of plantar flexion and 1.4 ± 1.1 degrees of dorsiflexion. Trunk flexibility was evaluated by Sit and Reach test. Young athletes without shoes were asked to sit on the ground with their feet approximately hip-wide against the testing box keeping their knees extended, putting one hand on the other, and slowly reaching forward as far as they could (López-Miñarro et al., 2009). All measurements were performed by the same observer with more than 10 years of experience, recording the mean of 3 consecutive readings.

All participants, parents, or care givers 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 (protocol numbers: 161/2016 on September 29, 2016). The study was performed according to the principles expressed in the Declaration of Helsinki.

Statistical analysis

All data were presented as means ± standard deviation (SD). The test of normality was performed using Shapiro-Wilk tests. Comparison between two groups were analysed by independent samples T-test or Mann-Whitney U test. Comparisons among multiple groups were analysed by one-way ANOVA, Kruskal-Walls test or Chi square test using the Bonferroni correction for multiple comparisons. The strength of the association between two variables has been evaluated by Pearson's or Spearman's correlation test. A 2-tailed P value of < .05 was regarded as statistically significant. All calculations were performed using the SPSS system for Windows Version 25.0 (SPSS Inc., Chicago, Illinois).

RESULTS

The subjects investigated were young athletes enrolled in sports clubs from Tuscany who had positively replied to the invitation to participate in the study. According to the inclusion criteria in the various groups studied BMI was fully comparable while the average age of gymnasts was significantly higher than that of the other groups (Table 2).

Table 2. Main characteristic and joint mobility of subjects who practiced different sports and comparison between groups.

	Soccer	Ballet	Volleyball	Basketball	Gymnastics	*p-value*
Gender (M/F)	175/8	0/22	39/64	23/2	0/11	< .001[a]
Age (years)	11.8 ± 2.6	12.4 ± 3.2	12.3 ± 1.9	10.8 ± 1.0	14.6 ± 1.1	< .001[§]
BMI (Kg/m^2)	18.9 ± 2.5	19.3 ± 3.4	18.8 ± 2.7	20.4 ± 4.3	18.9 ± 2.1	.738[§]
Plantar Flexion (°)	27.3 ± 8.5	31.1 ± 7.0	34.4 ± 6.4	32.1 ± 9.6	20.1 ± 1.8	< .001[§]
Dorsal Flexion (°)	97.2 ± 17.2	127.3 ± 10.0	107.6 ± 13.5	108.0 ± 17.5	119.4 ± 11.9	< .001[§]
Total AJM (°)	124.5 ± 20.7	158.4 ± 9.9	142.0 ± 16.3	140.1 ± 23.1	139.4 ± 11.4	< .001[§]
Right AJM (°)	62.7 ± 10.8	79.2 ± 5.0	71.2 ± 8.5	69.9 ± 10.5	72.6 ± 5.3	< .001[§]
Left AJM (°)	61.7 ± 11.2	79.3 ± 5.9	70.8 ± 9.0	70.2 ± 13.3	66.9 ± 6.8	< .001[§]
Δ R/L AJM (°)	5.6 ± 4.6	3.8 ± 2.4	4.5 ± 4.3	4.9 ± 3.6	5.7 ± 4.4	.102[§]
S/R test (cm)*	-2.6 ± 7.2	8.2 ± 7.2	-0.6 ± 9.9	-7.3 ± 7.2	18.3 ± 3.5	< .001*

*Values are means ± standard deviation. Comparisons among groups were performed using [a]: By χ^2 method. *: One-way ANOVA test. §:Kruskal-Walls test. Abbreviations: AJM: ankle joint mobility; BMI: body mass index; R/L: right/left; S/R: Sit and Reach; Δ: difference; °: degree; cm: centimetres.*

Despite this difference, the group of gymnasts was still considered included in the study both because young athletes were aged in the required range, and because previous studies showed that in the age group considered the AJM was constant (Boone & Azen. 1979).; Kumar et al., 2011; Francia et al., 2019).

