Effect of the application of a metatarsal bar on pressure in the metatarsal bones of the foot

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Abstract. [Purpose] The aim of this study was to determine the effect of application of a metatarsal bar on the pressure in the metatarsal bones of the foot using a foot analysis system (pressure on the forefoot, midfoot, and rearfoot). [Subjects and Methods] Forty female university students in their twenties were selected for this study, and an experiment was conducted with them as the subjects, before and after application of a metatarsal bar. The static foot regions were divided into the forefoot, midfoot, and rearfoot, and then the maximum, average, and low pressures exerted at each region were measured, along with the static foot pressure distribution ratio. 1) Static foot pressure: The tips of both feet were aligned to match the vertical and horizontal lines of the foot pressure measuring plate. The subjects were told to look toward the front and not to wear shoes. 2) Distribution ratio: The distribution ratio was measured in four regions (front, back, left, and right) using the same method as used for static foot pressure measurement. [Results] The results of this study showed that the maximum, average, and minimum static pressures in the forefoot were significantly decreased. The minimum static pressure in the midfoot was significantly increased, and the pressure in the other parts was significantly decreased. The maximum and average static pressures in the rearfoot were also significantly decreased. [Conclusion] As reduction of foot pressure with a metatarsal bar results in lowering of the arch and an increased contact surface, the foot pressure was dispersed. These results suggest that wearing shoes with a bar that can decrease the foot pressure is therapeutically helpful for patients with a diabetic foot lesion or rheumatoid arthritis.

Key words: Foot pressure, Distribution ratio, Metatarsal bar

INTRODUCTION

Musculoskeletal disorders and deformities are related to increased forefoot pressure1). As concerns regarding foot health have risen, foot pressure measurement has been widely used to solve foot problems in patients with foot pain, diabetes mellitus, and rheumatoid arthritis2). Foot pressure is one of the measurement areas considered most in clinical trials and sports science research, and it has been measured to observe the pressure exerted onto a specific area of the foot while engaging in activities of daily living and functional activities3). Therefore, foot pressure measurement can be used in various areas to determine the influence of foot problems on abnormal gait in patients with foot deformation, cerebral palsy, arthritis, amputation, and hemiplegia3). Physical fatigue, injury, and chronic diseases may be caused by repeated impact and the force between the foot and the sole during gait4). In normal persons, a proper protection mechanism for mechanical stimulation during gait is applied to protect the body, but if the foot pressure is concentrated on one spot, malformations such as hyperkeratosis, pain, hallux valgus, claw toe, and hammer toe arise5). In addition, patients with neuropathic disorder or peripheral diseases may incur an injury because they cannot properly cope with a stimulus6). Thus, a sensory deficit in the sole may have a great influence on posture and gait control, and a sensory disability in the sole can lead to neurological diseases such as neural damage, nerve root compression in the spine, or diabetes mellitus7).

The pressure exerted onto a specific part of the foot can be observed by measuring the foot pressure, which can be used to solve foot problems in patients with foot pain, diabetes mellitus, and rheumatoid arthritis8). It is a proven method of evaluating foot functions, and is also a means of detecting pathological problems like diabetes mellitus and preventing ulcers9). Also, foot pressure analysis has been used in various areas, including investigation of the influence of foot pressure on foot deformity caused by foot problems10). A foot pressure measurement system measures the force and pressure applied to a specific position10), and the gait pattern can be determined by examining the distribution of foot pressure during gait11). Therefore, analyzing foot pressure in relation to the gait pattern is helpful for treating patients with clinical foot problems and for observing their progress12). Foot pressure data also provide useful information for managing diseases related to the musculoskeletal, integumentary, and...
nervous systems. Several methods of decreasing foot pressure by applying foot orthosis, wedge, or gait strategies and by evaluating abnormal increases in foot pressure due to various foot diseases are under investigation. Studies on foot orthoses, diabetic shoes, and footwear for the elderly have also been conducted recently. Seo and Park reported that functional diabetic shoes, and footwear for the elderly have been used to treat many biodynamic problems. There have been limited studies, however, on orthotic devices such as the metatarsal pad, dome, and wedge. Therefore, in this study, a bar was applied on the metatarsophalangeal joint area in normal persons, and a foot analysis system and measurement of the pressure exerted on the forefoot, midfoot, and rearfoot were used to determine if any changes occurred in spatiotemporal indices and kinematic parameters.

