ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 8, pp. 13004-13011, August, 2016

International Journal of Recent Scientific Research

Research Article

HIGHER PLANTAR PRESSURES ON THE MEDIAL SIDE OF FOOT IN ELITE SOCCER PLAYERS DURING STATIC STANDING AND WALKING

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ARTICLE INFO

Article History:

Received 05th May, 2016
Received in revised form 08th June, 2016
Accepted 10th July, 2016
Published online 28st August, 2016

Key Words:

Elite soccer players, subelite soccer players, arch index (AI), plantar pressure distributions (PPD), pronated foot.

ABSTRACT

Objective: The purpose of this study is to investigate the plantar pressure characteristics, foot types and the possible pain profiles in the elite soccer players during static standing and walking.
Methods: Research participants were divided into three groups as follows: 22 male elite college soccer players (ES), 28 male subelite college soccer players (SS) and 32 male sedentary controls. In the research, JC Mat (View Grand International Co., Ltd., Taiwan) optical plantar pressure analysis system was applied to examining whether there were statistically significant differences in the arch index (AI), regional plantar pressure distributions (PPD) and footprint characteristics among three groups. The ES' pain profiles were examined for evaluating their common pain areas.
Results: According to the findings from the ES, their AI fell into the normal range and their static PPD of both feet was higher at the medial metatarsal bone and the medial heel. Yet, their PPD was mainly transferred to the medial metatarsal bone followed by the medial heel of both feet during the midstance phase of walking. The results showed that the ankle joint and the biceps femoris were the most common musculoskeletal pains in the ES.
Conclusion: On the basis of the findings, the ES' AI could be classified as normal arches and their PPD tended to parallel the features of pronated feet. The pain profiles appeared to consist with the symptoms of foot pronation. The findings revealed the possible relationships between foot pronation and soccer players, and the correlation is worth further studies.

INTRODUCTION

Soccer is a high intensity contact sport and characterized as quick starts and stops, rapid running and pivoting, instant cutting and turning, heading and kicking of the ball [1, 2]. Previous research has indicated that overload injuries are a common problem in soccer [3]. Most soccer injuries were located in the lower extremities [4]. The ankle, knee, upper leg, groin, hip and foot were the most frequently injured parts in the body [2, 5].

In general, the arch index (AI) measurement from footprint can be treated as a reliable and valid method to characterize the structures of the foot [6]. Morphology of the AI greatly influences dynamic foot function [7] and possible development of musculoskeletal pathology [8]. Assessment of static arch mobility, associated with the lower extremities and footprint measures, appeared to be put at the core of understanding the overall function of the foot and lower extremities during running [9]. In addition, the growing evidence suggests that foot structures influence plantar pressure distribution (PPD) during walking [10, 11]. It was anticipated that exploring the pressures in the soles in soccer players' movement was crucial not only for footwear design, but also for the studies of prevention and rehabilitation of the pressure areas in the soles [12].

Plantar pressure assessment of footprint is one of the effective methods to evaluate the plantar loading characteristics during functional activities [13]. The parameters can be used to reveal the relations between the multi-segmented foot structure and foot function, [14] and assist in detecting the foot pathologies [15]. Moreover, the parameters are significant for preventing, treatment and rehabilitation of the deformities which could occur in the foot [16]. In addition, static plantar pressure measurement is considered to be useful to address many questions regarding the association between PPD and lower-extremity posture. Hence, the measurement techniques are useful for understanding the biomechanics of human feet in bipedal standing [17].

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Plantar pressure has been examined mostly during adult walking and running in the available literature [18-20]. The peak pressure and relative load during soccer-specific movements as well as on soccer-specific playing surfaces were discussed in previous studies [12, 21-23]. In contrast to much information that is available on examining PPD patterns during activities, few studies have examined soccer players' plantar loading characteristics during standing. To compare the difference between static PPD and results with those of the previous studies, therefore, the purpose of this study is to explore the arch index, three regional PPD (forefoot, midfoot and rearfoot), six distinct sub-regional PPD and the footprint characteristics of both feet among the male elite college soccer players (ES), the male subelite college soccer players (SS) and the male healthy individuals during static standing and walking on bare foot. Moreover, all ES' pain assessment and self-reported health status were examined and questioned for accurately evaluating the pain areas which occurred frequently in the body. We hypothesized that there were statistically significant differences in the plantar pressure characteristics and foot types among three groups.

