Original scientific article
received: 2023-07-04

DOI: https://doi.org/10.35469/ak.2023.395
UDC: 796.322

FOOT POSTURE INDEX AND HIP JOINT ROTATION MOBILITY IN HANDBALL AND SOCCER PLAYERS

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ABSTRACT

Purpose: *To assess the foot posture and hip joint mobility of elite handball and soccer players and to investigate possible correlations between these measurements.*

Methods: *We compared the differences in means of Foot Posture Index (FPI), passive hip internal (IR), and external (ER) rotation range of motion (ROM) between three groups of male subjects (17 handball players, 17 soccer players, and 16 non-athletes). The Kruskal-Walli's test and post-hoc pairwise comparison with the Mann-Whitney U test were used to determine the differences between the group means, and associations between variables were analyzed with Spearman's correlation coefficient.*

Results: *No significant differences in the mean FPI were found between the soccer players (1.3 ± 2.9), handball players (0.7 ± 2.1), and the control group (1.7 ± 2.5) ($p > 0.05$). Similarly, no significant difference was found between the groups in the hip ER ROM. In contrast, a significantly lower ($p < 0.05$) hip IR ROM was observed in the soccer players (30.6° ± 5.3°) compared to the handball players (41.0° ± 8.1°) and the control group (41.1° ± 6.4°). A weak positive correlation was only observed between the FPI and hip IR ROM in the soccer players (ρ: 0.36, $p = 0.035$).*

Conclusions: *Handball and soccer players show a tendency toward less pronated feet compared to non-athletes, but the differences are not significant and the mean FPI values are still within the range of normal foot posture. The range of hip IR seems to be* *reduced in soccer players and weakly, but significantly and positively associated with the FPI value, which needs to be further investigated in future studies.*

Keywords: *foot shape, hip mobility, soccer players, handball players*

INDEKS DRŽE STOPALA IN GIBLJIVOST ROTACIJE KOLČNEGA SKLEPA PRI IGRALCIH ROKOMETA IN NOGOMETA

IZVLEČEK

Namen: *Oceniti držo stopala in gibljivost kolčnega sklepa pri vrhunskih rokometnih in nogometnih igralcih in raziskati mogoče povezave med temi merami.*

Metode: *Primerjali smo razlike v povprečnem indeksu drže stopala (FPI) ter pasivnega obsega giba zunanje (ZR) in notranje rotacije (NR) rotacije kolka med tremi skupinami moških preiskovancev (17 rokometašev, 17 nogometašev in 16 gibalno netreniranih). Za ugotavljanje razlik povprečji med skupinami smo uporabili test Kruskal-Wallis in jih naknadno parno primerjali z U-testom Mann-Whitney. Za analizo povezanosti spremenljivk je bil uporabljen Spearmanov koeficient korelacije.*

Rezultati: *Ni bilo ugotovljenih statistično pomembnih razlik v povprečnem FPI (p > 0,05) med skupino nogometašev (1,3 ± 2,9), rokometašev (0,7 ± 2,1) in kontrolno skupino (1,7 ± 2,5). Prav tako nismo ugotovili pomembne razlike med skupinama glede obsega giba ZR kolka. Nasprotno pa smo pri nogometaših (30,6° ± 5,3°) opazili značilno manjši (p < 0,05) obseg giba NR kolka v primerjavi z rokometaši (41,0° ± 8,1°) in kontrolno skupino (41,1° ± 6,4°). Šibko pozitivno korelacijo smo zaznali le med FPI in obsegom giba NR kolka pri nogometaših (ρ: 0,36, p = 0,035).*

Zaključki: *Rokometaši in nogometaši kažejo težnjo po manj proniranih stopalih v primerjavi s športno netreniranimi posamezniki, vendar so razlike neznačilne in srednje vrednosti FPI še vedno znotraj mej normalne oblike stopal. Zdi se, da je pri nogometaših obseg notranje rotacije kolka zmanjšan ter šibko, vendar značilno in pozitivno povezan z vrednostjo FPI, kar bi bilo v prihodnje smiselno podrobneje proučiti.*

Ključne besede: *oblika stopala, gibljivost kolka, nogometaši, rokometaši*

INTRODUCTION

The foot and ankle complex provides a kinetic link between the ground and the lower extremity that is essential for gait and other activities of daily living (Brockett & Chapman, 2016). Its pathological biomechanics could alter the mechanism of the proximal joints of the lower extremity, especially the knee and hip joints (Gross, 1995), the effect of which is enhanced during athletic activities. There is evidence that increased foot pronation causes mechanical changes in the lower extremities that may overload the knee and hip (Mei, Gu, Xiang, Baker, & Fernandez, 2019). People with foot pronation also show a greater range of motion (ROM) in the barbell squat, with increased flexion in the hip, knee, and ankle joints, as well as greater hip adduction causing knee valgus, which is associated with hip internal rotation (Lu, Li, Rong, Baker, & Gu, 2022).