From the comparison of all groups, AJM in young sport players practicing different sports activities results different ($p < .001$; Table 2). Ankle ROM was found to be higher in the group of young subjects practicing classical ballet ($p < .005$) and reduced in those practicing soccer ($p < .005$), while it was similar between the groups of volleyball, basketball and artistic gymnastics players (Table 2).

Among the groups, considering each movement measured, ankle joint ROM in dorsiflexion was significantly compromised in the group of soccer players ($p < .005$) while it was increased in the females practicing ballet with the exception of gymnasts ($p < .001$). The plantar flexion of soccer players was reduced compared to that shown by other groups with the exception of gymnasts ($p < .03$) who showed an even more significant reduction of the only plantar flexion in comparison to all other groups ($p < .001$).

The averages of joint mobility between the right and left ankles (Table 2) or dominant and non-dominant limbs (data not shown) were not as significantly different as the values of each movement.

Considering all the subjects investigated, the analysis of AJM differences between males and females showed a significantly higher mobility in females ($p < .001$). These differences of ankle joint ROM were not significant if subjects practicing soccer and classic ballet were excluded from the analysis (Table 3).

Table 3. Main characteristic and joint mobility of subjects divided according to sex, with and without Soccer and Classic Ballet groups or in the Volleyball group.

	All groups			**All subjects less Soccer and Dance groups**			**Volleyball group**		
	Male (237)	Female (107)	p-value	Male (62)	Female (77)	p-value	Male (39)	Female (64)	p-value
Age (years)	11.7 ± 2.3	12.6 ± 2.4	< .001	11.8 ± 1.6	12.5 ± 2.2	.047	12.4 ± 1.6	12.2 ± 2.1	.596
BMI (Kg/m^2)	19.0 ± 2.9	19.0 ± 2.7	.689	19.4 ± 3.6	18.8 ± 2.5	.561	18.9 ± 3.0	18.6 ± 2.4	.613
Plantar Flex. (°)	28.7 ± 8.4	32.2 ± 8.4	< .001	31.9 ± 7.5	33.7 ± 8.0	.116	32.1 ± 6.1	35.8 ± 6.2	< .005
Dorsal Flex. (°)	99.9 ± 16.9	112.3 ± 16.4	< .001	107.2 ± 16.4	109.7 ± 12.6	.296	106.4 ± 15.9	108.3 ± 11.9	.496
Total AJM (°)	128.5 ± 21.0	144.6 ± 18.5	< .001	139.0 ± 21.0	143.4 ± 13.4	.138	138.6 ± 19.6	144.1 ± 13.6	.094
Δ R/L AJM (°)	5.5 ± 4.6	4.0 ± 3.2	.522	5.4 ± 4.9	4.1 ± 3.5	.08	5.57 ± 5.5	3.9 ± 3.4	.127
S/R test (cm)	-4.1 ± 7.7	5.7 ± 8.7	< .001	-7.9 ± 8.0	5.7 ± 9.1	< .001	-7.5 ± 9.1	3.4 ± 8.0	< .001

Comparisons among two groups were performed using Independent samples T-Test (TT) or Mann-Whitney U test (MW); Abbreviations: AJM: ankle joint mobility; BMI: body mass index; R/L: right/left; S/R: Sit and Reach; Δ: difference; °: degree; cm: centimetres.

While the young basketball players showed a lower trunk flexibility ($p < .001$) the young classical ballet dancers and in particular the gymnasts showed a mobility significantly higher than that of other groups ($p < .001$; Table 2). In the whole population investigated as well as in the mixed group of volleyball players, females showed a higher trunk mobility than males ($p < .001$; Table 3).

Considering the whole population investigated, ankle mobility was significantly correlated to the Sit and Reach test ($p < .001$) and inversely correlated to the BMI ($p < .005$; Table 4).

For the groups of basketball and young soccer players the total AJM and in particular the dorsiflexion was inversely correlated with age ($p < .05$). The AJM in plantar flexion of classic ballet dancers was directly correlated with age ($p < .02$; data do not show).

Table 4. Correlation matrix of all subjects investigated (N° = 344).