METHODS

Subject Selection

The study included three groups of college and university students in Taiwan. One of the groups, labelled as the 'elite soccer group (ES)', was composed of 22 first-division male soccer players. All subjects within the ES group in this study were current members of the college and university soccer team and the length of being the qualified first-division players is to have more than successive eight-year experiences in soccer competitions. Their routine training included: doing agility/sprint training on Monday and Thursday, doing weight training on Tuesday and Friday, and doing interval endurance/cardiovascular training, coupled with short sprint, 3 days per week. The 'subelite soccer group (SS)' consisted of 28 male soccer players who were the same age range (between 18 and 21 years old) as the ES group. All subjects in the SS group were eligible whether they were single-sport athletes who participated only in team-based soccer training. They were playing soccer at least once a week at the football field. The sedentary controls were 32 healthy age-matched male university students who had neither specialties in sports nor regular time for exercise (the average time for exercise weekly was less than 2 days or 6 hours).

Table 1 Demographic characteristics and training experience in elite soccer (ES), subelite soccer (SS) players, and controls.

Demographics	Control	ES	SS
Numbers	32	22	28
Age (years)	20.0 ± 1.0	20.3 ± 0.8	19.4 ± 1.2
Height (cm)	173.0 ± 3.6	179.0 ± 3.3	175.7 ± 3.7
Mass (kg)	68.7 ± 3.9	76.3 ± 2.5	72.9 ± 3.6
BMI	23.0 ± 1.2	23.8 ± 0.3	23.6 ± 0.5
Experience (years)	---	8.9 ± 0.7	6.8 ± 0.9

Data are represented as mean ± SD. The control group: male university students who had neither specialties in sports nor regular time for exercise (the average time for exercise weekly was less than 2 days or 6 hours). The elite soccer group: first-division male soccer players. The subelite soccer group: single-sport athletes who participated only in team-based soccer training (playing soccer at least once a week at football field).

Each subject's age, height, body weight and body mass index (BMI) were recorded in the research process. Considering the effect of the body weight on shape characteristics of the foot arch, each subject's BMI within this research was required to range between 18.5 and 24 and this particular range was defined by the World Health Organization (WHO) as healthy weight. A total of 82 subjects participated in this study, and their average age, height, weight and BMI value were shown in Table 1.

All subjects' pain and health assessments were based on the self-reported health status and measurements which were diagnosed by the professional physiotherapist at the rehabilitation department. The pain and health assessments were essential for this research to ensure that all subjects had no history of previous fracture and surgery, and that they were free from injuries in their foot, ankle joints, knee joints, hip joints, spine, bones and muscles of lower limbs, and free from neurological disease and peripheral neuropathy within a year as this study was underway. Prior to the experiments, all participants were informed on the experimental procedure, potential risks and rights to terminate the experiment at any time. Each participant was asked to read and sign the informed consent form approved by the institutional review board. The entire process of the experiments within this study followed the guidelines of the local Ethical Committee and the recommendations of the Declaration of Helsinki.

Instruments and Equipment

The plantar pressure distribution (PPD) was recorded via the 'JC Mat' (View Grand International Co., Ltd., Taiwan). The measurement technology and approaches of JC Mat were similar to the operation principles of Harris footprint measurement instrument. The key attributes of JC Mat were as follows: (1) the subtle characteristics of the foot were easily distinguished; (2) the plantar pressure distribution and footprints coincided with the weight calibration data (data not shown); (3) there were 25 sensors in each square centimeter for the plantar pressure measurement, and thus 13600 sensors were on each side (32*17 cm) of JC Mat; (4) the pressure sensing was sensitive and the scope of the sensor was large. A smooth and delicate plantar pressure image was shown in the form of round dots; (5) the pressure profiles from footprints and barefoot images were captured instantly; and (6) the built-in FPDS-Pro software was competent for analyzing the following parameters: the arch index, plantar pressure values, balance of the center of gravity, toe angles and footprints.

Experimental Design and Procedure

It took approximately five months to select the subjects and conduct the experiments for this study. Before the experiments, all subjects were informed of the purpose and processes of this study and their consent to participate in this research was obtained. For the sake of consistency and trustworthiness of the experiments, time for each experiment was set between 3pm and 5pm. All subjects were required to measure their body weights and heights when the experiments were conducted. This was helpful for recording the basic and accurate data of subjects' physiological conditions in terms of weights and heights. The subjects' weights and heights recorded during the experiments, associated with the given formula (body weight (kg)/height (m^2)), served as the base for calculating the BMI values for this study.