Both handball and soccer involve high-intensity activities such as running, jumping, cutting, sprinting, lateral and backward movements (Drust, Atkinson & Reilly, 2007; Michalsik, Aagaard & Madsen, 2015), which place a great load on the lower extremities, especially the ankles. Dayakidis and Boudolos (2006) point out that cutting maneuvers and reversal movements generate relatively large forces in the vertical and mediolateral directions associated with the supination of the hindfoot, which can lead to an increased risk of ankle sprains. Ankle injuries are one of the most common types of injuries in both handball and soccer (Kolokotsios, Drousia, Koukoulithras, & Plexousakis, 2021; Martín-Guzón et al., 2022). Most of these injuries involve lateral sprains resulting in a tear of the anterior talofibular ligament (Fong, Hong, Chan, Yung, & Chan, 2007). Repetitive movement patterns typical of a particular sport may result in altered static and dynamic foot behavior, with one foot type predominating over the other. There is evidence that swimmers and volleyball players have a tendency toward the more pronated foot type (De Groot et al., 2012; Lopezosa-Reca, Gijon-Nogueron, Garcia-Paya, & Ortega-Avila, 2018) and handball players have a tendency toward the supinated foot type (Martínez-Nova et al., 2014), while no predominant foot type has been found in soccer players (Lopezosa-Reca et al., 2018).

Non-optimal lower leg mechanics in situations where the entire lower extremity is heavily loaded with body weight, such as fast cutting maneuvers and/or landing on one foot, may therefore affect both the ankle and hip joints. However, there is a considerable lack of published studies on this topic. The results of L'Hermette, Polle, Tourny-Chollet, and Dujardin (2006) show that years of frequent handball training can have a negative impact on hip mobility.

The aim of this study was therefore to investigate foot posture and hip joint mobility in elite handball and soccer players. Two main objectives were set: 1) to find differences in the Foot Posture Index (FPI) and in the hip rotation ROM among the two groups of athletes and the group of non-athletes, and 2) to find possible correlations between the FPI and hip rotation ROM.

METHODS

Participants

The study was conducted with a sample of 50 male participants from three different groups. The handball group consisted of 17 professional handball players (22.4 ± 3.6 years, 185.7 ± 4.7 cm, 85.7 ± 9.2 kg), the soccer group of 17 professional soccer players (25.9 ± 4.1 years, 183.8 ± 5.0 cm, 78.1 ± 5.9 kg), and the control group consisted of 16 non-athletes (25.4 ± 4.1 years, 181.9 ± 5.4 cm, 86.8 ± 12.6 kg) who were only sporadically engaged in recreational physical activity. The participants in the soccer and handball groups were top athletes who completed at least two training sessions per day on most days of the week and took part in at least one match per week.

Subjects who had lower limb injuries, pain, or swelling at the time of measurement or who had undergone lower limb surgery in the last three months were not eligible to participate in the study.

The handball players were members of the Trimo Trebnje handball club and the soccer players were members of the Olimpija Ljubljana soccer club. In the control group, the sample was drawn at random. Participants were included who were willing to cooperate and whose age corresponded to that of the other groups. Only people who were not involved in organized sports activities were included in the control group. The study was approved by the National Medical Ethics Committee of the Republic of Slovenia (No.: 0120-375/2017/3, date approved: 13.11.2017) and carried out in accordance with the Declaration of Helsinki. Each participant was required to sign a written informed consent before participating in this study.