SUBJECTS AND METHODS

The subjects enrolled in this study were women in their twenties who voluntarily agreed to take part in the experiment from June 29 to July 7, 2013, and were attending K Women’s University in the Kwangju region, South Korea. Excluded from the study were those who had no gait problem and those who had excessive valgus or varus of the subtalar joint, a foot deformity like hallux valgus, or a foot disease like foot ulcer and sprain. Forty subjects were randomly selected to participate in the experiment before and after placement of a metatarsal bar. The general features of the subjects are presented in Table 1. All the subjects signed an informed consent form, and the study was approved by K Women’s University.

A foot pressure measuring instrument (Gait Checker Hardware Spec., GHW-1100, South Korea) was used to measure the pressure distribution in the sole. The length, width, height, and frequency of the foot pressure measuring instrument were 1.3 m, 0.52 m, 0.055 m, and 50–60 Hz, respectively. The instrument had 61,444 sensors, which were 0.75 in size. A metatarsal bar with a height of 0.3 cm and a heel insert was attached to the metatarsophalangeal areas of the subjects’ bare feet using a paper bandage. The material, shape, size, and thickness of the metatarsal bars were the same.

The static foot regions were divided into the forefoot, midfoot, and rearfoot, and then the maximum, average, and minimum pressures exerted onto each region were measured, along with the static foot pressure distribution ratio. The static foot pressure was measured with the tips of both feet aligned to match the vertical and horizontal lines of the foot pressure measuring plate. The subjects asked made to look toward the front and not to wear shoes. The distribution ratio was measured in four regions (front, back, left, and right) using the same method as that used for static foot pressure measurement.

All the statistics were processed with SPSS 12.0 (SPSS Inc., Chicago, IL, USA) by encoding the measurement data obtained before and after the application of the metatarsal bar based on a repeated-measures design. The subjects were made to stand at the starting point of a gait path, and to walk comfortably in the direction indicated by the measurer for comparison of the foot pressures in the forefoot, midfoot, and rearfoot before and after the application of the metatarsal bar under static conditions. The paired t-test was used to examine the foot distribution ratio. The statistical significance level for all the tests was set at $\alpha=0.05$.

RESULTS

Comparison of the repeated-measures sample results for the forefoot between before and after application of the metatarsal bar to the left and right feet showed that the maximum pressure was significantly reduced according to time. The average pressure was also reduced according to the time after the application of the bar to the left and right feet compared with before application, and the minimum pressure was significantly reduced. The left and right feet showed significant differences in average and low pressure (Table 2).

Comparison of the repeated-measures sample results for the midfoot before and after the application of the metatarsal bar showed that the maximum pressure was significantly reduced in both the left and right feet. The average pressure was also significantly reduced according to the time after the application of the bar to both the left and right feet compared with before application, and the minimum pressure was significantly increased. The left and right feet showed significant differences in maximum, average, and low pressure (Table 3).

Comparison of the two-way ANOVA results with the repeated-measures results for the rearfoot showed that the maximum pressure was reduced, and the minimum pressure showed no significant difference between before and after application of the bar to both feet. There were significant differences, though, in the maximum and minimum pressures of the left and right feet (Table 4).