Since the brief trials of the static upright standing were essential for gaining the data of the static footprints, the subjects in the experimental processes were asked to follow the instructions listed below:

1. Roll both trouser legs up to above the knees if necessary, in order to prevent the clothing from limiting movements of the extremities.
2. Stand with bare feet on the sensing cushion with marks of the specific measuring range of JC Mat.
3. Relax the body; then, control and balance the center of gravity by standing with feet shoulder-width apart and with body weight evenly distributed on both feet.
4. Stampede for 6-8 steps, and then, stand still with a natural and comfortable posture and arms hanging straight down at sides.
5. Face the guide of the experiment, and look the guide straight in the eye. Keep the body stationary and balanced until there were no obvious changes in the pressure values of both feet measured by JC Mat.

When the condition above was met, the subjects' pressure profiles from the static footprints were acquired immediately. The follow-up measurement of the dynamic footprints was then undertaken based on the procedures below: the subjects were asked to walk at a self-selected speed over a 4-m-long walkway in which JC Mat was embedded. Multiple walking trials were completed until at least three steps for each limb were correctly acquired (i.e., the sensing cushion with marks of the specific measuring range of JC Mat was struck with a single foot).

Plantar Pressure Data

In order to examine the subjects' plantar pressure distributions in three regions and six sub-regions of both feet, the images of the static and walking footprints of both feet were digitized and imported into the specific computer program, FPDS-Pro software. The software formed a perpendicular line on the footprint images of the static and midstance phase of walking. The perpendicular line extended from the tip of the second toe to the centre of the heel, and then was drawn tangential to the most anterior and posterior part of the footprint excluding the toes. The software automatically generated four parallel lines which were perpendicular to the line and divided the outlined footprint into three equal parts. Three equal parts (region A, B and C) and six distinct sub-regions were appeared simultaneously among the footprint (Figure 2). In this study, 'regions A, B and C' of the footprint were defined, respectively, as the 'forefoot, midfoot and rearfoot regions'. As for the six sub-regions, 'sub-regions 1, 2, 3, 4, 5 and 6' were defined, respectively, as the 'lateral metatarsal bone (L.M.), lateral longitudinal arch (L.LA.), lateral heel (L.H.), medial metatarsal bone (M.M.), medial longitudinal arch (M.LA.) and medial heel (M.H.)'. The percentage of relative load (%) in all regions and sub-regions of each footprint was calculated. The arch index ratio method developed by Cavanagh and Rodgers assumed that the arch index (AI) was calculated as the ratio of the area of the middle third of the footprint divided by the entire footprint area excluding the toes, i.e. AI=B/(A+B+C). Based on Cavanagh and Rodgers' assertion, a normal arched foot was defined by the ratio between 0.21 and 0.26, a high-arched foot was defined by the ratio lower than 0.21, and a flat arched foot was defined by the ratio higher than 0.26.

Pain Assessment and Self-Reported Health Status of the Subjects

The process of pain assessment and self-reported health status of the subjects was conducted though the assistance of a professional physiotherapist at the rehabilitation department. This process functioned as the basis for the subject selection criteria, the subject's physiological symptom assessment and confirmation of their pain locations. All subjects should subject to the skeleton arrangement and soft tissue pain assessment after the completion of plantar pressure measurement. Specifically, lower limb pain was defined as the musculoskeletal pain which occurred during the past month and originated from the structures of the foot, ankle, knee, lower leg and thigh. This definition excluded intermittent cramps, dermatological conditions, digital calluses and night-time paresthesia from analysis. A standardized protocol of the questioning and examination techniques was used within this research for determining the precise nature of the complaint (e.g., metatarsalgia and plantar fasciitis). The procedures for evaluating the pain areas which occurred frequently in the subjects' body were presented as follows:

1. The professional physiotherapist evaluated and documented the subjects' self-reported health status and pain areas which occurred frequently in the body.
2. The subjects were asked to stand with bare feet and roll both trouser legs up to above the knees if necessary.
3. Inspection of subjects' lower extremities by pressing their foot (including phalanges, metatarsal bones, navicular bone, cuboid bone and calcaneus), ankle joints, knee joints, hip joints, tibias, fibulas and femur, and then, assessing the bones arrangement of their lower extremities.

The procedures for assessing the soft tissue pains were listed as follows:

1. The professional physiotherapist pressed the subjects' self-reported pain areas and re-checked the corresponding locations on the opposite side of pain areas.
2. Based on their clinical experiences, the professional physiotherapist pressed and examined the specific points in the subjects' common pains areas, including plantar metatarsal heads, plantar fascia, the inferior margin of navicular bones, the Achilles tendon, the medial and lateral sides of ankle joints, the medial and lateral fossas of knee joints, gastrocnemius, tibialis anterior and posterior, biceps and quadriceps femoris. This allowed the physiotherapist to definitely confirm the pain areas in the subjects' body.