Foot Posture Assessment

The Foot Posture Index (FPI) was used to assess the anatomical and morphological properties of both feet in a weight-bearing position according to the original instructions for the use of the tool (Redmond, 2005). Each foot was evaluated separately by a physiotherapist skilled in the use of the FPI tool. During the assessment, the subject stood in a relaxed bilateral position on firm ground in a well-lit room. The investigator assessed all six clinical criteria of the FPI (Redmond, 2005):

1. Talar head palpation, 2. Supra and infra lateral malleolar curvature, 3. Calcaneal frontal plane position, 4. Prominence in the region of the talonavicular joint, 5. Congruence of the medial longitudinal arch, 6. Abduction/adduction of the forefoot on the rearfoot. Each criterion was valued with one of the following values: -2 (highly supinated), -1 (supinated), 0 (neutral), +1 (pronated), +2 (highly pronated), and summated to calculate the FPI value for each foot, ranging from -12 (highly supinated) to +12 (highly pronated) (Redmond, 2005). The assessment of each subject took approximately 2 minutes to complete. FPI values ranging from +1 to +7 were considered normal (Redmond, Crane & Menz, 2008).

Measurements of the Hip Joint External and Internal Rotation

Bilateral measurements of passive hip external (ER) and internal rotation (IR) range of motion (ROM) were performed according to a standard protocol using a universal goniometer (Jakovljević & Hlebš, 2011). The subject lay prone on an examination table, with the hip in a neutral position (0°) and the knee flexed at 90°. The center of the goniometer was placed over the basis of the patella, its stationary arm parallel to the floor, and the moving arm aligned with the longitudinal axis of the tibia. The leg was passively rotated inward and outward three times by the examiner. The subject's pelvis was manually stabilized against the table by a second examiner to prevent it from tilting and to detect the anatomical limit of joint motion.

Statistical Analysis

Descriptive statistics with means and standard deviations were used to present the demographic characteristics of the groups. The normality of the data distribution was tested using the Shapiro-Wilk test. Since a great majority of the measured parameters were not normally distributed, the non-parametric Kruskal-Wallis test (K-W test) was used to analyze differences in the means of the three groups. In case of an overall significant difference, a post-hoc pairwise comparison of means was made using the Mann-Whitney U test. Spearman's correlation coefficient (ρ) was calculated to evaluate the association between the FPI values and the hip rotational ROM (IR and ER). The significance level was set at $p < 0.05$ for a two-tailed test. All the values are presented as mean ± standard deviation, unless stated otherwise.

RESULTS

The data on the basic characteristics of the sample (age, body height, and weight) and all the measured parameters exhibited non-normal distribution ($p < 0.05$), except for the FPI values in the control group ($p > 0.05$). The soccer group had a significantly lower body weight compared to the handball ($p = 0.024$) and control ($p = 0.033$) groups, whereas no significant differences were detected among the groups for age and body height (Table 1).

Table 1: Basic characteristics of the sample

Variable	Handball (n=17)	Soccer (n=17)	Control group (n=16)	K-W test (p-value)
Age (years)	22.4 ± 3.6	25.9 ± 4.1	25.4 ± 4.1	p = 0.076
Height (cm)	185.7 ± 4.7	183.8 ± 5.0	181.9 ± 5.4	p = 0.142
Weight (kg)	85.7 ± 9.2	78.1 ± 5.9*	86.8 ± 12.6	p = 0.011

Legend: * – Significantly different from both the control and handball groups at $p < 0.05$

The mean FPI values and hip ROMs for all the groups are presented in Table 2. The highest mean FPI was obtained in the control group (1.7 ± 2.5) and the lowest in the handball group (0.7 ± 2.1). There were no significant differences between the three groups ($p = 0.450$).

However, there was a significant difference between the groups in the internal rotation ROM ($p < 0.001$). The pairwise comparison showed significantly lower internal rotation ROM in the group of soccer players (30.6° ± 5.3°) compared to both the handball group ($p < 0.001$) and the control group ($p < 0.001$).

Table 2: Mean values of FPI and hip rotation range of motion

	Handball group	Soccer group	Control group	K-W test (p-value)
FPI value (min / max)	0.7 ± 2.1 (-4 / +7)	1.3 ± 2.9 (-3 / +8)	1.7 ± 2.5 (-3 / +6)	0.450
Hip joint IR (min / max)	41.0° ± 8.1° (25° / 60°)	* 30.6° ± 5.3° (20° / 45°)	41.1° ± 6.4° (30° / 60°)	< 0.001
Hip joint ER (min / max)	39.9° ± 7.1° (25° / 50°)	39.4° ± 7.0° (25° / 50°)	42.2° ± 5.4° (30° / 50°)	0.294

Legend: FPI – Foot Posture Index, IR – internal rotation, ER – external rotation, * – different from the control group and handball group at $p < 0.001$

