J. Phys. Ther. Sci. 31: 530–535, 2019

The Journal of Physical Therapy Science

Original Article

Characteristics of plantar pressure distribution in elite male soccer players with or without history of proximal fifth metatarsal fracture: a case-control study

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Abstract. [Purpose] Studies have demonstrated a relationship between plantar pressure distribution and proximal fifth metatarsal fracture. We aimed to investigate the plantar pressure patterns of soccer players with or without a history of proximal fifth metatarsal fracture. [Participants and Methods] Fifty-one male soccer players (31 professional, 20 high-school) participated in this study (mean age, weight, and height ± SD: 21.1 ± 4.7 years, 68.8 ± 5.8 kg, and 175.4 ± 5.9 cm, respectively). Seven of them had a history of proximal fifth metatarsal fracture before this study (the fracture group) and 44 had no history of fracture (the control group). A Win-Pod (Medicapteurs) platform was used to measure foot pressure forces. The center of plantar pressure was measured during double and single-limb stances for 25 seconds. Fifth metatarsal pressure and the center of plantar pressure angle was calculated from the walking footprint. The calculated data were compared between the fracture group and the control group. [Results] Comparisons between the fracture and control groups in terms of morphology and the center of plantar pressure length showed no significant differences. However, the fifth metatarsal pressure and the center of plantar pressure angle were significantly higher in the fracture group. [Conclusion] The results of this study revealed that players with excessive loading in the lateral areas of the foot while walking have a risk of developing proximal fifth metatarsal fracture.

Key words: Proximal fifth metatarsal fracture, Plantar pressure analysis, Soccer player

(This article was submitted Feb. 14, 2019, and was accepted Apr. 3, 2019)

INTRODUCTION

Soccer, known as Football in Europe and America, is one of the most popular participation sports in the world. Research in the past has shown that risk of injury in soccer player is high, especially in the lower limb[1)]. Proximal fifth metatarsal fractures, commonly referred to as a 'Jones Fracture' is particularly common among soccer players[2)]. Previous research reports that 78% of stress fractures occurring in professional soccer players involved the fifth metatarsal in a European soccer league in 2000–2009[3)]. Proximal fifth metatarsal fractures are often related to repetitive movements such as cutting, running and splinting during high intensity sports activities and it often takes certain amount of time to return to previous level of activities[4)]. Sir Robert Jones first reported a series of four-fifth metatarsal stress fractures in 1902[5)]. It has been noted that this injury

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does not heal quickly, a fact that has been attributed to the relatively poor blood supply and the resultant slow healing process[6]. The non-union rate has been reported at 14% and a re-fracture rate at 27%[7]. The base of the fifth metatarsal is strongly attached to the cuboid and fourth metatarsal by strong ligaments, which all transmit high levels of stress to this area during cutting and splinting activities[8]. These anatomical features allow this region to be biomechanically more susceptible to delayed union. Risk factors such as excessive weight bearing in the lateral aspect of the foot and poor single leg balance in weight bearing assessment have been identified[4, 9]. The research shows that players with a history of proximal fifth metatarsal fractures exhibit abnormal plantar pressure patterns[8]. However, how these plantar loading parameters are related to proximal fifth metatarsal fracture when compared with healthy soccer players during walking is unknown. Therefore, the aim of the current study is to identify the plantar pressure patterns with or without a history of proximal fifth metatarsal fractures. Comparison between players with or without a history of proximal fifth metatarsal fractures was hold in this research.

Fig. 1. Win-pod (MEDICAPTEURS).
Win-pod consists of a computer, a sensor plate, and a display monitor and it is used for podometry data analysis such as multi steps acquisition, analysis per foot area, static and dynamic analysis.