Statistical Analysis

Descriptive statistics used for this study was to summarize all subjects' ages, heights, weights, BMI values and experience. Numerical data gained in the research process was presented as mean ± SD. One-way ANOVA was used for dealing with the comparisons of the arch index, three regional and six sub-regional plantar pressure distributions among three groups. Post Hoc, associated with t-test and Scheffe correction, was used for dealing with the between-group comparisons. All statistics were calculated with the Statistical Package for the Social Sciences for Windows (Version 17.0; SPSS Inc., Chicago, IL). Statistical significance were defined as $P < 0.05$ (marked as *) and $P < 0.01$ (marked as **) between the ES group and control group, $P < 0.05$ (marked as †) and $P < 0.01$ (marked as ††) between the SS group and control group, and $P < 0.05$ (marked as #) and $P < 0.01$ (marked as ##) between the ES and SS groups.

RESULTS

Arch Index

As Table 2 illustrates, the arch index of both feet in the sedentary controls was 0.21, and was classified as normal arches. There was no significant difference among three groups in the arch index of both feet.

Table 2 Arch index of the foot in the elite soccer (ES) and subelite soccer (SS) players.

	Control (*n* = 32)	ES (*n* = 22)	SS (*n* = 28)	*P*-value
Left foot	0.21 ± 0.02	0.21 ± 0.02	0.21 ± 0.02	0.413
Right foot	0.21 ± 0.02	0.21 ± 0.02	0.22 ± 0.02	0.213

The arch indices of both feet are represented as mean ± SD during static standing. *P* value for one-way ANOVA across groups.

Plantar Pressure Distributions of the Forefoot, Midfoot and Rearfoot Regions

Plantar pressure distributions of the forefoot, midfoot and rearfoot regions were illustrated in the form of percentages of the relative load. During static standing, the relative load in the forefoot region of both feet was higher in the elite soccer players as compared with sedentary controls (p < .05). There was no significant difference in the midfoot region of both feet among three groups. In addition, the relative load in the rearfoot region of both feet was lower in the elite soccer players than in the sedentary controls (p < .05). However, compared with the subelite soccer players, the relative load of both feet was found to be significantly lower in the rearfoot region in the elite soccer players (Table 3).

Table 3 Plantar pressure distributions of the forefoot, midfoot and rearfoot regions in the elite soccer (ES) and subelite soccer (SS) players

Region	Control (*n* = 32)	ES (*n* = 22)	SS (*n* = 28)	*P*-value
Left foot				
Forefoot (%)	23.63 ± 6.25	26.12 ± 2.79*	23.72 ± 4.71	0.023
Midfoot (%)	10.18 ± 9.17	9.40 ± 8.57	9.39 ± 8.30	0.852
Rearfoot (%)	16.19 ± 5.27	14.48 ± 4.06*#	16.89 ± 3.48	0.035
Right foot				
Forefoot (%)	23.88 ± 7.19	26.16 ± 4.54*	23.61 ± 5.01	0.047
Midfoot (%)	9.65 ± 8.55	9.83 ± 8.88	9.18 ± 8.09	0.922
Rearfoot (%)	16.47 ± 6.47	14.01 ± 3.34*##	17.09 ± 2.76	0.006

The percentage of relative load is represented as mean ± SD for each foot region during static standing. *P* value for one-way ANOVA across groups. *$P < 0.05$, **$P < 0.01$, significant differences between the ES and control group. #$P < 0.05$, ##$P < 0.01$, significant differences between the ES and SS group.

During the midstance phase of walking, the relative load was mainly transferred to the forefoot and rearfoot regions of both feet in the elite soccer players. In comparison with the sedentary controls, the relative load in the midfoot region of both feet was lower in the soccer players, particularly the elite soccer players (p < .01). Furthermore, compared with the subelite soccer players, the relative load of both feet was particularly higher in the rearfoot region in the elite soccer players (p < .05) (Table 4).