Comparison of the sample t-test results with the distribution ratio showed a significant difference between before and after application of metatarsal bar. Both the left and right

| Table 1. General characteristics of the study subjects (n=40) |
|-------------|-------------|-------------|-------------|
| Age (years) | Height (cm) | Weight (kg) | Foot size (mm) |
| Mean±SD     | 20.9±1.4    | 162.0±5.1   | 52.7±7.1    | 234.9±7.4   |

| Table 2. Forefoot pressure comparison after applying a metatarsal bar under static conditions (n=40) (Units: N/cm²) |
|-------------|-------------|-------------|
|             | Pre         | Post        |
| Maximum     | R           | 315.5±33.4  | 310.8±31.7  |
| pressure    | L           | 284.4±35.7  | 282.6±24.6  |
| Average     | R           | 175.9±20.3  | 165.6±15.7  |
| pressure    | L           | 156.0±18.2  | 150.2±12.5  |
| Low         | R           | 30.8±4.98   | 20.4±2.9    |
| pressure    | L           | 27.6±3.8    | 17.8±4.4    |
| Mean±SD     |             |             |             |
distribution ratios showed no significant difference between before and after application of the bar (Table 5).

**DISCUSSION**

In the study entitled “Comparison of the Peak Planter Pressure between Bare Feet and In-Shoes in Diabetic Patients” conducted by Yang\(^{14}\), the conditions before and after 17 diabetic mellitus patients two kinds of diabetic shoes by were measured and compared. The results showed that, the foot pressure in all the regions of the sole decreased significantly after the subjects wore the two kinds of diabetic shoes. Therefore, the wearing of diabetic shoes for both indoor and outdoor activities was recommended. In addition, in a study conducted by Lee et al., a longitudinal arch and longitudinal arch plus metatarsal pad were added to right-heel and left-heel inserts for 33 normal persons, respectively, and the maximum pressure in the sole was measured. Consequently, the foot pressure was found to be lower in the rearfoot, midfoot, and 3rd, 4th, and 5th metatarsal regions with a heel insert with a metatarsal pad in the medial longitudinal arch was used compared with when a heel insert with a longitudinal arch was used\(^{15}\). Like these studies, this study showed significant reduction of the maximum pressure in the foot with the metatarsal pad was attached to the orthotics, the maximum foot pressure in the forefoot was significantly low in the rearfoot, midfoot, and 3rd, 4th, and 5th metatarsal regions. The results of the present study showed that application of a metatarsal bar significantly lowered the maximum pressure in the forefoot, midfoot, and rearfoot. As a reduction in foot pressure results in lowering of the arch and an increase in contact surface, the pressure in the foot was dispersed.

In the study entitled “Effect of the use of a metatarsal pad on foot pressure” conducted by Lee et al.\(^{16}\), a metatarsal pad was attached to the bare foot and shoes of 33 normal persons, and the results were measured. The results showed that the maximum pressure in the foot with the metatarsal pad was significantly low in the rearfoot, midfoot, and 3rd, 4th, and 5th metatarsal heads. In addition, the study was identical to the relevant past studies in that like the past studies, it also showed a significant reduction of the maximum pressure in the forefoot, midfoot, and rearfoot.

In the study entitled “Effect of the use of a metatarsal pad on foot pressure during walking” conducted by Yoon\(^{17}\), general orthotics and five types of metatarsal pad were applied to 21 women in their twenties and fifties, respectively, and the pressure in different areas of their feet was measured. The results showed that when a metatarsal pad was attached to the orthotics, the maximum foot pressure in the forefoot was significantly reduced. The left foot had a higher maximum pressure in the midfoot and rearfoot than the right foot, and the maximum pressure in the right foot was significantly high in the forefoot and metatarsal head. In this study showed significant differences between the left and right feet, but the maximum foot pressure was higher in the right forefoot, midfoot, and rearfoot than in the left foot. This is because the difference in the lengths of the legs in a standing position caused a significant difference in foot pressure between the right and left feet. Therefore, relevant research about the COP (center of pressure) and the length of the legs is needed.

