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Pedobarographic differences between female soccer players and sedanteries during barefoot walking and bilateral stance

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Abstract

The athletic function of the foot is also extremely important in soccer and constantly exposed to the full impact of weight bearing, because it plays a vital role as a contact point with the ground, absorbing abnormal forces, and main area of the body to kick the ball. The purpose of this study was to compare female soccer players and sedentary individuals in terms of plantar pressure distribution while walking and bilateral standing with barefoot. Eleven female soccer players (21.44±2.12 years, 162.25±5.77 cm, 53.12±6.01 kg, BMI=20.23±1.52 kg/m2, Experience=5.98±0.78 years) and 14 sedentary individuals (23.38±5.79 years, 164.92±5.88 cm, 56.31±6.56 kg, BMI=20.67±1.78 kg/m2) participated in this study. Participants performed self-paced walking and 30 seconds bilateral standing on a 1.5-meter walking platform with barefoot. Each footprint was divided into 12 areas as total foot, hindfoot, midfoot, forefoot, 1st metatarsal, 2nd metatarsal, 3rd metatarsal, 4th metatarsal and 5th metatarsal, big toe, second toes and toes 3-4-5. Maximum force [MF (N)], peak pressure [PP (kPa)], contact area [CA(cm2)], mean pressure [MP (kPa)] and maximum force normalized to body weight [MFNBW (N)] plantar pressure values were analyzed with Mann-Whitney-U test. Results indicated that sedentary group showed significantly higher CA in the forefoot, 3rd and 4th metatarsals; MF in 4th and 5th metatarsals; MP in 5th metatarsal, $p<0.05$. On the other hand, soccer players demonstrated significantly higher MP in the forefoot, 2nd and 3rd metatarsals and PP in 2nd and 3rd metatarsals, $p<0.05$. This study indicates that soccer players and physically inactive sedentary individuals demonstrate different plantar pressure patterns during gait and bilateral stance. Coaches and athletic trainers should consider these different patterns while planning intervention protocols.

Keywords: Pedobarography, plantar pressure, soccer, female athletes

INTRODUCTION

The foot is constantly exposed to full impact of weight bearing, because it plays vital role as contact point with ground, absorbing abnormal forces, and main area of body to kick the ball in soccer (Ozer et al., 2012). The athletic function of the foot is also extremely important as it is important to maintain posture and balance during walking, running, and movements related to agility and jumping. It has been previously reported that most of the injuries on the foot are associated with repeated, excessive plantar pressure (Mueller, 1995). Foot injuries represented between 6 -7 % of in game injuries among soccer players (Hawkins et al., 2011; Junge et al., 2012) and Sobhani et al., (2012) indicated that soccer is most commonly researched sport in terms of foot injuries. While it may be expected that athletes who participate in regular soccer exercises would enhance foot function in athletic tasks, overuse of foot and configuration of the soccer footwear are the two main reasons causing non-contact foot injuries.

Knowles et al. (2006) and Philips (2000) emphasized that exposure of force per hour or minute is the most appropriate method to express the incidence rate of injuries. Therefore, undergoing extremities to forces repetitively may lead to overuse injuries. The most prevalent foot injuries related to overuse are Achilles tendon pathology and stress fractures of the foot (Paavola et al., 2002). To illustrate fifth metatarsal fractures in soccer was associated with overuse (Shuen et al., 2009). Moreover, Eils et al. (2004) indicated that soccer specific movements lead to loading forces to heel region of the foot. Nunns et al. (2016) suggested that these injuries caused by repetitive forces in soccer may lead to temporary weakening of the structure of foot. Thus, injuries related to overuse of foot might affect the daily life and sport performance of athletes.