Table 4 Plantar pressure distributions of the forefoot, midfoot and rearfoot regions in the elite soccer (ES) and subelite soccer (SS) players

Region	Control (*n* = 32)	ES (*n* = 22)	SS (*n* = 28)	*P*-value
Left foot				
Forefoot (%)	28.77 ± 3.26	30.33 ± 3.94**	30.50 ± 4.26††	0
Midfoot (%)	8.54 ± 2.71	4.28 ± 2.64**	6.30 ± 2.62†	0.003
Rearfoot (%)	12.69 ± 4.07	15.40 ± 3.95*#	13.21 ± 3.21	0.039
Right foot				
Forefoot (%)	28.50 ± 4.16	30.34 ± 4.30**	30.19 ± 3.55††	0
Midfoot (%)	8.73 ± 3.14	4.97 ± 2.69**	6.37 ± 2.60†	0.005
Rearfoot (%)	12.78 ± 4.17	14.70 ± 4.44*#	13.28 ± 4.21	0.025

The percentage of relative load is represented as mean ± SD for each foot region during the midstance phase of walking. *P* value for one-way ANOVA across groups. *$P < 0.05$, **$P < 0.01$, significant differences between the ES and control group. †$P < 0.05$, ††$P < 0.01$, significant differences between the SS and control group. #$P < 0.05$, ##$P < 0.01$, significant differences between the ES and SS group.

Plantar Pressure Distributions at the Six Sub-Regions

The relative load at the six distinct sub-regions was calculated from the data gained from the forefoot, midfoot and rearfoot regions. During static standing, the relative load in the forefoot region of both feet at the medial metatarsal bone was higher in the soccer players, the elite soccer players in particular (left foot: 23.94 ± 2.05%; right foot: 22.91 ± 2.27%), than in the sedentary controls (left foot: 18.05 ± 1.62%; right foot: 17.69 ± 2.45%) (p < .01). In the midfoot region, there was no statistically significant difference among three groups. Compared with the sedentary controls, the relative load in the rearfoot region of both feet in the soccer players was significantly higher at the medial heel, but was significantly lower at the lateral heel, the elite soccer players in particular (p < .01). Compared with the subelite soccer players, the relative load in the elite soccer players was dramatically higher at the medial metatarsal bone of both feet and the medial heel of the left foot, whereas it was lower at the lateral heel of both feet (p < .01) (Figure 1 and 2).

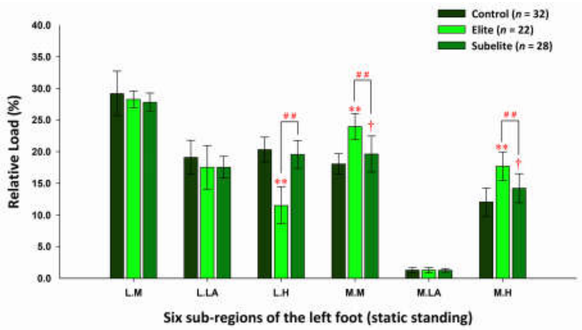

Figure 1 The percentage of relative load at the six distinct sub-regions of the left foot during static standing. *P < 0.05, **P < 0.01 are significant differences between the elite soccer players and control group. †P < 0.05, ††P < 0.01 are significant differences between the subelite soccer players and control group. #P < 0.05, ##P < 0.01 are significant differences between both soccer players.

The results from the midstance phase of walking showed that, compared with the sedentary controls, the relative load of both feet in the soccer players, particularly the elite soccer players, was exerted more on the medial metatarsal bone and the medial heel, but decreased more at the lateral metatarsal bone and the lateral longitudinal arch.

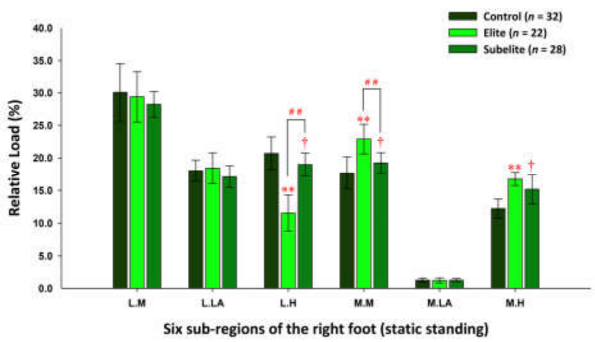

Figure 2 The percentage of relative load at the six distinct sub-regions of the right foot during static standing. *P < 0.05, **P < 0.01 are significant differences between the elite soccer players and control group. †P < 0.05, ††P < 0.01 are significant differences between the subelite soccer players and control group. #P < 0.05, ##P < 0.01 are significant differences between both soccer players.

Nonetheless, in the comparisons between both groups of soccer players, the elite soccer players' relative load was especially higher beneath the medial metatarsal bone, but was significantly lower at the lateral metatarsal bone and the lateral longitudinal arch (Figure 3 and 4).