PARTICIPANTS AND METHODS

Fifty-one male athlete soccer players participated in this study. The participant's mean age was 21.1 ± 4.7 years, mean weight was 68.8 ± 5.8 kg, mean height was 175.4 ± 5.9 cm and mean Body Mass Index (BMI) was 20.5 ± 1.0 kg/m^2. Thirty-one male professional players from a team belonging to the Japanese professional soccer league division 1, and 20 male under-eighteen premier league soccer players who had taken part in the national championship tournament participated in this study.

Seven players (five professional and two high-school players) had suffered from proximal fifth metatarsal fractures previous to this study (the fracture group); two players had been treated with a screw fixation, and five players had been treated conservatively. Six players had the injury on the non-dominant leg (stance leg when kicking) and one player was diagnosed with the injury on the kicking leg. All players in the fracture group had healed prior to this research. Forty-four players without previous proximal fifth metatarsal fractures constituted of the control group. The players in the control group had no surgical history of their lower limbs and all players were able to participate their current team training.

Plantar pressures were measured with a Win-pod device (Fig. 1), made by Medicapteurs Corporation. The Win-pod consists of a computer, a sensor plate, and a display monitor. The planter pressure was measured in double limb stance, single limb stance and walking. Center of pressure (COP) length was calculated in single and double limb stance. Planter pressure and the COP angle were calculated to assess the relationships with proximal fifth metatarsal fractures during walking.

Measurement protocols followed the recommendations of Ageberg et al[10]. For double leg stance, the participant stands on the sensor plate for 25 seconds and calculated the total distance of COP. For single leg stance, the participant's arms hung straight down on each side, and the non-stance leg was held at 90° of hip flexion (Fig. 2-a). Each participant completed one familiarisation trial for each leg. The participants then completed three measurement trials of 25 seconds for each leg, alternating sides. The walking measurement followed as per the method recommended by Rosenbaum[11]. The starting position for participants was marked where their fifth step hit the sensor plate. The participant walked in bare feet at their natural speed and was instructed to walk at a comfortable pace, and a successful trial required the full length of the foot to be captured on the sensor plate (Fig. 2-b). Following two familiarisation trials for each lower limb, three valid trials were recorded for each leg alternatively. During double and single leg stance, COP track length was recorded. The COP track length is the total distance traced by the COP during the 25 seconds in both double and single leg stance. The fifth metatarsal pressure and the COP angle were measured from the average of these three steps.

The fifth metatarsal pressure (Fig. 3-a) was calculated from data representing the middle 25% of a walking footprint, as the average and maximum pressure for this area. The middle of the foot is located in the Lisfranc joint and the proximal fifth metatarsal is located just above the Lisfranc joint; therefore, the proximal fifth metatarsal is located in the middle quarter of a foot from the anatomical structure[12].

Walking speed can influence plantar loading and there is a correlation between walking speed and vertical ground reaction force[13]. Therefore, all of the measurements were taken at a natural walking speed. Furthermore, individual variations of plantar pressure were regularized using a formula that calculated the percentage the maximum pressure (g/cm^2) divided by their body weight (g) to standardize the pressure. (The fifth metatarsal pressure: maximum pressure in the middle 25% area (g/cm^2)/body weight (g)/100)

The COP angle (Fig. 3-b) was measured based on the method of Hastings et al[14]. The angle is defined as the angle between the base line and the traffic line. The base line was measured as the angle formed between the longitudinal bisector of the inside the COP on the pressure map. The traffic line runs from the innermost COP to the outermost COP of the waking

