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ORIGINAL ARTICLE

# Influence of Obesity on Postural Stability in Young Adults

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**Abstract**
**Objectives:** The purpose of this study was to determine whether obesity is associated with less postural stability in young adults, and whether it is influenced by anterior pelvic tilt angle and sensory dysfunction.
**Methods:** Center of gravity (COG) velocity and total sway distance with eyes open or eyes closed on firm or foam floors were determined in 12 obese individuals and 12 individuals with normal weight.
**Results:** On firm and foam floors with eyes closed, center of gravity velocity and total sway distance were significantly greater in the obese group than in the normal-weight group. However, on firm and foam floors with eyes open, center of gravity velocity and total sway distance were not significantly different in the two groups.
**Conclusion:** The clinical implication of our findings is that obese young adults exhibit poor postural stability. Our findings also suggested that postural instability in obese individuals is associated with increased lordosis due to abdominal fat and poor integration of plantar somatosensory input.

## 1. Introduction

Obesity is related to various medical complications, such as heart disease, diabetes, cancer, breathing problems, and disabling musculoskeletal conditions that impede quality of life [1—3]. Obesity is also associated with postural instability [4], which is commonly described as the ability to maintain or restore the center of mass with respect to the base of support. Several systems, such as the brain, visual, vestibular, proprioceptive sense, and musculoskeletal systems, contribute to the control of postural stability while standing [5], and deficits in these systems result in postural instability. Previous studies have suggested that obese individuals are at increased risk of falling [6,7]. Vincent et al [8] reported that obese individuals have reduced functional ability as compared with individuals with normal weight.

Several hypotheses have been proposed to explain the effect of body weight on balance control in obese individuals. In obese individuals, body geometry is modified by the increased mass of body segments [9,10]; for example, previous studies have reported that obese individuals have significantly greater trunk mass and that increased abdominal fatness is correlated with a higher body mass index (BMI) [9,10]. Increased abdominal fatness contributes to increased lumbar lordosis and anterior shift of the center of gravity (COG) [6,11]. Another hypothesis concerns changes of sensory functions of lower limb [4,12]. Hue et al [4] suggested

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that obese individuals have reduced sensory functions of lower limb due to the pressure generated by large mass. These altered body geometry and impaired sensibility impose functional limitations and postural instability that impact the activities of daily life.

Therefore, the purposes of this study were to determine whether obesity is associated with decreased postural stability in young adults, and whether postural instability is influenced by the angle of anterior pelvic tilt and sensory dysfunction.

## 2. Materials and methods

### 2.1. Participants

Twenty-four healthy young volunteers, age range 20−26 years, were equally allocated to one of two groups, a normal group (BMI $< 25$ kg/m$^2$) and an overweight group (BMI $> 25$ kg/m$^2$), in accord with the World Health Organization classification (World Health Organization, 2003) [13]. Table 1 details the physical and anthropometrics characteristics of the 24 study participants. Candidates were excluded if they had a balance problem, cardiovascular disease, or diabetes; were pregnant at the time of assessment; had an uncorrected vision problem; or had a severe musculoskeletal injury of the lower limb that might interfere with assessments. Prior to participation, the purpose of this study was explained to all participants and all provided informed consent. This study was approved by the local committee of the Institutional Review Board of a Cheongju University, Cheongju, Republic of Korea and was conducted in accord with the ethical principles of the Declaration of Helsinki.

### 2.2. Measurements

Waist circumference was recorded to the nearest 1 mm at the midpoint between the lowest rib and the superior border of the iliac crest using an inelastic measuring tape. Hip circumference was measured at the maximum posterior extension of the buttocks, and BMI was calculated by dividing body weight (kg) by the square of body height (m$^2$).

A palpation meter (PALM; Performance Attainment Associates, St. Paul, MN, USA) was used to measure anterior pelvic tilt angle. After palpating the anterior superior iliac spine and posterior superior iliac spine, an examiner attached a tape to these bony landmarks. The examiner then placed one caliper arm tip of the palpation meter on the anterior superior iliac spine and the other on the posterior superior iliac spine. An intraclass correlation coefficient of 0.92−0.99 has been reported for measurements of pelvic tilt using this technique [14,15].