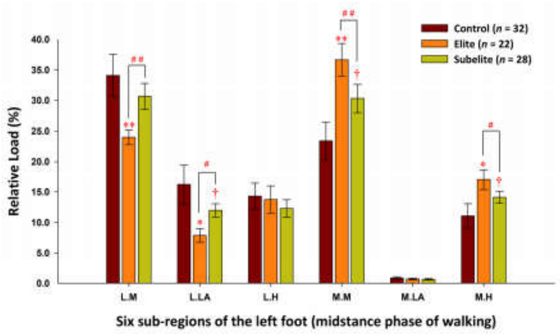

Figure 3 The percentage of relative load at the six distinct sub-regions of the left foot during the midstance phase of walking. *P < 0.05, **P < 0.01 are significant differences between the elite soccer players and control group. †P < 0.05, ††P < 0.01 are significant differences between the subelite soccer players and control group. #P < 0.05, ##P < 0.01 are significant differences between both soccer players.

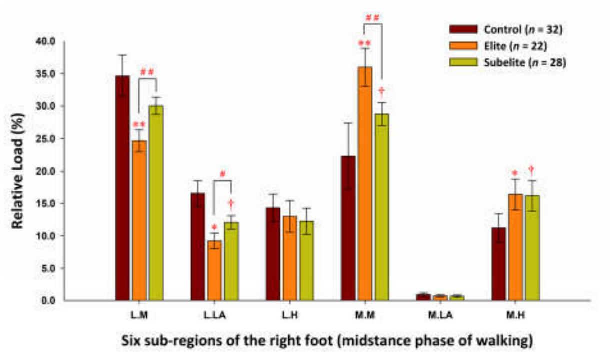

Figure 4 The percentage of relative load at the six distinct sub-regions of the right foot during during the midstance phase of walking. *P < 0.05, **P < 0.01 are significant differences between the elite soccer players and control group. †P < 0.05, ††P < 0.01 are significant differences between the subelite soccer players and control group. #P < 0.05, ##P < 0.01 are significant differences between both soccer players.

Footprint Characteristics

As demonstrated in Figure 5, the soccer players' static footprint were recognized as the higher pressure profiles in the medial portion of the foot, especially at the medial metatarsal bone and the medial heel. According to the findings, the soccer players' foot type could be classified into pronation.

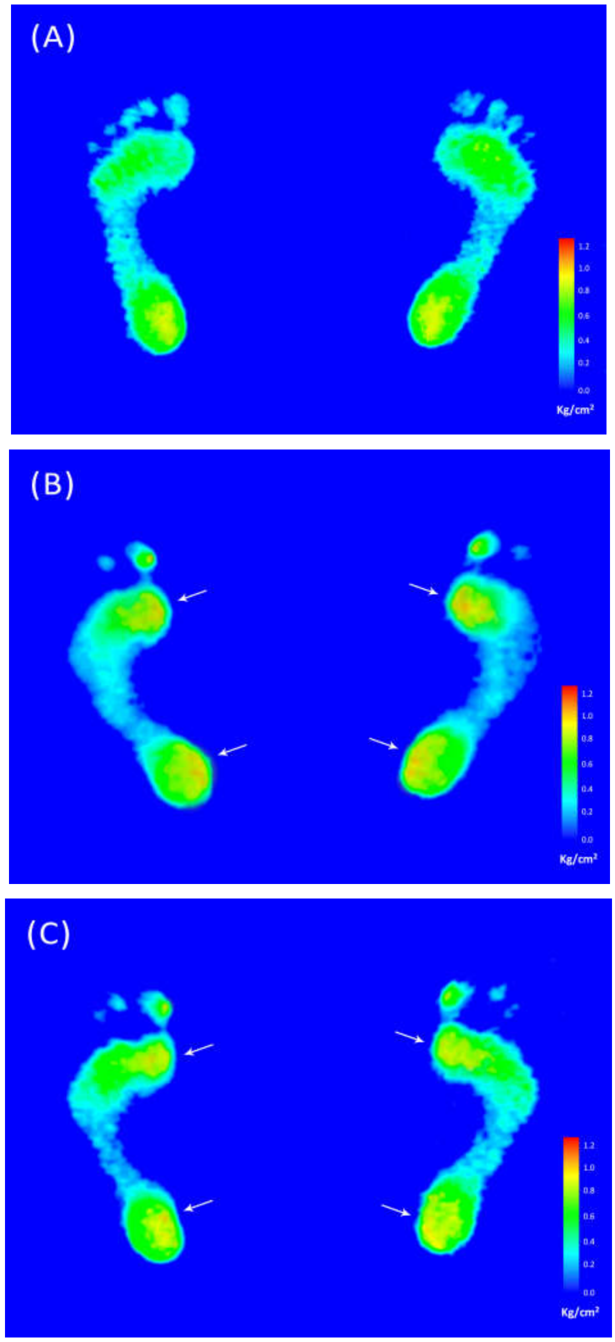

Figure 5 Static footprints of both feet between the (A) male sedentary controls, (B) male elite college soccer players and (C) male subelite college soccer players. White arrows indicated the higher pressure areas

