

## Comparison of Foot Posture, Joint Position Sense, Dynamic Balance, and Plantar Pressure between Young Adults with and without Obesity

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**Background** Obesity has been suggested as a social issue, but problems in the foot and ankle have not been clearly identified in people with obesity.

**Purpose** To compare foot posture, joint position sense, dynamic balance ability, and plantar pressure in obesity group (OG) and normal weight group (NWG).

**Study design** Cross-sectional study

**Methods** This study included 52 adults (26 for OG and 26 for NWG). All subjects had their foot posture index-6 and joint position sense (20° of inversion, 20° of plantar flexion, 10° of eversion, and 10° of dorsiflexion) measured, as well as their dynamic balance ability using a dynamic balance test and plantar pressure of the medial forefoot during the dynamic balance test. These variables were compared between OG and NWG.

**Results** OG showed significantly larger joint position sense error for eversion and increased plantar pressure of the medial forefoot during the dynamic balance test in the posteromedial direction. Significant differences were unobserved in other variables between the two groups.

**Conclusions** Adults with obesity have deficits in joint position sense and increased plantar pressure of the medial forefoot.

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**Key words** Dynamic balance; Foot posture index; Joint position sense; Obesity; Plantar pressure.

### INTRODUCTION

Even before the COVID-19 pandemic, obesity was identified as a social issue. Due to this pandemic, governments worldwide imposed some restrictions, such as social distancing, telecommuting, and isolation, on daily activities to protect public health.<sup>1</sup> This leads to decreased physical activity, necessitating an increased number of young people with overweight or obesity.<sup>2</sup> Therefore, exploring obesity-related problems is crucial.

Obesity could affect posture, arch, function, and muscle strength of the foot and ankle, inducing various musculo-

skeletal diseases.<sup>3,4</sup> For instance, a recent meta-analysis study revealed that obesity is one of the risk factors for flat foot.<sup>5</sup> Notably, flat foot is significantly correlated with body mass index (BMI).<sup>6,7</sup> The BMI, a value obtained by dividing weight (kg) by the square of the height (m<sup>2</sup>), is used as an indicator of obesity. The WHO obesity criteria revealed that Asian adults are classified as normal (18.5–22.9 kg/m<sup>2</sup>), underweight (<18.5 kg/m<sup>2</sup>), overweight (23–24.9 kg/m<sup>2</sup>), and obesity (≥25 kg/m<sup>2</sup>) using the BMI value.<sup>8</sup>

Since obesity affects foot deformity,<sup>3,4,9,10</sup> variables that may be affected by foot deformity, such as foot structure, balance ability, and plantar pressure, need to be identified

when evaluating the characteristics of people with obesity.<sup>11,12</sup> The foot posture index-6 (FPI-6) is a widely used tool for evaluating structural deformity of foot.<sup>13</sup> FPI-6 was used to evaluate foot structure in previous studies that examined injury risk factors in athletes, treatment of plantar heel pain, and orthosis treatment.<sup>14</sup> However, studies that have evaluated foot structure with FPI-6 based on the BMI are insufficient.

As structural deformities and instabilities of the foot and ankle are intensified in functional activities with weight bearing, evaluating the dynamic balance ability and joint position sense of the ankle and subtalar joint is important.<sup>12,15</sup> Notably, increased BMI has been associated with reduced dynamic balance ability in firefighters.<sup>16</sup> Male athletes with ankle sprain had a higher BMI and reduced dynamic balance ability than those without ankle sprain.<sup>17</sup> However, no previous studies have measured the changes in plantar pressure caused by pronation during a dynamic balance test in adults with obesity.<sup>16,17</sup> In addition, joint position sense is mainly impaired in subjects with ankle injury, leading to loss of protective reflexes.<sup>15</sup> Despite the functional importance of joint position sense in ankle and subtalar joint, studies identifying joint reposition sense in adults with obesity are limited.

Overall, to structurally and functionally evaluate foot and ankle musculoskeletal problems that may be caused by obesity, evaluations of foot structure, joint position sense, and dynamic balance should be included. Therefore, this study compared FPI-6, joint position sense, dynamic balance ability, and plantar pressure between adults with and without obesity.