		Plantar F.	Dorsal F.	Tot. AJM	Δ R/L AJM	S-R Test
Age	R	-.037	-.071	-.074	-.108	.109
	p-value	.497	.196	.177	.049 *	.052
BMI	R	-.111	-.142	-.166	-.099	-.034
	p-value	.050 *	.012 *	.003 **	.078	.564
Plantar F.	R	—	.209	.592	-.092	.081
	p-value	—	< .001 ***	< .001 ***	.090	.147
Dorsal F.	R		—	.895	-.007	.201
	p-value		—	< .001 ***	.891	< .001 ***
Tot. AJM	R			—	-.054	.214
	p-value			—	.319	< .001 ***
Δ R/L AJM	R				—	-.051
	p-value				—	.363

*Test of normality was performed using Shapiro-Wilk tests. Comparisons were performed using Spearman's rho test (r). *p < .05, **p < .01, ***p < .001.Abbreviations: AJM: ankle joint mobility; BMI: body mass index; F: flexion; T: test; S/R: sit and reach; R-L: right-left; Δ: difference.*

DISCUSSION

According to the initial hypothesis of the study, the assessment of a large sample size of subjects allowed the researchers to verify that sport practice in youths may induce significant variations of ankle joint ROM (Table 2).

The most evident result of this study concerns the effect on AJM induced by the practice of soccer. In the groups of young soccer players investigated, AJM resulted significantly reduced compared to all other groups.

The groups of gymnastics, volleyball and basketball players have instead shown a AJM in line with what has been reported in in large-size samples studies that show how AJM in plantar and dorsiflexion is about 70° (Boone & Azen, 1979; Russell et al., 2008; Kumar et al. 2011; Francia et al., 2019).

The low value of AJM detected in young soccer players (Table 2) resulted similar to that detected in elderly people (Kaumeyer & Malone, 1980; Basnett et al., 2013; Francia et al., 2015). Such AJM values could be considered worrying because they can increase the risk of ankle sprain, overuse, and affect, overtime, the quality of gait, and dynamic balance even due to the partial deafferentation of articular and periarticular structures (Kaufan et al., 1999; Basnett et al., 2013; Terada et al., 2013; Francia et al., 2018).

Moreover, according to this study assessments, soccer seems to cause a significant AJM reduction already in the youngest subjects. Children's growth ensures that plantar flexion, already significantly reduced compared to the subjects practicing the other sports investigated, remains almost stable with aging, while the dorsal flexion continues to decrease. Such a trend has not been detected in young subjects practicing other sports. This seems to show a progressive joint stiffness that increasingly hinders the dorsiflexion.

Such phenomenon may be due to the gradual increase in the stiffness of foot flexor muscles in particular of triceps surae (Kaumeyer & Malone, 1980; Terada et al., 2013; Francia et al., 2018; Rössler et al., 2018). However, the real cause of a limited AJM condition in young soccer players and is still unknown.

The high incidence of traumatic events to which soccer players are exposed could play a role (Read et al., 2016). The repetitive direct microtrauma on the ankle by repetitive kicking action in soccer will induce inflammation and other negative effects such as the development of scar tissue, calcification and, reactive spur formation (Ribeiro et al., 2003; Faude et al., 2013; Golanò et al., 2014; Read et al., 2016).

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 (Faude et al., 2013; Read et al., 2016).

Moreover, it has been reported that these injuries could be increased by using artificial surface in addition to inappropriate footwear (Kaumeyer & Malone, 1980; Faude et al., 2013; Rössler et al., 2018).

However, the AJM assessed in the basketball, gymnastics and volleyball group resulted to be in line with the reference values reported in scientific literature (Boone & Azen, 1979; Kumar et al., 2011; Francia et al., 2019). These sports are also characterized by a high incidence of ankle injuries and trauma caused by high intensity movements (Bahr & Bahr, 1999; Mckay et al., 2001; Golanò et al., 2014). This condition suggests that other factors may contribute to cause a limited joint mobility in soccer players.

Although, in the lack of clear scientific evidences, a number of studies suggested that the type of movements and specific sport postures required on the soccer field could contribute to the reduced AJM detected (Ribeiro et al., 2003; de Noronha et al., 2006; DeLang et al., 2017; Read et al., 2016; Rössler et al., 2018).