Biomechanical researches focused on (I) various footwear (Bentley et al., 2011; Carl et al., 2014; Urabe et al., 2014) (II) shoe inserts (Nunns et al., 2016) and (III) soccer-related movements with various footwear (Girard et al., 2011; Wong et al., 2007) to prevention of foot injuries (Jordan & Barlett, 1995). Diversities in shape, materials and thickness of insoles of soccer footwear may lead to change in plantar pressure distributions and this is especially important to reduce excessive loads on foot during athletic performance (Santos et al., 2001). Santos et al. (2001) demonstrated that soccer footwear increases lateral forefoot loading comparing to running shoes. Insufficient information on effect of exercises and sport specific footwear does not allow comprehending the effect of these factors on daily routines of athletes. As athletes spend genuine time on practices and games, their foot are expected to be exposed to excessive forces comparing to sedentary individuals. However, there is still lack of study investigating whether regularly participating soccer practices and wearing soccer specific footwear make any difference to individuals' plantar distribution in daily routines such as walking and standing with bare foot compared to sedentary individuals who never experienced soccer practice and footwear. Therefore, the purpose of this study was to compare female soccer players and sedentary individuals in terms of plantar pressure distribution while walking and standing with bare foot to explicate long-term effect of soccer and soccer footwear on daily movements. Based on the literature, we hypothesized that plantar pressure values of the dominant and non-dominant foot would be different in soccer players during walk test and bilateral stance comparing to sedentary individuals in selected areas of foot.

METHOD

Study design

Cross-sectional study design was implemented in this research. Maximum force [MF (N)], peak pressure [PP (kPa)], contact area [CA(cm^2)], mean pressure [MP (kPa)] and maximum force normalized to body weight [MFNBW (N)] plantar pressure values of the dominant and non-dominant foot were dependent variables and being in a soccer group or control was the independent variable of this study. Ethical approval was obtained from Ethical Board Commission of Osman Gazi University (Protocol No.:80558721/175).

Participants of the Study

In total, 25 participants voluntarily completed this study. Soccer group (SG) consisted of 11 female soccer players (21.44±2.12 years, 162.25±5.77 cm, 53.12±6.01 kg, BMI=20.23±1.52 kg/m^2, Experience=5.98±0.78 years). Participants reported that they are completing at least 4 training sessions per week. Moreover, a soccer player who was previously injured in lower extremities (i.e., foot, ankle and knee) was excluded from the study for maintaining internal validity. On the other hand, control group (CG) consisted of 14 sedentary individuals (23.38±5.79 years, 164.92±5.88 cm, 56.31±6.56 kg, BMI=20.67±1.78 kg/m^2). Inclusion criteria for control group were to have physically inactive life style (i.e., <60 mins physical activity per week) and had no athletic background. One of the participants in the control group was excluded from the study because of active life style, reported by International Physical Activity Questionnaire which was found valid and reliable in Turkish language (Saglam et al., 2010). All participants provided informed consent forms. Foot dominance was determined according to kicking feet. Right foot was dominant limb of all participants.

Data Collection Protocol

Measurements were applied in two different conditions (condition I: dynamic walking; condition II: bilateral stance). Participants performed self-paced walking on 1.5-meter walking platform (Emed, Novel GmBH, Germany) with bare foot. Walking protocol consisted of 5 trials (Bosch and Rosenbaum, 2010). Then, participants performed 2 unilateral stances for 30-seconds with 2 minutes resting time between trials (Fernandes et al., 2015). Familiarization protocols were conducted for dynamic walking and static balance tests. Data were collected at 100 Hz sampling frequency. Each foot print was divided into 12 areas as total foot, hindfoot, midfoot, forefoot, 1st metatarsal, 2nd metatarsal, 3rd metatarsal, 4th metatarsal and 5th metatarsal, big toe, second toes and toes 3-4-5 with Multimask software (Novel GmBH, Germany). From each of the observed parts of foot, the following parameters were evaluated (Emed System Manual v.23):

- *Maximum force* [PF(N)] was the peak force on the total foot or region.
- *Peak pressure* [PP(kPa)] was the maximum pressure value on the total foot or region.
- *Contact area* [CA(cm^2)] was the maximum contact area during stance.
- *Mean Pressure* [MP (kPa)] was the ratio of the sum of peak pressures under the sensors to the number of loaded sensors.