A paper by Chang et al.\(^{18}\) reported that the factors affecting foot pressure were related to the location and size of the metatarsal pad, and suggested the importance of careful adjustment of the pad position. The study entitled “The change in the in-shoe plantar pressure according to the lever point of the metatarsal bar” conducted by Lee et al.\(^{19}\) reported that when the bar was located at the center of the...
metatarsal head, the sole pressure was effectively reduced. The results obtained with the bar located at the center of the metatarsal head were the same as those obtained by the previous researchers.

In this study suggests that further studies comparing the results of application of a 0.3 cm bar to the metatarsophalangeal region should be conducted, and that such studies should include male subjects in examination of the changes in foot pressure according to the difference in leg length. Therefore, wearing shoes with a bar that can reduce the foot pressure for patients with foot problems like diabetic foot lesions and rheumatoid arthritis and help cure such patients.

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REFERENCES

1) Ko DY, Lee HS: The changes of COP and foot pressure after one hour’s walking wearing high-heeled and flat shoes. J Phys Ther Sci, 2013, 25: 1309–1312. [Medline] [CrossRef]
2) Lee GH, Park SB, Lee SG, et al.: Analysis of the stance phase by measurement of plantar pressure. J Korean Acad Rehab Med, 1996, 20: 524–531.
3) Roh JS, Kim TH: Reliability of plantar pressure measures using the parotec system. Phys Ther Kor, 2001, 8: 35–41.
4) Nigg B, Hintzen S, Ferber R: Effect of an unstable shoe construction on lower extremity gait characteristics. Clin Biomech (Bristol, Avon), 2006, 21: 82–88. [Medline] [CrossRef]
5) Yun MC: The effect of metatarsal pad on peak plantar pressure of the forefoot during walking. Kyonggi University Dissertation of Master’s Degree, 2007.
6) Kim YG: The diabetic foot lesions. Diabetologia, 1995, 19: 1–5.
7) Gong WT, Kim JH, Kim TH: The analysis of dynamic foot pressure on difference of functional leg length inequality. J Kor Soc Phys Ther, 2009, 21: 43–49.
8) Gurney JK, Kersting UG, Rosenbaum D: Between-day reliability of repeated plantar pressure distribution measurements in a normal population. Gait Posture, 2008, 27: 706–709. [Medline] [CrossRef]
9) Park SB, Lee JS: Functional evaluation of tennis shoes using foot-pressure distribution. Korean J Sport Biomech, 2008, 18: 89–97. [CrossRef]
10) Orlin MN, McPoil TG: Plantar pressure assessment. Phys Ther, 2000, 80: 399–409. [Medline]
11) Perry J, Davids JR: Gait analysis: normal and pathological function. J Pediatr Orthop, 1992, 12: 815. [CrossRef]
12) Alexander I, Campbell K: Dynamic assessment of foot mechanics as an adjunct to orthotic prescription. The Biomechanics of the Foot and Ankle, 1990, 148–52.
13) Kim YG: Clinical characteristics of diabetic foot lesions. Chungnam medical Journal, 1997, 24: 135–141.
14) Yang DC, Jang SH, Choi KS, et al: Comparison of peak plantar pressure between bare foot and in-shoe in diabetic patients. J Korean Acad Rehab Med, 2003, 27: 600–4.
15) Seo KC, Park KY: The effects of foot orthosis on the gait ability of college students in their 20s with flat feet.
16) Lee GH, Han SJ, Lee SG, et al.: The effect of metatarsal pad for foot pressure. Ann Rehabil Med, 2004, 28: 94–97.
17) Park IS, Jung JY, Jeon KH, et al.: Effects of forefoot rocker shoes with metatarsal bar on lower extremity muscle activity and plantar pressure distribution. Korean J Sport Biomech, 2012, 22: 113–121. [CrossRef]
18) Goo BO: The effect of height increase elevator shoes insole on gait and foot pressure. J Korean Soc Phys Med, 2011, 6: 199–205.
19) Lee WJ, Jang SH, Lee SG, et al: The change of in-shoe plantar pressure according to lever-point of metatarsal-bar. J Korean Acad Rehab Med, 2006, 30: 266–70.