Pain Assessment and Self-Reported Health Status of the Subjects

As can be seen in Table 5 which illustrates the findings from the soccer players' pain assessments and self-reported health status, eight most common pain areas in the elite soccer players are as follows: the lateral ankle joint (63.6%), the medial ankle joint (59.1%), the medial knee joint (59.1%), the plantar metatarsal bone, particularly the first to the third metatarsal heads (40.9%), the tibia (22.7%), the calcaneus (18.2%), the patella (18.2%) and the femur (9.1%). Seven most common pains in soft tissues are as follows: the anterior talofibular ligament (72.7%), the deltoid ligament (59.1%), the biceps femoris (59.1%), the anterior cruciate ligament (50.0%), the quadriceps femoris (31.8%), the Achilles tendon (22.7%) and the gastrocnemius (18.2%).

Pain areas	ES (*n*= 22)	Proportion	SS (*n* = 28)	Proportion
Bone				
Lateral ankle joint	14/22	63.60%	13/28	46.40%
Medial ankle joint	13/22	59.10%	13/28	46.40%
Medial knee joint	13/22	59.10%	11/28	39.30%
Metatarsal heads (1st~3rd)	9/22	40.90%	9/28	32.10%
Tibia	5/22	22.70%	10/28	35.70%
Calcaneus	4/22	18.20%	6/28	21.40%
Patella	4/22	18.20%	5/28	17.90%
Femur	2/22	9.10%	6/28	21.40%
Soft tissue				
Anterior talofibular ligament	16/22	72.70%	13/28	46.40%
Deltoid ligament	13/22	59.10%	13/28	46.40%
Biceps femoris	13/22	59.10%	11/28	39.30%
Anterior cruciate ligament	11/22	50.00%	10/28	35.70%
Quadriceps femoris	7/22	31.80%	6/28	21.40%
Achilles tendon	5/22	22.70%	7/28	25.00%
Gastrocnemius	4/22	18.20%	6/28	21.40%

Pain assessment and self-reported health status of the elite soccer players (ES) and subelite soccer players (SS) was conducted though the assistance of the professional physiotherapist at the rehabilitation department.

DISCUSSION

The purpose of the present study was to examine the differences among the elite and subelite soccer players and the sedentary controls in terms of their plantar pressure characteristics during static standing and walking. The results revealed that the static arch index of both feet was considerably close to each other within the respective groups. There was no significant difference among three groups. According to the arch index for normal ranged between 0.21 and 0.26 [24], the soccer players' arch types could be recognized as normal arches.