Statistical Analyzes

Five trials were averaged automatically by the Emed software for each mask of each foot for dynamic walking test. The data obtained from the second attempt of the static balance stance were used in statistical analyzes. All dependent variable values (MF, PP, CA, MP, and MFNBW) were recorded separately for each masks and foot. Parameters of the foot geometry were also observed as hallux angles (HA), arch indexes (AI), display of each frame in rollover process (ROP%) and foot lengths (FL).

Mean and standard deviations were calculated for demographic information regarding each of the participants. Before the statistical analysis, all of the measures were found to be distributed non-normally based on the Shapiro-Wilk test. It was examined whether there were any statistically significant differences between the experimental and control groups' means by using Mann Whitney-U test in dynamic walking test and bilateral stance according to distribution of normality. The data were analyzed using SPSS Statistics 20.0 (SPSS, Chicago, IL). In the measurements 95% reliability range and $p<0.05$ were accepted as significance level.

RESULTS

Totally 50 feet of 25 participants were investigated. Twenty-two of the feet belonged to SG and other 28 to CG. Mann Whitney-U test indicated that there were no significant differences in age, weight, height and BMI values between groups ($p>0.05$). Similarly, no significant differences were observed for hallux angles (HA), arch indexes (AI), display of each frame in rollover process (ROP%) and foot lengths (FL) values between groups (Table 1).

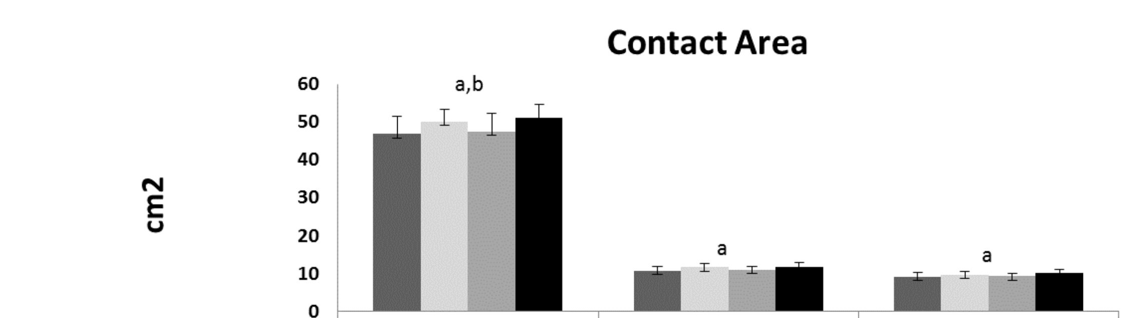
Table 1. Female soccer players' and sedentary individuals' demographics of dominant and non-dominant foot

Foot Geometry Parameters	Non-Dominant Foot			Dominant Foot		
	SG	CG	p	SG	CG	p
FL	24.59±0.95	25.30±1.37	0.232	24.58±1.06	25.53±1.24	0.088
AI	0.23±0.04	0.22±0.05	1.000	0.22±0.06	0.23±0.03	0.927
HA	4.13±3.14	4.56±3.27	0.784	3.60±2.69	3.94±2.43	0.693
ROP%	94.09±2.21	94.88±2.01	0.343	95.63±2.63	95.06±2.10	0.208

FL: Foot Length (cm); **AI:** Arch Index; **HA:** Hallux Angle (degree); **ROP%**: Rollover Process

Dynamic Walking Test
Contact Area
Forefoot:
For fore foot mask, results indicated that CG demonstrated significantly higher CA comparing to SG, in dominant foot [(SG= 47.47±4.75), (CG= 51.08±3.66), p= 0.049] and non-dominant foot [(SG= 46.76±4.77), (CG= 50.09±3.17), p= 0.026].

Metatarsals:
Significant differences were also observed for CA in dominant foot [(SG= 10.84±1.08), (CG= 11.80±1.07), p= 0.042] for 3rd metatarsal mask. Contact Area results were also significantly different between groups for 4th metatarsal mask in dominant foot [(SG= 9.21±0.77), (CG= 10.12±0.88), p= 0.021].