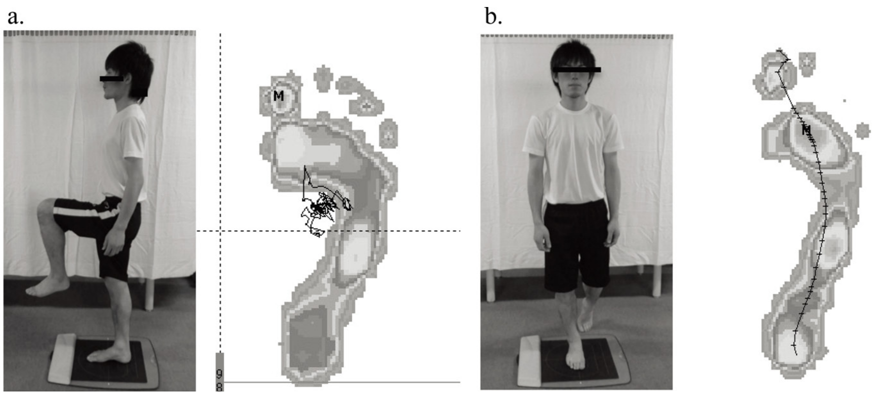

Fig. 2. a. Single-limb standing, Track length of COP, b. Walking, track length of COP and fifth metatarsal pressure.
a. Foot was placed pointing straight forward and maintains this position 25 seconds, black line shows track of COP. It is measured through static standing in double and single limb and calculated a total length of COP track. (Example of fracture foot).
b. The participants walked in bare feet at their natural speed and confortable walk, and were measured their planter pressure. Doted-line is indicated as track of the COP and calculated pressure distribution. (Example of fracture foot).

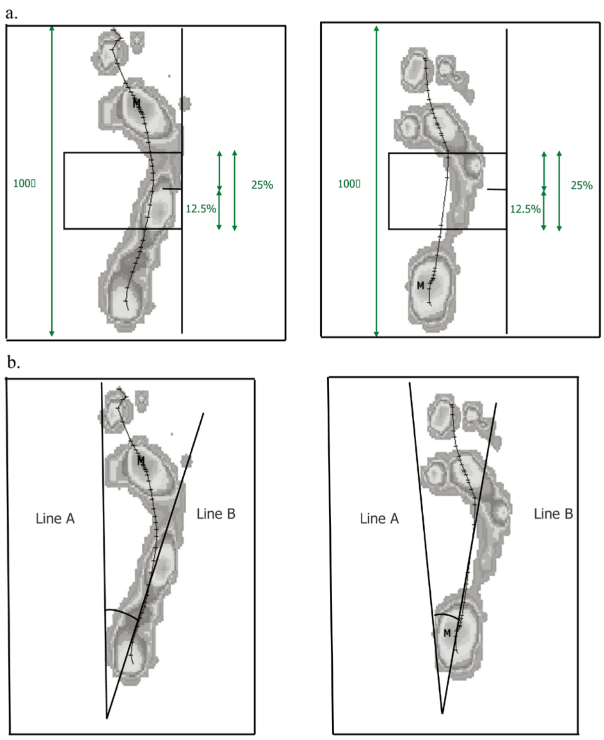

Fig. 3. a. Fifth metatarsal pressure in walking, b. The COP angle in walking.
The pressure was calculated thorough a walking foot print. Example of fracture foot (Left), and non-fracture foot (Right). Fifth metatarsal pressure: the domain is the range of anteroposterior 12.5% from the midpoint of the foot (25% of the foot length). Measured maximum pressure and divided by body weight to modify the pressure during the domain.
The fifth metatarsal pressure (%)=Maximum pressure in the middle 25% area (g/cm^2)/body weight (g) × 100.
b. COP angle: formed by Line A from the inside of the calcaneum to the inside of the hallux, and Line B, from the most inside point to the most outside point of the walking track. Example of fracture foot (Left), and non-fracture foot (Right).