Table 3: Mean Foot posture Index values by criterion

Criterion	Handball group	Soccer group	Control group	K-W test (p-value)
Talar head palpation	0.03 ± 0.17*	0.38 ± 0.54	0.19 ± 0.53	0.008
Curves above/ below LM	0.21 ± 0.58	0.32 ± 0.58	0.34 ± 0.54	0.628
Inversion/ eversion calcaneus	-0.03 ± 0.57	0.09 ± 0.56	0.25 ± 0.61	0.153
Prominence TNJ	0.03 ± 0.38	-0.06 ± 0.48#	0.28 ± 0.57	0.016
Congruence MLA	0.00 ± 0.64	0.00 ± 0.94	0.19 ± 0.53	0.534
Abd/add forefoot/ rearfoot	0.47 ± 0.61	0.59 ± 0.65	0.44 ± 0.50	0.659

Legend: LM – lateral malleolus, TNJ – talonavicular joint, MLA – medial longitudinal arch, ABD – abduction, ADD – adduction, * – statistically significant difference vs. the Soccer group ($p < 0.05$), # – statistically significant difference vs. the Control group ($p < 0.05$)

A comparison of the six individual clinical criteria of the FPI showed that there were significant differences between the groups for the talar head palpation (p = 0.008) and the prominence of the talonavicular joint (p = 0.016) (Table 3). The pairwise comparison showed significant differences in the prominence of the talonavicular joint between the control group and the soccer group (p = 0.017), and in the position of the talar head between the soccer group and the handball group (p = 0.006).

For soccer players, a weak but significant positive correlation was found between the FPI values and IR (ρ: 0.36, p = 0.035) (Figure 1). No significant correlations were found between any other variables.

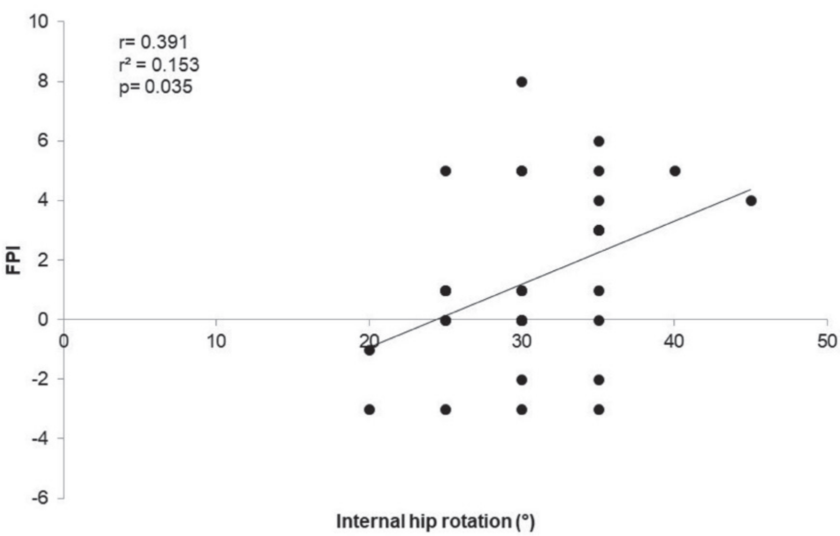

Figure 1: Spearman's correlation coefficients (ρ) between the FPI value and internal hip rotation range of motion in soccer players

DISCUSSION

Our results show that the mean FPI of the soccer players and their non-athlete peers is within the expected normal range (from +1 to +7) for their age (Redmond et al., 2008), while handball players are on the left edge, with a tendency toward a more supinated foot type. However, the observed group differences were not significant. The soccer players had a significantly lower ROM of hip internal rotation than the other two groups, which was also weakly but significantly positively correlated with their FPI values. However, no significant correlation was found between the FPI and hip rotation ROM in handball players and non-athletes.