	Forefoot	3rd Metatarsal	4th Metatarsal
Soccer Players Non-dominant	46,76	10,6	9,11
Sedantery Group Non-dominant	50,09	11,58	9,59
Soccer Players Dominant	47,47	10,84	9,21
Sedantery Group Dominant	51,08	11,8	10,12

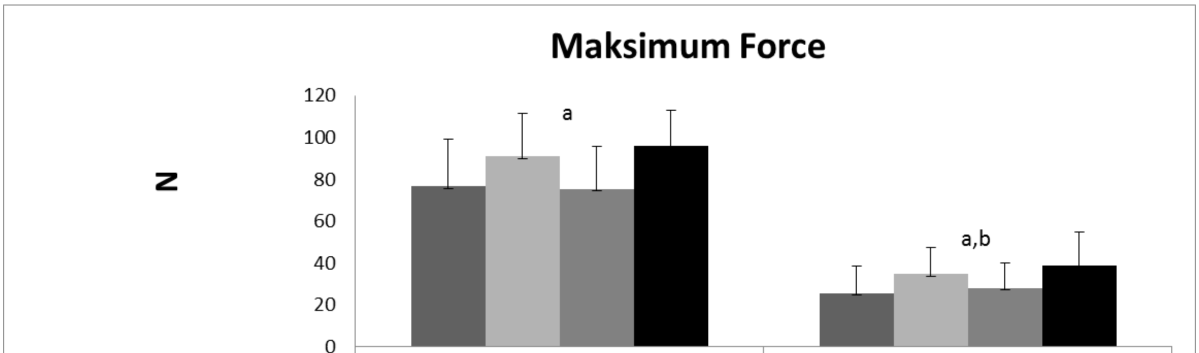
a: Differences between dominant foot of soccer players and control group
b: Differences between non-dominant foot of soccer players and control group
$p<0.05$

Figure 1. Contact area differences between during walking test

Maximum Force

Metatarsals:

Maximum force [(SG= 75.33±20.56), (CG= 95.74±17.27), p= 0.036] values were significantly different for 4th metatarsal mask in dominant foot. Similarly, CG demonstrated significantly higher MF in both dominant [(SG= 28.05±12.03), (CG= 39.00±16.01), p= 0.036] and non-dominant foot [(SG= 25.68±12.87), (CG= 34.66±12.86), p= 0.012] for 5th metatarsal mask.



	4th Metatarsal	5th Metatarsal
Soccer Players Non-dominant	76,63	25,68
Sedantery Group Non-dominant	90,81	34,66
Soccer Players Dominant	75,33	28,05
Sedantery Group Dominant	95,74	39

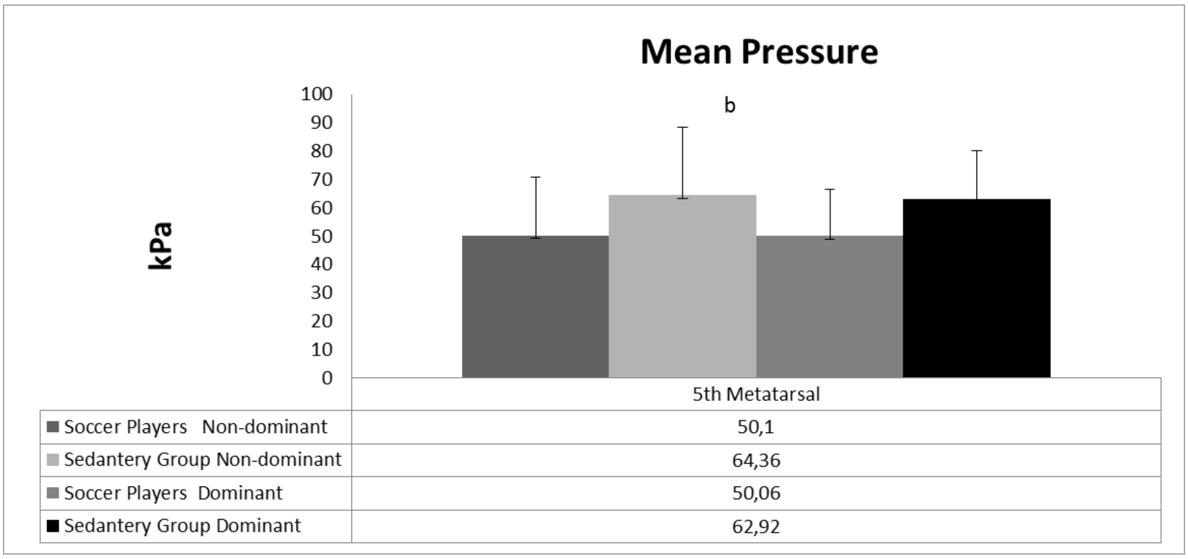
a: Differences between dominant foot of soccer players and control group
b: Differences between non-dominant foot of soccer players and control group
$p<0.05$