Table 1. Comparison of measurement items in the fracture and control groups

	Fracture group (n=7)	Control group (n=44)	p value
Age (years)	23.9 ± 3.5	24.0 ± 5.0	p=0.952
Height (cm)	175.9 ± 5.5	177.4 ± 5.6	p=0.510
Body weight (kg)	70.0 ± 4.7	69.8 ± 5.1	p=0.952
BMI (kg/m^2)	22.6 ± 1.0	22.0 ± 0.9	p=0.150
Double limb stance COP length (mm)	275.4 ± 37.1	264.8 ± 31.8	p=0.480
Single-limb stance COP length (mm)*	1,182.4 ± 224.6	1,118.8 ± 124.6	p=0.472
Fifth metatarsal pressure (%)*	55.4 ± 27.4**	24.0 ± 5.0	p<0.01**
COP angle (degrees)*	18.2 ± 1.4***	12.4 ± 2.3	p<0.05***

BMI: Body Mass Index; COP: Center of Pressure.
Results are reported as mean ± SD. Age, Height, Body weight, BMI, Double and single limb stance COP length, Fifth metatarsal pressure and COP angle.
*Average of fractured foot (7 feet).
**p<0.01, ***p<0.05.

footprint. The COP angle reflects the medial-lateral pressure distribution of COP.

The study was carried out between January 2008 and March 2010 and was approved by the Research Ethics Committee of the Funabashi Orthopaedic Hospital and approved No.105. This study conforms to the Declaration of Helsinki. Each candidate provided informed consent, and also provided a written informed consent form prior to allowing their data to be obtained.

Study participants were divided into the fracture and control group and the following comparisons were carried out between the groups. The morphology of the studs, age, height, weight and BMI were carried out between the groups through unpaired t-tests. The other statistical analyses were conducted using the Mann-Whitney U test and the alpha level was set at 5% for the significance level. A two-way repeated measurement analysis of variance with the four factors (COP track length in double and single limb stance, the fifth metatarsal pressure, and the COP angle) between the fracture group and the control group was utilised. Demographics of groups were reported as means (standard deviations) for continuous variables and frequency distributions were used for categorical data. All statistical analyses were conducted using SPSS version 11.0 (SPSS Japan Inc.).

RESULTS

The fracture group was comprised of 7 players 14 feet (all unilateral fracture), while the control group accounted for 44 players 88 feet. Single leg COP length, Fifth metatarsal pressure and the COP angle in the fracture group were measured only fractured feet (7 feet). Comparison between the fracture and control groups in the morphology showed no significant difference in their age, height, weight and BMI. The mean age, height, weight and BMI in the fracture and control group were 23.9 ± 3.5 and 24.0 ± 5.0 years (p=0.95), 175.9 ± 5.5 and 177.4 ± 5.6 cm (p=0.51), 70.0 ± 4.7 and 69.8 kg ± 5.1 (p=0.95) and 22.6 ± 1.0 and 22.0 ± 0.9 kg/m^2 (p=0.15) respectively (Table 1).

There was no significant difference in both groups in double limb stance COP length (facture group, 275.4 ± 37.1 mm; control group, 264.8 ± 31.8 mm; p=0.48). There was also no significant difference in both groups in the single-limb stance COP length (facture group, 1,182.4 ± 224.6 mm; control group, 1,118.8 ± 124.6 mm; p=0.47). Fifth metatarsal pressure was significantly higher in the fracture group (fracture group, 55.4 ± 27.4%, control group, 24.0 ± 5.0%; p=0.01). The COP angle was also significantly higher in the fracture group, (fracture group, 18.2 ± 1.4°, control group, 12.4 ± 2.3°, p=0.02) (Table 1).

DISCUSSION

The center of pressure is the point where the total sum of a pressure field acts on a body, causing a force to act through that point[15)]. This study examined plantar pressures and COP angles in elite male soccer players with or without a history of proximal fifth metatarsal fractures during double and single limb stance, and walking. No difference was seen in double and single limb COP lengths in both groups, however there was significantly higher in the fifth metatarsal pressure and the COP angle in the previously injured group. Wright et al. suggested that the mechanism of the proximal fifth metatarsal fractures is related to the excessive pressure in the plantar metatarsal ligament and the plantar tarsal ligament[6)]. Lawrence et al.[2)] and Sims et al. identified repetitive outside loading of the foot during kicking and cutting motions whilst playing soccer would cause proximal fifth metatarsal fractures. Although the current study is hard to distinguish whether the high fifth metatarsal pressures and increased COP angle were present prior to injury or developed as a result of the injury, the findings would support our hypothesis if the players have excessive lateral pressure before the fracture, which would support the mechanism of repetitive mechanical overload as the cause of the injury. Increased COP angle in this study also contributed to an increased risk of a fracture because of repetitive pressure on the fifth metatarsal same as previous studies[2, 6)].