Compared to the main normative values of the FPI (Redmond et al., 2008), all our participants had lower mean FPI values (i.e. less pronation) than expected as has been shown to be the case in the healthy non-athletic adult population (aged 18-59 years; mean FPI = 4). The reason for this cannot be fully established, but some reasonable assumptions can be made. Based on the FPI data published by Scott, Menz, and Newcombe (2007) showing lower foot pronation in young adults (aged 20.9 ± 2.6 years; FPI = 2.54 ± 2.35) than in older people (aged 80.2 ± 5.7 years; FPI = 4.14 ± 3.86), it could be hypothesized that the lower foot pronation in our sample is due to their younger age. However, the more representative normative data from Redmond et al. (2008) do not support this hypothesis. On the contrary, their data show that the FPI scores exhibit a U-shaped relationship with age, i.e., greater foot pronation in minors under the age of 18 (mean FPI = 6) and again at older ages (mean FPI = 5) (Redmond et al., 2008). Thus, a more plausible explanation for the difference could be the difference in training status, as our sample consisted of elite athletes, whereas the normative data of Redmond et al. (2008) was based on a sample of non-athletes. It appears that the FPI decreases toward a less pronated or even supinated foot posture in people with different foot pathologies (Redmond et al., 2008). Since soccer and handball players are exposed to the daily overloading of their feet during their sporting activities, they might develop a pre-pathological decrease in foot pronation. This could also be the case in our control group, whose activity level we do not know exactly. Although the subjects did not exercise several times a week, their activity level was most likely higher than the average of the non-athlete population used in Redmond et al. (2008). In addition, there may be other unknown specific characteristics of our control group that we did not identify but that influenced the FPI results.

Although not significant, both the soccer and handball players showed a tendency to have less pronated feet than the control group. Handball players even showed a tendency to a supinated foot posture, while the other two groups showed a tendency to a more normal (i.e. slightly pronated) foot posture, which is almost consistent with the published FPI data from different sports (Table 4), including handball (Martínez-Nova et al., 2014) and soccer players (Lopezosa-Reca et al., 2018). Martínez-Nova et al. (2014) speculated that this could be due to the constant rotations/pivoting and lateral displacements that cause inversion moments in the knee and hip joints of handball players. As shown in Table 4, there are large differences in FPI between sports. The difference is most pronounced in swimmers with highly pronated feet (FPI = 6.5 ± 2.0, Table 4). The intensity and pattern of mechanical loading on the feet of swimmers are the opposite of the forces generated in the feet of handball players or soccer players. Swimming is a non-weight-bearing activity under conditions of reduced gravity with essentially non-existent longitudinal compressive forces in the foot, which significantly reduces the need for muscle activity in the lower leg and foot. Liebenberg et al. (2011) have shown this by measuring the EMG amplitude of the lower limb muscles during running, which decreased linearly with the decrease in body weight transferred to the lower limbs.

Table 4: FPI values in various sports practitioners reported in the literature

Study	Sport	Age	Mean FPI
Kuo & Liu, 2017	basketball, volleyball, badminton, tennis	22.0 ± 3.0	3.5 ± 3.0
Cherati et al., 2016	futsal	22.1 ± 3.6	right foot: 4.9 ± 2.9 left foot: 4.7 ± 3.1
Martínez-Nova et al., 2014	basketball	32.1 ± 8.9	3.9 ± 4.1
	running	40.2 ± 7.3	2.9 ± 2.8
	handball	21.8 ± 3.2	-0.4 ± 6.9
Lopezosa-Reca et al., 2020	basketball	22.5 ± 3.9	2.7 ± 3.1
De Groot et al., 2012	volleyball	26.0 ± 5.5	4.0 ± 3.5
Lopezosa-Reca et al., 2018	swimming	17.2 ± 1.7	6.5 ± 2.0
	soccer	17.3 ± 1.0	2.3 ± 1.7

Handball players have been shown to have an increased risk of hip joint damage due to the repetitive and intense loading of the joint beyond the physiological limits of the cartilage that occurs in handball (L'Hermette et al., 2006). It has been shown that retired handball players (age 44.9 ± 4.7 years) have a lower ROM of the hip IR (16° ± 8°) compared to non-athletes of the same age

(IR = 23° ± 4°), most likely due to osteoarthritic changes in the hip joint caused by years of handball training (L'Hermette et al., 2006). We found no difference in hip rotation ROM in handball players compared to non-athletes, but our sample was much younger compared to participants in the study conducted by L'Hermette et al. (2006). However, we found a significantly lower ROM of passive IR of the hip in soccer players who are also exposed to specific overloads of the hip joint during soccer (Nunome, Asai, Ikegma, & Sakurai, 2002). Frequent lateral side-foot kicks, where the ball is kicked with the medial side of the foot, may cause repetitive exaggerated hip external rotation moments in the final phase of the kicks. This requires chronic overactivity, high muscle tone, and shortness of the external rotators of the hip, which can lead to a reduction of the internal rotation ROM and can have a long-term negative effect on the hip joint. The repetitive nature of movements that are specific to handball can lead to long-term alterations in the hip ROM, i.e. lower flexion and internal rotation and higher abduction, extension, and external rotation, and have been shown to have a strong association with an increased risk of developing premature hip OA in retired handball players (L'Hermette et al., 2006). Furthermore, lower hip internal and external rotation ROM have been shown to increase the risk of adductor strain in professional soccer players (Ibrahim, Murrell & Knapman, 2007).