Figure 2. Maximum force differences during walking test

Mean Pressure

Metatarsals:

Finally, MP results were also significantly different between groups in non-dominant foot [(SG= 50.10±20.77), (CG= 64.36±23.93), p= 0.049] for 5th metatarsal.



b: Differences between non-dominant foot of soccer players and control group
p<0.05

Figure 3. Mean pressure differences during walking test

Bilateral Stance Test

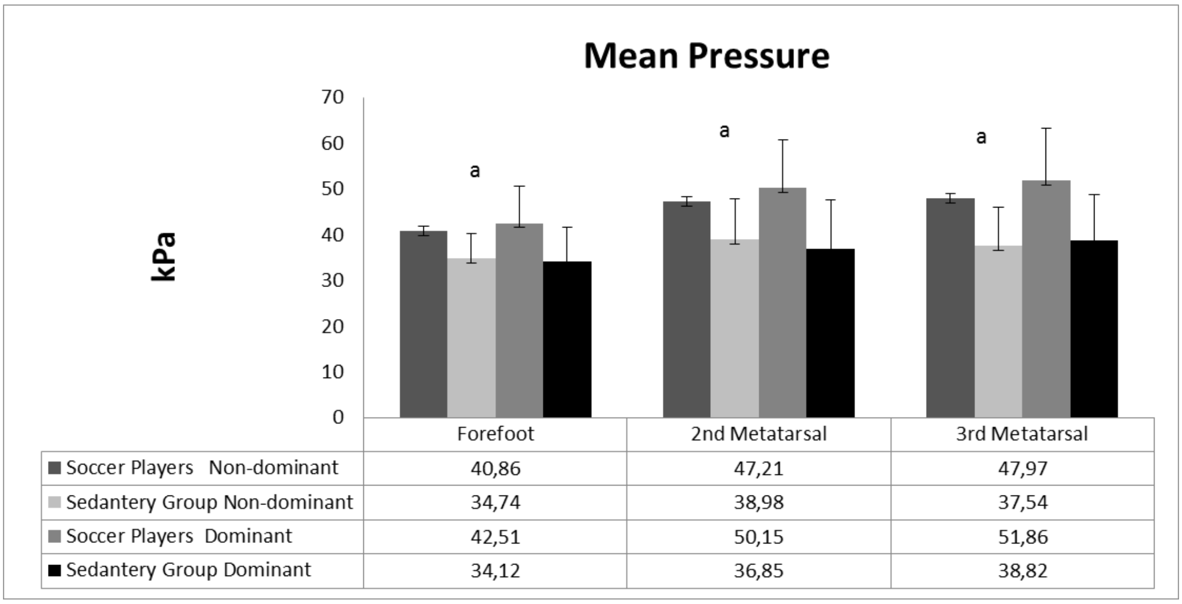
Mean Pressure

Forefoot:

For forefoot mask, SG (42.51±8.10) significantly higher than CG (34.12±7.58) in MP for dominant foot, (p=0.042).