The testing device used in this study (WinPod) can be used to evaluate the effect of muscle and balance training on plantar pressures[16]. The visual feedback to patients of their planter pressure distribution can help them to understand their own risk of injury. This portable device has a potential to be used for screening during a field level assessment. Plantar pressure distribution when walking may be a useful screening tool to identify the risk of proximal fifth metatarsal fracture because excessive lateral foot loading from over-supinated foot may increase the risk of stress fracture of the ankle and foot[17].

Early detection and appropriate treatment of proximal fifth metatarsal fracture is important as injury result in time off and occasionally related to their incomes[18]. The research in this field also recognises that it is more desirous to use the tool for injury prevention. Previously, it has been required imaging such as X-ray or other huge equipment to assess diagnosing the fracture[19]. However, the WinPot device is small, easily accessible, and can be carried to the soccer field. Therefore, plantar pressures can be measured quickly and easily during regular screening assessments not only at hospitals or private practices but also on the field. The field level assessment is more suitable for screening and consequently would lead to injury prevention.

Some researches have shown that muscle training and orthotic treatment can alter the planter pressure distribution[20, 21]. Similarly, a research has shown that toe flexor strength can alter or modify the ground reaction force[4]. Strengthening and stabilizing hip and trunk muscles especially gluteus medias has also been shown as useful in controlling lower leg alignments[22], and recent reviews also identified a relationship between hip muscle strengthening and lower limb stress fractures[7, 21].

The similar research proposed that proximal fifth metatarsal fracture was related to the foot length, arch height, and ankle ROM as these structure could influence the planter pressure and the load in the fifth metatarsal[23]. It suggested that proximal fifth metatarsal fracture was related to q-angle and grip strengthening, and that limited dorsiflexion could contribute to increased loads on the lateral foot[23].

A limitation of this research was that plantar pressures were measured in barefoot, whereas the loads believed to contribute to the injury occur wearing soccer boots, and while sprinting or running. In addition, the number of participants in the fracture group was relatively small; therefore, it was required monitoring each individuals' planter pressure for an extended period. Further studies are required, with larger sample size especially in the fracture group. It is needed to assess the fracture group or higher pressured and angled players for a long term whether they have the proximal fifth metatarsal fracture in the future. Despite these limitations, this study makes an important contribution to knowledge that planter pressure could affect the risk of injury and it would have a benefit for screening of the injury and early interventions could prevent aggravating the injury or reoccurring fractures.

In conclusion, the plantar pressure distribution was found to differ between soccer players who had a history of the proximal fifth metatarsal fracture (n=7) and had no fracture (n=44). Specifically, higher pressures on the fifth metatarsal and the higher COP angle were found in those with the fracture group. These findings may have important implications for manipulating the load for intervention. Although it is not known whether these differences were present prior to the development of the injury, early screening of planter pressure distribution might have a benefit for early intervention and injury prevention in the future.

Conflict of interest

Authors have no conflict of interests to disclose.

ACKNOWLEDGEMENTS

The researchers wish to thank all the 51 athlete soccer players who participated in the research. We are grateful to the team manager and trainer for the support and allow us to use pictures for publication. Our special thanks to Dr. Gaida Jamie (University of Canberra) and Dr. Akihiro Tsuchiya (Funabashi Orthopaedic Hospital) for technical assistance. This work was also supported by Funabashi Orthopaedic Hospital to use the facility and planter pressure device for this research.

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