



Original Article

Effects of body mass index on plantar pressure and balance

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Abstract. [Purpose] To suggest physiotherapy programs and to determine foot stability based on the results of plantar pressure and spontaneity balance in the normal group and in the obesity group according to the body mass index (BMI). [Subjects and Methods] The plantar pressure and balance of 20 females college students in their 20s were measured according to their BMI. BMI was measured by using BMS 330. The peak plantar pressure was measured in a static position in the forefoot and hind-foot areas. To study balance, the spontaneity balance of each foot was measured on both stable and unstable surfaces. [Results] In terms of plantar pressure, no significant change was observed in the forefoot and hind-foot peak pressure. In terms of spontaneity balance, no significant difference in foot position interaction was observed on both stable and unstable surfaces, while a significant difference was observed in the foot position between the groups. [Conclusion] The index of hind-foot spontaneity balance was low, particularly in the obesity group. This meant significant hind-foot swaying. The forefoot body weight support percentage increased to reinforce the reduced spontaneity balance index.

Key words: Plantar pressure, Spontaneity index, Balance ability

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INTRODUCTION

The WHO Regional Committee of the Western Pacific about a new BMI for Asians defined 23 kg/m² or higher BMI as overweight, and 25 kg/m² or higher as obesity¹⁾. It is associated with increased body fat, BMI, and waist measurements, which adversely affect the activities in daily living and physical activities²⁾. Also the incidence of degenerative foot diseases increases with increasing life expectancy, and diabetic foot disease also increases with the growing number of diabetes patients³⁾.

Plantar pressure is frequently measured to solve foot problems in patients with pain, diabetes, or rheumatism⁴⁾. When foot bones are not properly distributed, the body weight is unevenly applied to the sole, thereby resulting in various symptoms⁵⁾. Rheumatoid arthritis patients experience foot symptoms in the early stage of their disease (20%) as well as in the latter stage (90%); then, after 10 years, most of them experience foot deformity^{5, 6)}.

The effects of the pressure applied to the foot can be investigated through measurements that can be used to solve the foot problems of diabetes or rheumatoid arthritis patients⁷⁾. Tests on body weight support of the foot include the sole pattern test and the foot-scan test, which is used to observe the sole contact features and to automatically calculate plantar pressure values that are used to evaluate balance and movement^{8, 9)}.

It is necessary to understand the nature of maintaining balance to differentiate the cause of balance disorders from other factors. Studies on balance and the maintenance of balance have been conducted^{10–12)}. As skeletomuscular factors, muscular strengths and their stability have been studied. Posture and balance control through the improvement of the spontaneity index have been reported. Studies on neurologic factors, including somesthesia, visual senses, and vestibular sense have also

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Table 1. General features of the subjects

	Weight	Height	BMI
Normal BMI group (n=10)	47.1 ± 2.5	159.6 ± 3.5	18.5 ± 1.1
Obesity BMI group (n=10)	71.4 ± 6.2	162.4 ± 5.8	27.4 ± 1.4
Mean ± SD			

Table 2. Comparison of forefoot peak pressure (kg/cm²) between the groups in the static condition

Static forefoot	Peak pressure
Normal BMI group (n=10)	139.7 ± 23.8
Obesity BMI group (n=10)	138.1 ± 21.4
Mean ± SD	

Table 3. Comparison of hindfoot peak pressure (kg/cm²) between the groups in the static condition

Static hindfoot	Peak pressure
Normal BMI group (n=10)	164.1 ± 11.9
Obesity BMI group (n=10)	152.3 ± 22.8
Mean ± SD	

been conducted^{13, 14}). Thus, the purpose of this study is to suggest physiotherapy programs and to determine foot stability according to the results of plantar pressure and spontaneity balance in the normal group and in the obesity group based on BMI. The data obtained from this study may also be used for further studies.

SUBJECTS AND METHODS

Twenty subjects were 20 female volunteers. The subjects were divided into two groups: a normal BMI groups (thin body type) and obesity groups (plump body type). The subjects without those who had gait disorders, foot pain, foot deformity, and foot diseases were excluded. General characteristics of the subjects are shown in Table 1. All the subjects signed an informed-consent form, and the study was approved by K Women's University.

The measured their plantar pressure and balance ability were investigated according to BMI. BMI was calculated by using BMS 330 (Biospace Co., Ltd., Korea) after the subjects' age, height, and body weight was measured. Also measures plantar pressure distribution, Gait Checker Hardware spc. (GHW-1100, KOREA) was used. To measure plantar pressure, the subjects comfortably stood on the foot scan on bare feet with even body weight on both legs. They stood facing forward or looking at a red spot in the front without moving their feet and without holding anything.