Metatarsals:

For dominant foot MP [(SG= 50.15±10.59), (CG= 36.85±10.74), p= 0.031] values were significantly different in 2nd metatarsal. Similarly, MP values in 3rd metatarsal were different in dominant foot [(SG= 51.86±11.65), (CG= 38.82±9.88), p= 0.042].



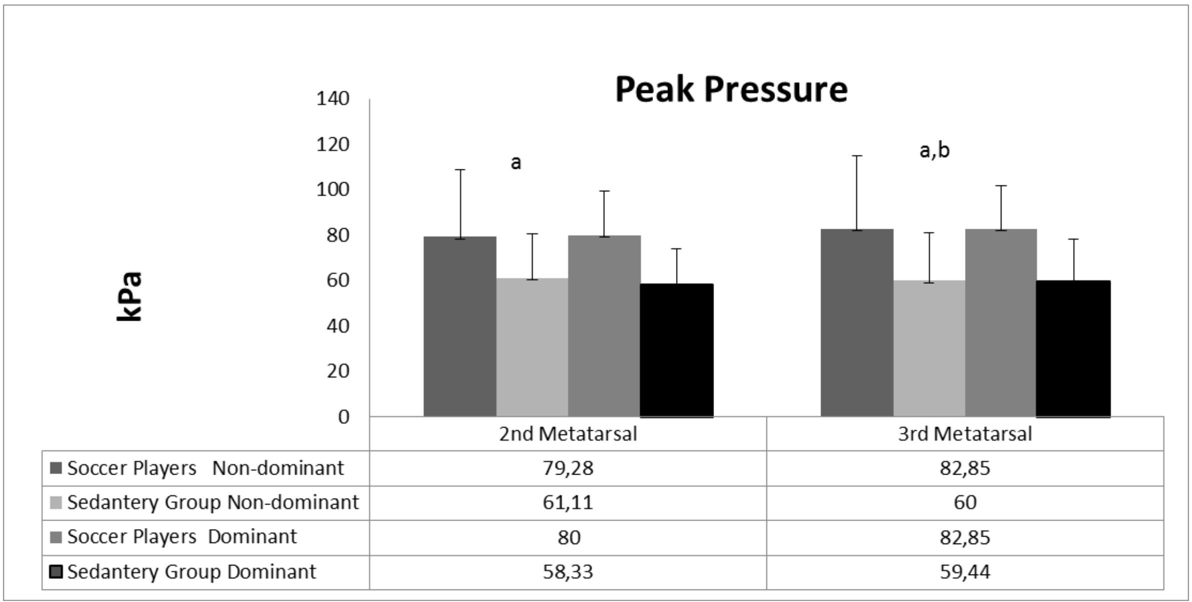
a: Differences between dominant foot of soccer players and control group
p<0.05

Figure 4. Mean pressure differences during bilateral stance

Peak Pressure

Metatarsals:

Soccer group demonstrated significantly higher PP [(SG= 80.00±19.36), (CG= 58.33±15.61), p= 0.031] 2nd metatarsal in dominant foot. For 3rd metatarsal mask, PP values were also significantly different between groups for both dominant [(SG= 82.85±18.89), (CG= 59.44±18.61), p= 0.042] and non-dominant foot [(SG= 82.85±32.25), (CG= 60.00±21.06), p= 0.042].



	2nd Metatarsal	3rd Metatarsal
Soccer Players Non-dominant	79,28	82,85
Sedantery Group Non-dominant	61,11	60
Soccer Players Dominant	80	82,85
Sedantery Group Dominant	58,33	59,44

a: Differences between dominant foot of soccer players and control group
b: Differences between non-dominant foot of soccer players and control group
$p<0.05$

Figure 5. Peak pressure differences during bilateral stance

DISCUSSION

In this research MF, PP, CA, MP and MFNBW values of female soccer players were examined in twelve selected areas of the foot and compared to sedentary controls for both dominant and non-dominant foot separately. The main purposes of this examination and comparisons were to evaluate the effects of regular soccer participation on plantar distribution as foot function in daily activities such as walking and stance. Although previous studies examined pedobarographic differences between female soccer players and sedentary individuals during barefoot walking (Uzun et al., 2013), there was no study examined differences during static stance.