## METHODS

### Subjects

The sample size was determined by G-Power analysis

using 0.8 statistical power, 0.8 effect size, and 0.05 significance level. Based on the G-Power analysis, 52 adults (26 adults with obesity and 26 adults with normal weight) who fully understood the purpose of this study and agreed to participate in it were recruited. According to the WHO guidelines, the subjects were classified into the normal weight group (NWG) (<25 kg/m<sup>2</sup> of BMI) and the obesity group (OG) (≥25 kg/m<sup>2</sup> of BMI).<sup>18</sup> Those with foot and ankle diseases, pain in the foot and ankle, or neurological diseases, or those taking drugs related to obesity and diseases were excluded from this study. Table 1 lists the general characteristics of all subjects, and the Catholic University of Pusan Institutional Review Board (CUPIRB-2019-063) approved the study procedure.

### Foot posture index-6

FPI-6, which comprises 6 items, is widely used for evaluating structural foot deformity. The scores can be given from -2 to +2 for each section. A total score of 0 to 5 is classified as normal, 6 or more as pronated foot, and -1 or less as supinated foot.<sup>13</sup>

### Evaluation of joint position sense

To perform the joint position sense test of the ankle and subtalar joint, an examiner first moved the subject's ankle and subtalar joint throughout the range of motion, after which the examiner passively moved the subject's ankle and subtalar joint at a specific position within the range of motion and held it for 3 s. Second, the examiner instructed the subjects to actively place their ankle and subtalar joint at a specific position set by the examiner. In this study, the specific positions were set at 20° of inversion, 20° of plantar flexion, 10° of eversion, and 10° of dorsiflexion.<sup>19</sup> The difference angle value between the specific position angle and the subject's reposition angle was measured using a goniometer. Each movement was repeated three times, and the

Table 1. Descriptive data of dependent variables

	NWG (n=26)	OG (n=26)	<i>t</i>	<i>p</i>
Age (year)	21.96±2.24	21.46±1.53	0.941	0.351
Height (cm)	167.50±8.92	170.50±9.58	-1.168	0.248
Weight (kg)	62.27±11.32	84.08±13.48	-6.320	<0.001*
BMI	22.04±2.42	28.84±3.32	-8.434	<0.001*
Gender	Female=12 (46.2%) Male=14 (53.8%)	Female=12 (46.2%) Male=14 (53.8%)	-	-
Dominant foot	Right=25 (96.2%) Left=1 (3.8%)	Right=23 (88.5%) Left=3 (11.5%)	-	-

NWG, normal weight group; OG, obesity group.

\**p*<0.05.

mean value was calculated.

### Dynamic balance test

To measure dynamic balance ability, the subjects performed the Star Excursion Balance Test in anterior, posteromedial, and posterolateral directions.<sup>20</sup> The subjects stood with the dominant legs on a plantar pressure analyzer and reached the free limb (e.g., the nondominant leg) in anterior, posteromedial, and posterolateral directions. After six practice trials in each direction, two test trials were performed in each direction in a randomized order. The reach distance was normalized to the dominant limb length, and the composite reach distance was determined as the mean value of the normalized reach distances in three directions.

### Measure of plantar pressure

To evaluate the amount of pronation movement during the dynamic balance test, plantar pressure distribution on the medial forefoot was measured using a plantar pressure analyzer (FDM-S, Zebris Medical GmbH, Germany). In this study, pressure distribution was calculated by averaging the pressure values in six columns (Figure 1).

### Experimental procedures

All tests were performed in the following order: FPI-6, joint position sense test, dynamic balance test with measures of plantar pressure. A 3-min rest period was provided after each test, and a 1-min rest period was taken between repeated measurements.

### Statistical analysis

The general characteristics of the subjects were analyzed with descriptive statistics, and an independent *t*-test was performed to examine the differences in FPI-6, joint position sense, dynamic balance, and plantar pressure between the two groups. For statistical analysis, the SPSS 18.0 for Windows program (SPSS Inc., Chicago, USA) was used, and the statistical significance level was set to 0.05.