The balance tester, Tetrax Interactive Balance System (Sunlight Inc., Israel), had four ground reaction force sensors at each right and left foot and forefoot and hindfoot area to measure the pressure changes. Body weight changes on the sensors were evaluated to calculate the posture variables. Spontaneity index was calculated after two of the A, B, C, and D, ground reaction force sensors were selected. The measured vibration values ranged from -1,000 to 1,000. The normal absolute value was 700 or higher. The lower level signified deteriorating balance¹⁵). Balance was evaluated in a quiet room with minimal external stimulation. The subjects stepped on the force platform on bare feet without holding anything, and stood still, facing forward. The tests were conducted in a standing position facing forward with their eyes open, and in the same position on an unstable spring plate (31 cm × 12 cm). Each test was conducted for 32 seconds. When the subjects were on the spring plate, the tester was there to stand by them to prevent any accidents.

The statistical analyses were performed using Windows SPSS version 12.0. The Mann-Whitney U test was used to compare pressure distribution according to BMI. The two-way ANOVA test with repeated measurement was also used to compare balance according to BMI. Statistical significance was accepted at $\alpha=0.05$.

RESULTS

Both groups did not show a significant difference in forefoot peak pressure in the static condition according to BMI (Table 2); and no significant difference in hindfoot peak pressure either (Table 3). Both groups showed significant differences in the spontaneity index on a stable surface according to BMI between the areas, but showed no significant difference between the groups. Moreover, no significant difference was observed between the groups and areas (Table 4). On an unstable surface, both groups showed significant difference between the areas, but showed no significant difference between the groups, and there was no significant difference between the groups and areas either (Table 5).

DISCUSSION

In this study, both plantar pressure and spontaneity balance were investigated according to BMI to obtain data for future use in the fields of physiotherapy intervention, assistive devices, and shoes that address foot diseases.

According to the Kim et al.¹⁶) study on "Peak pressure changes in the forefoot area according to the metatarsal pad size

Table 4. Comparison of spontaneity index (%) in both groups on a stable surface (%)

	AB	CD	AC	BD
Normal BMI group (n=10)	-783.6 ± 99.2	-795.4 ± 118.1	515.4 ± 215.9	-692.9 ± 139.0
Obesity BMI group (n=10)	-538.3 ± 326.2	-608.4 ± 282.9	109.6 ± 379.4	-594.3 ± 431.4

Mean ± SD. AB: left fore/hindfoot; CD: right fore/hindfoot; AC: left/right hindfoot; BD: left/right forefoot

Table 5. Comparison of spontaneity index (%) in both groups on an unstable surface (%)

	AB	CD	AC	BD
Normal BMI group (n=10)	-799.5 ± 116.1	-746.3 ± 189.6	561.1 ± 278.2	718.1 ± 120.7
Obesity BMI group (n=10)	-523.5 ± 345.2	-701.1 ± 209.1	43.7 ± 626.1	665.6 ± 93.3

Mean ± SD. AB: left fore/hindfoot; CD: right fore/hindfoot; AC: left/right hindfoot; BD: left/right forefoot

and shape,” the peak forefoot plantar pressure decreased with the use of a shoe pad. According to the Lee et al.¹⁷⁾ study on “Effects of the metatarsal pad on the sole pressure in normal adults,” the pressure was significantly low in the areas of hindfoot, midfoot, and the 3rd, 4th, and 5th metatarsal bones. This meant that the use of a metatarsal pad had resulted in no significant changes in foot pressure. Shoes and metatarsal pads were not used in this study, but no significant changes were observed in the forefoot and hindfoot areas.

According to the Barbosa et al.¹⁸⁾ study on the ability to maintain balance in the daily activities of low and high BMI groups, the high BMI group showed decreased quickness and ability to maintain balance. Lee et al.¹⁹⁾ on the gait of mentally retarded children, the contact surface decreased in all areas, and the contact ratio decreased in the hindfoot and midfoot areas, while the ratio increased in the forefoot area. Similar to the above-mentioned study, a decreased hindfoot contact ratio and spontaneity balance with swaying posture were expected in this research. The outcomes correspond with those of this study, which confirmed a decrease in the spontaneity balance index in the hindfoot area of both the normal and obese BMI groups. This is thought as a mechanism of compensating for the decreased hindfoot balance in the forefoot area, and forefoot pressure will increase to compensate for balance.

Many studies on plantar pressure and balance have been conducted, but the effects of BMI on plantar pressure have not been sufficient. Moreover, many comparative studies on plantar pressure and balance in patients suffering from specific diseases have been conducted, but not many of them were on foot changes among the general population. Among the limitations of this study is its small sample size. Further studies in the future involving more samples of various ages may enhance reliability with a variety of outcomes. The results of this study may be used as basic data for exercise programs to enhance hindfoot spontaneity balance in the obesity group by increasing forefoot balance, or for studies on reducing foot swaying.

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