One of the main finding of this study was sedentary individuals' demonstrated higher CA in their both dominant and non-dominant foot for forefoot mask and in dominant foot 3rd and 4th metatarsals comparing to SG during self-paced walking. A possible explanation of these results could be attributed to soccer specific movements. Eils et al. (2004) highlighted that plantar pressure is significantly increasing in medial heel, medial forefoot, big toe and metatarsal heads during running movement in soccer players with boots. As pressure variable increases with decreasing contact area surface, the significant differences during dynamic condition can be explained by soccer specific training effects. Thus soccer specific movements may lead to decrease in contact surface in some specific areas of the foot such as metatarsal heads. Secondly, Santos et al. (2001) highlighted (I) football boots are cut narrower comparing to regular shoes to improve control feeling in the soccer field and (II) soccer players are generally reported that they use 1 size smaller football boots comparing to other shoes. To illustrate, their results indicated that the contact area with the soccer boots was 7.2 % less comparing to trainers, in dominant foot. Another explanation of significant CA differences between SG and CG attributed to foot arch index. Although it is not significant CG group foot arch index is higher than SG which indicates CG group is closer to pes planus (Cavanagh & Rodgers, 1987). Therefore, similar to our results, Queen et al. (2009) indicated that a participant with pes planus demonstrates higher contact area during different athletic tasks.

Another main finding of this study was that MF variable was significantly higher in CG group comparing to SG in 4th metatarsal of dominant feet and 5th metatarsal of both foot during dynamic walking test. Fourth and fifth metatarsals are placed in lateral side of the foot; however, literature has demonstrated that soccer specific movements predominantly load forces to medial side of the foot (Eils et al., 2004; Wong et al., 2007). In addition, Shuen et al. (2009) and Jacquot et al. (2005) highlighted that fifth metatarsal fracture is highly in common among soccer players because of overuse of this area. Therefore, soccer players might behave protective on those sensitive areas which are prone to injury because of overuse. The mean pressure differences in 5th metatarsal head might me related to this possible explanation as well.

Other important observations were the MP and PP differences between CG and SG. In bilateral stance SG demonstrated significantly higher MP on dominant foot for forefoot mask, 2nd and 3rd metatarsals. Moreover, SG demonstrated significantly higher PP in both foot for 2nd and 3rd metatarsals. One of the possible explanations might be related to joint laxity. Barber Foss et al. (2009) has demonstrated that joint laxity is attributed to higher plantar loading in medial side of the foot among female athletes. Similar to results of current study, their study indicates that female athletes with joint laxity demonstrated higher PP and MF in medial side of both dominant and non-dominant foot. Ferrari and Atkinson (2005) reported that joint laxity is more pronounced among girls compared to boys. Another explanation of might be attributed to soccer boots. Notwithstanding they had measured athletes with the regular soccer boots, Uzun et al. (2013) indicated that female soccer players demonstrated higher pressure in inner part of their forefoot comparing to control group. In line with our results, they have concluded that long term participation in soccer may lead to change in foot structure which can create different pressure distribution values in different areas of the foot among female soccer players.

This study has some methodological limitations. First of all, considering the different type of soccer boots cause different pressure distribution in various areas of the foot (Nunns et al., 2016), our SG group reported that players use different types of soccer boots. Secondly, this study could not consider the methodological limitation of large sample size. Finally, the experience level of soccer players could be considered as moderate, as more experience level is expected to more structural change in foot structure. With regard to results and limitations of this study, professional participation in soccer exercises and matches may lead to structural changes in foot such as, joint laxity and highly common metatarsal stresses. These changes might affect the soccer player's athletic and daily life in long term with respect to injuries. Instantaneous feedback practices with shoe insoles should be considered for coaches and researchers to refrain from unexpected injuries caused by overuse leaded changes in foot structure and plantar distribution. Moreover, guiding athletes to select proper soccer boots also suggested in order reducing injury risk and obstacles caused by repetitive loads in athletic tasks.

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