## RESULTS

FPI-6 scores and joint position sense did not significantly differ ( $p>0.05$ ; Table 2), except for joint position sense for eversion, between the two groups. In the joint position sense for eversion, OG showed a significantly larger position sense error than NWG (effect size=0.682,  $p=0.017$ ; Table 2).

No significant differences were found in dynamic balance ability between the two groups ( $p>0.05$ ; Table 3). In addition, plantar pressure was significantly greater in OG than

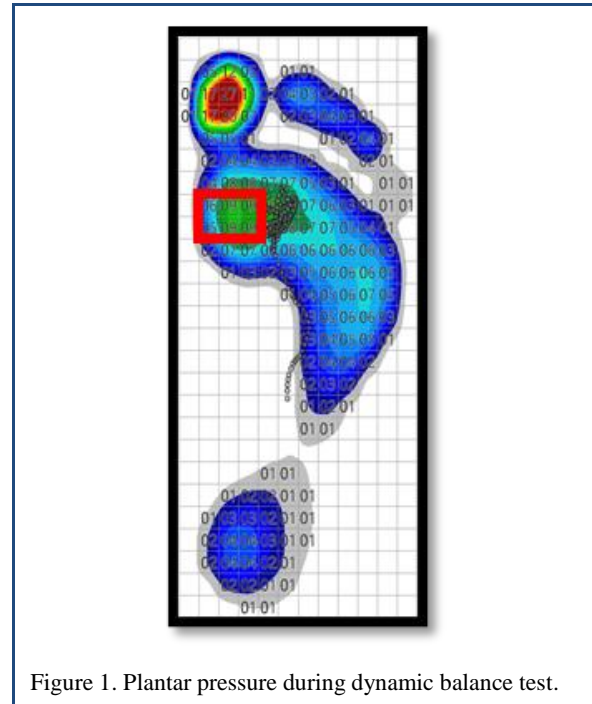


Figure 1. Plantar pressure during dynamic balance test.

in NWG during only the posteromedial reach (effect size=0.687,  $p=0.017$ ; Table 3) but not the anterior and posterolateral reaches ( $p>0.05$ ; Table 3).

## DISCUSSION

In this study, no significant difference was observed in the FPI-6 scores between OG and NWG ( $p=0.388$ ). Similarly, a previous study showed that BMI was not clearly associated with FPI.<sup>21,22</sup> However, another previous study found higher FPI scores in individuals with obesity compared to individuals with overweight.<sup>23</sup> In this previous study,<sup>23</sup> the criteria for obesity were 30 kg/m<sup>2</sup> or higher, and the criteria for overweight were 25–29.9 kg/m<sup>2</sup>. However, in the present study, 25 kg/m<sup>2</sup> or higher were used as the criterion for obesity. In addition, the average BMI of OG in this study was 28.84 kg/m<sup>2</sup>, which corresponds to being overweight by Western criteria. Moreover, Unver et al.<sup>23</sup> showed no significant difference in FPI scores between individuals with normal weight and those with overweight, supporting our results. Therefore, differences in obesity criteria between Asia and the West may have led to conflicting results between the previous<sup>23</sup> and present studies.

Although a previous study found that male athletes who suffered ankle sprain had lesser anterior reach distance during dynamic balance test as well as higher BMI than those without ankle sprain,<sup>17</sup> no significant difference in reach distance between the two groups during dynamic balance test was found in the present study ( $p>0.05$ ). This

Table 2. Comparison of foot posture index-6 and ankle joint position sense between two groups

	NWG (n=26)	OG (n=26)	<i>t</i>	<i>p</i>
FPI-6 (score)	3.42±1.72	3.85±1.78	-0.870	0.388
Dorsiflexion (°)	1.87±1.06	1.77±1.28	0.294	0.770
Plantar flexion (°)	1.44±1.31	1.67±1.04	-0.703	0.486
Inversion (°)	1.38±1.00	1.33±1.02	0.206	0.838
Eversion (°)	0.96±0.84	1.71±1.31	-2.468	0.017*

NWG, normal weight group; OG, obesity group; FPI, foot posture index.