Postural stability was evaluated using a force platform (IBALANCE; Cybermedic Co., Iksan, Korea) of size 600 mm $\times$ 400 mm, equipped with four load cells to determine the locations of COGs. During postural stability tests, the participants were asked to stand barefoot and adopt a comfortable stance on the platform. With arms alongside the body, the mean COG sway velocity and total sway distance were measured under four conditions, that is, with or without a layer of foam rubber on the supporting base, and/or with eyes open or close. These conditions were defined as follows: Condition 1 = hard surface with eyes open, Condition 2 = hard surface with eyes closed, Condition 3 = foam surface with eyes open, and Condition 4 = foam surface with eyes closed. All trails lasted 10 seconds and were initiated with eyes open. For measurements with eyes closed, an auditory signal indicating that the participant closed his/her eyes was given 5 seconds before trails. Each participant repeated the four conditions three times.

### 2.3. Statistical analysis

SPSS version 12.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. The Kolmogorov−Smirnov test was used to determine whether data were normally distributed, and the significance of intergroup differences in age, height, weight, waist circle, pelvic angle, BMI, and balance capacity was determined using the independent $t$ test. Statistical significance was accepted for $p < 0.05$.

**Table 1.** General characteristics of the participants.

| | Obese group ($n$ = 12) | Normal-weight group ($n$ = 12) | $t$ | $p$ |
|---|---|---|---|---|
| Gender (male/female) | 5/7 | 5/7 | | |
| Age (y) | 22.50 ± 2.43 | 21.83 ± 1.11 | 0.86 | 0.401 |
| Weight (kg) | 84.06 ± 14.95* | 58.00 ± 10.06 | 5.01 | < 0.001 |
| Height (cm) | 166.76 ± 11.54 | 169.33 ± 11.55 | 0.56 | 0.582 |
| Waist circumference (cm) | 99.83 ± 8.33* | 76.67 ± 4.71 | 8.38 | < 0.001 |
| Hip circumference (cm) | 111.25 ± 6.83* | 91.17 ± 4.53 | 8.89 | < 0.001 |
| BMI (kg/m$^2$) | 30.02 ± 1.89* | 20.12 ± 2.19 | 11.85 | < 0.001 |
| Anterior pelvic tilt angle (°) | 8.75 ± 3.36* | 4.33 ± 2.27 | 3.77 | 0.001 |

Data are presented as mean ± standard deviation. * Significant difference between the obese and normal-weight groups ($p < 0.05$). BMI = body mass index.

## 3. Results

No significant differences were observed between the obese and normal-weight groups in terms of sex, age, and height, but weight, waist and hip circumferences, BMI, and anterior pelvic tilt angle were significantly different.

The means ± standard deviation of COG velocity and total sway distance scores for the two groups during four conditions are shown in Table 2. On a firm and foam base with eyes closed (Conditions 2 and 4), COG velocity and total sway distance were significantly greater in the obese group. However, on a firm and foam base with eyes open (Conditions 1 and 3), COG velocity and total sway distance were not significantly different.

## 4. Discussion

The objective of this study was to determine whether obesity negatively affects postural stability in young adults. This study was a cross-sectional study, and no intervention was undertaken. Our study found that young overweight or obese individuals swayed faster and had greater sway displacement than normal-weight individuals in the eyes-closed condition on firm or foam floors. These results suggest that obese individuals have less ability to maintain postural stability when compared with individuals with normal weight.

There are at least two reasons why postural stability is influenced by obesity. The first is related to the contribution made by an altered body geometry in obese individuals. In the present study, pelvic anterior tilt was significantly higher in the obese group. The degree of pelvic tilt is associated with lumbar posture, because the lumbar spine is connected to the pelvis and an increased anterior pelvic tilt can lead to excessive lumbar extension [16]. The increased anterior pelvic tilt in obese individuals might be caused by an alteration of body geometry due to increased abdominal fat. Onyemaechi et al [11] reported that obese individuals had a significantly higher mean lumbar lordosis angle. To demonstrate the mechanism whereby upright standing balance is achieved, the human body is often compared with an inverted pendulum model [17], and because anterior tilt is increased by adipose tissue accumulation in the abdominal area, body COG is displaced forward at the ankle joint [6,18], which means that obese individuals need to adopt a larger corrective ankle torque in order to counter a greater gravitational torque. Corbeil et al [6] also suggested that obese individuals with abnormal amounts of abdominal body fat may be at greater risk of falling than normal-weight individuals.