Therefore, as a whole, the sport specific muscular connective tissue adaptation in addition to the possible muscle tendons alterations sport induced (i.e. muscle lesions, tendinopathy, ankle impingement and an abnormal toning of the leg and foot muscles) may affect, also young soccer players, and justify at least in part the limited AJM detected (Basnett et al., 2013; Golanò et al., 2014; Read et al., 2016; Rössler et al., 2018).

This condition could over time trigger a dangerous vicious circle adversely affecting the structures and posture of the body, in particular the ones of the lower limb and foot (Yaniv et al., 2006; Francia et al., 2018; Marencakova et al., 2018).

In spite of soccer players and according to what has been reported in previous articles, the young dancers investigated showed a condition of ankle "hypermobility" as to achieve significantly higher values compared to other groups (Bennell et al., 1999; Basnett et al., 2013).

In these young dancers trying to reach the AJM necessary to achieve the maximum plantar and dorsiflexion required for the assumption of postures and the execution of typical movements is considered the cause of the increased AJM constantly detected in them (Russell et al., 2008; Basnett et al., 2013).

The group of young gymnasts on one hand, showed a remarkable trunk mobility, higher than that showed by all other groups, especially subjects practicing basketball, on the other hand, their ankle plantar flexion resulted significantly reduced. This difference is compensated by an increased dorsiflexion so that the total ankle mobility was in line with that showed by volleyball and basketball players (Table 2).

Considering the groups of young subjects investigated and according to what has been published previously by a number of authors, the sport practice does not seem to change the mean mobility of one ankle compared to the other (DeLang et al., 2017).

This suggests that movements requiring body symmetry such as walking and running (Stefanyshyn & Engsberg., 1994; DeLang et al., 2017) may contribute to determining a comparable mobility of the two ankles even in subjects with an increased and reduced AJM. However, the results of this study show that considering the single subject the difference of mobility between the two ankles can achieve the 24.1%.

Therefore, it can be important to evaluate this difference in young subjects practicing sport, and, if necessary, provide functional recovery (Terada et al., 2013; Francia et al., 2018).

Important indications on gender differences regarding the AJM emerged from this study (Table 3). In fact, if evaluating all subjects involved in the study as a whole, females show a significantly higher mobility, however, such difference is not evident if the groups of soccer players and classic ballet dancers are excluded from the analysis. These two groups showed a significant reduction and increase of AJM mainly considering the bias of females practicing classical ballet and predominately males playing soccer in the groups analysed.

The analysis of the mixed and numerous groups of volleyball players where this bias did not occur, did not show a significant difference of mobility between the two genders even if AJM resulted higher in females.

All that has been reported above, can raise the interest of directly studying the cause of limited AJM in young soccer players. Such studies could be important for the definition of appropriate protocols aimed to prevent limited ankle joint mobility, ankle joint alterations and their possible long-term effects on subjects practicing sport (Kaumeyer & Malone, 1980; de Noronha et al., 2006; Faude et al., 2013).

CONCLUSIONS

The results of this study provide new information on the effect of sport practice on AJM and show that the AJM assessment can be useful for the management of young subjects practicing sports. In particular, the results achieved, in addition to clarify AJM differences between males and females indicate how soccer worryingly limits AJM already in young subjects as well. Other sports as volleyball, basketball or gymnastics do not induce marked changes of AJM. Even if the effects of an altered AJM on the development of young subjects practicing sport is not fully known, its negative effects on the quality of movement, in addition to representing a risk factor for injuries have been confirmed. As a result, an important goal of the sports trainers should be aimed at preventing AJM alterations by an adapted training program.

AUTHOR CONTRIBUTIONS

P.F., G.I., and S.T. designed the study. P.F. and A.V. performed the measurements. P.F., A.V., U.S. and L.B. contributed to the interpretation of the results. U.S. and L.B performed the analysis of the results. G.I. and S.T. wrote the final version of the manuscript with the support of all authors.

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