\* $p < 0.05$ .

Table 3. Comparison of dynamic balance and plantar pressure of the medial forefoot between two groups

	NWG (n=26)	OG (n=26)	<i>t</i>	<i>p</i>
Reach distance - Composite (% limb length)	94.61±11.39	95.73±10.58	-0.369	0.714
Reach distance - Anterior (% limb length)	85.26±9.81	87.78±9.42	-0.945	0.349
Reach distance - Posteromedial (% limb length)	104.56±15.83	105.74±17.55	-0.256	0.799
Reach distance - Posterolateral (% limb length)	94.00±15.99	93.67±14.27	0.079	0.938
Plantar pressure - Anterior (N/cm <sup>2</sup> )	7.09±1.90	7.33±2.08	-0.425	0.672
Plantar pressure - Posteromedial (N/cm <sup>2</sup> )	6.42±2.17	7.91±2.17	-2.464	0.017*
Plantar pressure - Posterolateral (N/cm <sup>2</sup> )	6.28±2.23	6.83±1.90	-0.952	0.346

NWG, normal weight group; OG, obesity group.

\* $p < 0.05$ .

conflicting finding may result from the different characteristics of subjects. Subjects had ankle sprain in the previous study,<sup>17</sup> whereas, in this study, individuals who had pain or disease in foot and ankle were excluded. Moreover, a previous study found significantly different reach distance and BMI only in males but not females;<sup>17</sup> however, our study included both males and females. Therefore, the characteristics of the subjects may influence our results.

In the present study, plantar pressure was significantly increased only in the posteromedial direction during the dynamic balance test in the OG compared to the NWG ( $p = 0.017$ ), suggesting that adults with obesity used a subtalar pronation strategy to perform a dynamic balance test in the posteromedial direction. Pronation occurs with eversion and abduction of the subtalar joint.<sup>24</sup> Therefore, increased eversion may induce increased pronation. The present study found a significantly greater position sense error for eversion in OG ( $p = 0.017$ ), indicating that OG may perform unnecessary eversion movement. Therefore, based on our findings, a deficit of joint position sense for eversion induced excessive eversion during a dynamic balance test in the posteromedial direction, thereby increasing plantar pressure of the medial

forefoot in OG. Increased BMI may be another possible explanation for the different plantar pressures of the medial forefoot between the two groups. Because obesity could lead to flat foot caused by lowered medial longitudinal arch,<sup>11,25</sup> the assumption that flat foot increases the plantar pressure of the medial forefoot is reasonable. The findings of Park and Park<sup>11</sup>, which revealed a significant increase in the plantar pressure of the medial forefoot during standing in individuals with obesity compared to individuals with normal weight, support our hypothesis. Therefore, based on the previous and present studies, a lower medial longitudinal arch caused by increased BMI can increase the plantar pressure of the medial forefoot during both static and dynamic balance tests.

This study has some limitations. First, we inferred that the lower medial longitudinal arch may influence plantar pressure, but the height of the medial longitudinal arch was not measured in this study. Second, this study examined differences in joint position sense and plantar pressure between OG and NWG but did not suggest interventions to improve these differences. Based on previous studies identifying the effects of strengthening exercise of foot and ankle

muscles on joint position sense,<sup>26,27</sup> future studies should investigate whether strengthening exercise of foot and ankle muscles can improve joint position sense in individuals with obesity.

## CONCLUSIONS

This study demonstrated that adults with obesity have deficits in joint position sense for eversion and increased plantar pressure of the medial forefoot during the postero-medial reach of dynamic balance test. Therefore, to prevent foot and ankle musculoskeletal diseases, management that can correct abnormal joint position sense and plantar pressure in individuals with obesity is needed.

### Key Points

**Question** Is there a difference in foot posture, joint position sense, dynamic balance ability, and plantar pressure between adults with obesity and those with normal weight?

**Findings** Adults with obesity have deficits in joint position sense and increased plantar pressure of the medial forefoot.

**Meaning** Adults with obesity have characteristics that can cause foot and ankle musculoskeletal diseases compared to those with normal weight.

### Article information

Conflict of Interest Disclosures: None.

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