As regards plantar pressure distributions during static standing, the elite soccer players' relative load in the forefoot region of both feet was higher than the sedentary controls. The elite soccer players' relative load, however, was lower in the rearfoot region, compared with the subelite soccer players and the sedentary controls. During the midstance phase of walking, the relative load in the soccer players, particularly the elite soccer players, was mainly exerted on the forefoot and rearfoot regions of both feet, but decreased in the midfoot region. The results tended to coincide with previous studies which verified that in the similar nature of exercises, for example, the young male runners' peak plantar pressure, associated with the related impulse, was lower in the midfoot region but higher in the forefoot region after a 30-minute intense run [25]. The studies by Willems *et al*. went further, arguing that after a long-distance fatigue running, runners' plantar pressure was found to be concentrated in the forefoot and inside of the foot [18]. In addition, findings from the six sub-regional plantar pressure distributions showed that during static standing, the soccer players' relative load was exerted more at the medial metatarsal bone and the medial heel of both feet. Yet, during the midstance phase of walking, the relative load was prominently transferred to the medial metatarsal bone followed by the medial heel of both feet. It is noteworthy that the relative load was dramatically decreased at the lateral metatarsal bone and the lateral longitudinal arch. Findings from the present study generally supported the findings reported by Wong *et al*, in which highest peak pressure in the soccer players was found on the medial side of the plantar surface, particularly at the hallux followed by the medial heel during jump landing [12]. The studies by Wong *et al*. maintained that the hallux, the medial and central forefoot, and the medial heel received higher pressures simply when players in four soccer-related movements [12]. However, Eils *et al*. observed that higher peak pressures occurred in the medial side rather than in the lateral side of the plantar surface during running and cutting movements in soccer [21]. Queen *et al*. argued that the peak pressure was higher in the hallux, the medial and middle forefoot region, and that the highest pressure occurred in the middle forefoot region in soccer players during the acceleration task compared with other athletic tasks [23]. Similar results were found in female soccer players whose plantar loading increased significantly beneath the medial portion of the foot (medial midfoot and forefoot) during both the acceleration and side cut tasks [26]. Furthermore, the results regarding the sports of similar nature show that runners' peak plantar pressure and the related impulse were generally concentrated more at the metatarsal and less at the lateral regions of the toes [27]. The studies by Willems *et al*. verified that higher peak forces usually occur underneath the second and third metatarsal particularly after a fatiguing race [18]. According to the common findings and arguments presented above, the medial portion of the foot appear to suffer from increased loading during exercise, and this could be associated with a high number of repetitions. In addition, previous studies verified that specific plantar pressure loading patterns may result in specific stress fractures [21]. In a sense, it can be summarized by saying that soccer players' feet with excessive pronation are prone to experience the related chronic injury. Previous study stressed that soccer players who were diagnosed with excessively pronated feet had a 29% increased risk of injury compared with those who did not report excess pronation [28]. As regards findings from the present research, the common bony pains in the elite soccer players were the ankle joint, the medial knee joint, the first to the third metatarsal heads, the tibia, the calcaneus, the patella and the femur. The common pains which occurred frequently in soft tissues were the anterior talofibular ligament, the deltoid ligament, the biceps femoris, the anterior cruciate ligament, the quadriceps femoris, the Achilles tendon and the gastrocnemius. The results seemed to be consistent with previous studies which revealed that the ankle, knee, upper leg, groin, hip and foot were the most common soccer injuries in the lower extremities [2, 5]. Ankle sprains are the most frequent injuries in adolescent [29, 30] and female [31] soccer players. After the inversion ankle trauma, injuries to the anterior talofibular ligament are the most common, followed by injuries to the calcaneofibular ligament. Muscle injuries which usually occur in soccer players' lower limbs are the hamstrings, the adductors, the quadriceps and the calf muscles [32, 33]. Moreover, the most common foot and ankle positions at the time of injury were pronated/neutral in the sagittal plane for weight bearing limbs [34]. Excessive and compensatory pronation of the foot in athletes could lead to a medial breakdown of the shoe, a lack of rear-foot control, and overuse injuries [35]. People with pronated feet often result in Achilles tendonitis and plantar fasciitis [36]. The forefoot abducts and increases force through the medial rays, which can result in problems over the first metatarsal, such as hallux valgus, and over the second metatarsal, such as metatarsalgia [37]. In addition, pressure loading exerted on the forefoot region may cause the Achilles tendonitis [18]. Yet, pressure loading exerted on the medial side of the pronated foot were found to be the main reason for runner's heel eversion. This may stress the medial structure of the knee [38], and result in the anterior knee pain and tibialis anterior pain [18]. Runners' calcaneal valgus in the stance phase of the gait cycle makes them prone to suffer from fatigued calf muscles, such as fatigued gastrocnemius and fatigued soleus, and this may make their ankles and feet unstable [39].

This study was limited in its centre on the plantar pressure characteristics of 22 male elite college soccer players, 28 male subelite college soccer players and 32 male sedentary controls aged between 18 and 21 in Taiwan. It is inevitable that the results of the small subset of subjects within this research limited the possibilities for generalization. However, little research is currently undertaken to examine the plantar loading characteristics in healthy people [40] and in soccer players by focusing exclusively on static standing. It is anticipated that findings from this study may shed light on the static pressure profiles and pain profiles of college soccer players, particularly those in Taiwan. Thus, it is expected that the result of the present research, associated with literature on dynamic states discussed in this study, will contribute to illuminating the issues of the possible correlation between pressure profiles and pain profiles.

To conclude, the elite soccer players' arch index and plantar loading characteristics could be classified into normal arched feet, and their plantar pressure distributions were categorized into the features of pronated foot (calcaneal valgus). The findings confirmed the ankle joint and the biceps femoris appeared to be the most common musculoskeletal pains in the elite soccer players. The results were consistent with the symptoms of pronated foot in athletes from other sports. Findings from this research reflected the potential relationships between foot pronation and soccer players. The correlation between soccer players and pronated foot development is worth further studies.

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How to cite this article:

Tong-Hsien Chow *et al.*2016, Higher Plantar Pressures on the Medial Side of Foot in Elite Soccer Players During Static Standing and Walking. *Int J Recent Sci Res.* 7(8), pp. 13004-13011.