Another possible explanation of the relationship between postural stability and increased body weight relates to the contribution made by foot mechanoreceptors to balance control. Several studies reported that obese individuals have a larger plantar contact area and greater mean pressure values [19–21]. For example, Hills et al [22] showed significantly greater pressure in the heels, midfoot, and metatarsal head in obese individuals. These results are important because desensitization of mechanoreceptor afferents might be induced by prolonged suprathreshold stimulation, and under such circumstances, sensory signals from mechanoreceptor would be less reliable. Bensmaïa et al [23] have also shown that prolonged suprathreshold vibratory stimulation was found to result in a reversible decrement in afferent sensitivity. This suggestion is reinforced by our result that obese individuals showed greater postural instability in the eyes-closed condition, but not in the eyes-open condition. These results suggest that visual inputs are used to compensate for postural instability caused by impaired plantar sensitivity in obese young adults. In addition, COG velocity and total sway distance on a firm and foam base with eyes open were not significantly different. Especially, we anticipated that foam base with eyes open is a significantly different in between the obese and normally weighted groups. As mentioned above, we think that these results were preferentially

**Table 2.** Means (±SD) of COG sway velocity and total distance in the obese and normal-weight groups.

| Parameters | | Obese group ($n$ = 12) | Normal group ($n$ = 12) | $t$ | $p$ |
|---|---|---|---|---|---|
| Firm-EO | COG velocity (cm/s) | 4.22 ± 0.78 | 3.978 ± 0.46 | 0.93 | 0.361 |
| | Total distance (mm) | 323.58 ± 50.87 | 295.58 ± 43.39 | 1.45 | 0.161 |
| Firm-EC | COG velocity (cm/s) | 18.74 ± 2.87* | 16.65 ± 1.92 | 2.20 | 0.039 |
| | Total distance (mm) | 385.75 ± 60.28* | 333.17 ± 52.73 | 2.27 | 0.033 |
| Foam-EO | COG velocity (cm/s) | 23.22 ± 4.79 | 20.18 ± 5.87 | 1.39 | 0.179 |
| | Total distance (mm) | 442.83 ± 92.88 | 393.75 ± 97.35 | 1.26 | 0.220 |
| Foam-EC | COG velocity (cm/s) | 39.24 ± 7.38* | 29.87 ± 7.64 | 3.07 | 0.006 |
| | Total distance (mm) | 731.42 ± 109.40* | 570.17 ± 130.59 | 3.28 | 0.003 |

Data are presented as mean ± standard deviation. * Significant difference between pre- and post-test ($p < 0.05$). COG = center of gravity; EC = eyes closed; EO = eyes open.

influenced by visual compensation rather than decreased foot mechanoreceptor.

Postural stability is essential for the activities of daily living, and our results show that postural stability is poorer in obese individuals. In addition, our study findings also indicate that instability in obese individuals is associated with an altered body geometry following increased lordosis and poor somatosensory integration. Clinically, our findings imply that obesity reduces balance ability and suggest obese individual are at greater risk of fall. Therefore, obesity could be considered as another potential contributing factor for fall. However, the present study has some limitations that require considerations. First, the study cohort was restricted to young obese adults, and thus, our results may be valid only in this population. Second, this study was conducted using a small sample of individuals, and variables of lower limb sensory function were not directly measured. However, adding a foam surface perturbs lower limb somatosensory information and use of visual block is also identified to the accuracy of lower limbs somatosensory information, because the use of a foam surface and visual block places greater reliance on the remaining lower limb of sensory system.

## Conflicts of interest

The author has no conflicts of interest to declare.

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