A direct comparison of the ROM values of hip rotation among different studies is complicated not only by the age difference of the samples, but also by differences in hip position during goniometric measurements. Hip goniometry performed in the prone position with the hip extended has been reported to yield higher values than measurements performed in the seated position with the hip flexed (Han, Kubo, Kurosawa, Maruichi, & Maruyama, 2015; Hollman, Burgess & Bokermann, 2003). The review of data from some other studies, presented in Table 5, shows significant variability in the ROM of hip rotations acquired in a seated or supine position in athletes of different ages, so no clear conclusion can be drawn in this regard.

In the present study, no significant correlations were found between the FPI and hip rotation ROM, except for a weak but significant positive correlation between the FPI and hip internal rotation in soccer players. This is consistent with the findings of Souza, Pinto, Trede, Kirkwood, and Fonseca (2010), which suggest that there is a temporal coupling of rearfoot pronation with hip IR during walking. The fact that the pronation of the foot was only associated with hip IR in soccer players who also exhibited reduced ROM of the IR suggests that the tightness of the hip external rotators may have some influence on foot position. Coaches, kinesiologists, and physiotherapists should pay more attention

Table 5: Range of motion of the internal (IR) and external (ER) hip rotation in various sports practitioners

Study	Group	Age (years)	Body position	IR Hip Joint	ER Hip Joint
Hogg et al., 2018	basketball	19.4 ± 1.3	prone	28.7° ± 9.5°	39.9° ± 12.7°
	cross-country skiing			32.6° ± 7.2°	28.5° ± 6.2°
	golf			27.9° ± 7.7°	34.3° ± 6.0°
	soccer			26.2° ± 8.4°	35.3° ± 12.9°
	softball / baseball			29.4° ± 6.9°	34.5° ± 6.4°
	tennis			26.6° ± 8.9°	43.0° ± 11.6°
Hollman et al., 2003	running	36.6 ± 12.1	prone	50.3° ± 6.1°	43.0° ± 8.3°
			sitting	43.8° ± 4.7°	33.1° ± 5.2°
Kouyoumdjian et al., 2012	general population	39.1 ± 10.8	prone	35.3° ± 11.9°	41.8° ± 10.2°
			sitting	37.9° ± 8.4°	40.7° ± 7.6°
López-Valenciano et al., 2019	soccer	25.5 ± 5	prone	47.1° ± 8.0°	49.9° ± 9.8°

to the mobility of hip rotation in soccer players and take preventive measures to reduce the overuse of the external rotators.

Methodological Limitations and Suggestions for Future Research

Some methodological limitations of our study need to be considered when interpreting our results. First, all the differences in FPI observed between the three subject groups were not significant, so no firm conclusions can be drawn about the influence of a particular sport on foot posture. Secondly, the small sample size hinders statistical power and thus reduces the sensitivity for detecting small changes in the mean values or weak correlations between the measured parameters. In future studies, larger and more representative samples should be drawn from different sports clubs. To increase the sensitivity for detecting correlations between hip ROM and foot posture, the sample should also include participants with pathological foot posture. Third, only goniometric measurements of the passive rotational ROM with the hip extended were used, which may not be fully representative of functional hip motion. In future studies, active ROM measurements should be used in both seated (with flexed hip) and prone positions and, if possible, combined with more complex biomechanical analyses of the hip, knee, ankle, and foot ROM during sport-specific activities. In addition, information on the use of orthotic insoles by athletes to correct their feet should be systematically collected and used as a covariate in future studies, as their influence on foot posture may be significant.

CONCLUSIONS

No significant differences were found in the Foot Posture Index between handball players, soccer players, and non-athletes. Handball and soccer players show a tendency toward less pronated feet compared to non-athletes, but the differences are not significant and the mean FPI values are still within the range of normal foot posture. The soccer players had significantly less hip internal rotation than the other two groups, which was also weakly but significantly and positively correlated with their FPI values. These results may serve as a guide for future studies of subgroups of athletes with pronounced postural defects of the feet. As it has previously been shown that a limited internal rotation of the hip joint also increases the risk of hip adductor injuries, further research is needed in this regard. Future studies should also use measurements of the active hip ROM or even more complex biomechanical analyses of the hip, knee, ankle, and foot ROM during sport-specific movement patterns.

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