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Plantar Foot Pressure Distribution of Middle-Aged Obese Women while Walking Over Obstacles of Different Heights

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Abstract. [Purpose] The purpose of this study was to investigate the effect of degree of obesity on the plantar pressure when middle-aged women walked over an obstacle. [Subjects] The subjects of this study were twenty-seven middle-aged female adults. The subjects were divided into a normal group (n=5), an overweight group (n=8), a lightobesity group(n=7), middleobesity group (n=7). The subjects were asked to step on a foot scanner immediately before crossing over an obstracle (height 0 cm, 10 cm, or 20 cm) while walking on a road 10 m course that was and 1 m wide at a speed of 80 m/min. The mean pressure value for each obstacle height was calculated from three trials. The pressure measurement was performed by dividing the sole into seven regions. [Result] Under the 0 cm height condition, the pressures at the hallux and heel were significantly greater in the overweight group, the lightobesity group, and moderateobesity group than in the normal group. Under the 10 cm height condition, the pressure at the hallux, the first metatarsal, and the heel in the moderateobesity group was significantly different from that in the normal group, overweight group, and the lightobesity group. Under the 20 cm height condition, there were no significant difference among any of the groups in any region. [Conclusion] An increase in weight in normal middle-aged women may result in an increase plantar pressure at certain regions when walking over obstructions that were 10 cm or higher, and may cause abnormal gait by inducing a motor abnormality at the ankle joint.
Key words: Obesity women, Obstruction gait, Plantar foot pressure

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INTRODUCTION

Walking is the most fundamental human movement. It is a series of continuous procedures that involve all physiological and neurological the systems used by a person including the nervous system and the musculoskeletal system[1)]. In particular, crossing over an obstacle while walking is a task that requires very harmonious joint movement in which the lower limb in its swing phase is delicately regulated the body balance is maintained as the lower limb in its stance phase is in direct contact with the ground. Moreover, as the height of the obstracle to be overcome increases, the activity of the lower limbs increases to maintain the balance[2)]. However, decreasing power of the lower limbs to control interactive and complicated activities result in coordination between the lower limbs in the stance and swing phases to be lost, causing a fall as the person stumbles over an obstacle or loses balance of the entire body. Also, as the age of a person increases, the proprioceptive sense becomes gradually dulled, and posture a imbalance occurs due to decreased nervous system capabilities such as sensory information input and righting reflex reaction[3)].

The human foot is a complex segment that performs three-dimensional motion[4)]. It is essentially unstable in the orthostatic position because a high center of gravity is maintained on a relatively small base area. Additionally, body weight can be an internal factor affecting foot pressures[5)]. Since the structure of the foot and the plantar foot pressure of obese people, who have different body alignment, are different from those of the normal persons, they have a higher risk of fall and fracture because of their lack of positional stability and limitations of the motion[6)].

Most of previous studies of obstacle crossing have focused on the effects the action of crossing over an obstacle have on the plantar pressure, but a few studies have assessed the effects of balance impairment caused by increaseing age and body weight of middle-aged persons on the act of crossing over an obstruction. Therefore, in this study, we investigated the effect of obesity degree on the plantar pressure when middle-aged women walked over an obstacle.

SUBJECT AND METHODS

The subjects of this study were twenty-seven middle aged female adults. The subjects were divided into a normal group (n=5), overweight group (n=8), a slightobesity group (n=7), moderateobesity group (n=7). A description of the purpose and method of this study was provided to the subjects before the experiment and the experiment was conducted after receiving the subjects'voluntary consent. The subjects were selected from among patients who had no orthopedic or neurologic diseases that might impair balance or normal gait. The normal group's average age was 52.80 ± 2.58 years, overweight group was 48.37 ± 6.30 years, a slightobesity group was 50.85 ± 6.01 years and moderateobesity group was 48.28 ± 5.05 years. No significant differences were found between any of the groups ($p<0.05$). The normal group's average BMI value was 21.90 ± 0.68, overweight group was 24.51 ± 0.95, a slightobesity group was 27.61 ± 1.80, moderateobesity group was 39.13 ± 13.93.

To measure the plantar pressure during the stance phase when crossing over the obstacle, we employed the Footmat System (Tekscan, USA) that uses piezoresistive pressure sensors in the form of a matrix. The width of the foor mat is 702.579 mm, and 44×52 sensors were embedded in a matrix by breadth and length, respectively (MatScan user manual). The pressure distribution data while walking were collected by using commercial software, Tekscan, at a rate of 60 Hz. The sole was divided into regions and analyzed using Tekscan Pressure Measurement System Version 5.23. The sole was divided into seven regions: two toe regions, three forefoot regions, one midfoot region, and one heel region. The toes were divided into two: the hallux region and the region of the other toes. Among the three forefoot regions, the inner forefoot region was defined as the area under the first midfoot condyle, the middle region as the area under the second and third midfoot condyles, and the external forefoot region as the are under the fourth and fifth midfoot condyles[7].

The height and weight of the subjects were measured before data collection with JEXIN(KOREA) and DS-102. Inbody 4.0 (Biospace, KOREA) automatically calculates the degree of obesity as BMI (Body Mass Index) and body fat percentage; in this study we chose BMI. The subject's body composition was measured with Inbody 4.0 to divide them into the normal weight, overweight, slightobesity, and moderateobesity groups. The measured weight was input to the Footmat system, Foot mat was calibrated by asking them subjects to adopt a standing position on the pressure-measuring mat without motion for 10 seconds. An obstracle of 1 m breadth and 3 m width was prepared such that the height could be set at 0, 10, or 20 cm. On the word of command 'go', the subjects practiced the act of crossing over the obstruction for three times on a course 10 m long and 1 m wide while walking barefoot at the comfortable speed of 80 m/min which was regulated by a metronome. Then, the experiment was performed with the obstruction height being decided at random. The subjects were asked to step on the foot mat with the left foot just before crossing over the obstacle, and the mean pressure value for each obstacle height was calculated from three trials.

To examine the difference in the plantar pressure at each region (peak pressure, kPa) at each obstruction height among the groups, one-way ANOVA and the Turkey test as a post-hot test were performed with the measured mean values using the SPSS/window (version 12.0). The significance level was chosen as $p<0.05$.

RESULTS

Table 1 shows the peak plantar pressure values to the heights of obstacles crossed in walking. The plantar foot pressures of the individual areas significantly differed in areas 1, 2, 3, 6 and 7 with degrees of obesity at an obstacle height of 0 cm. The post-hoc test showed that the plantar foot pressures of area 1 and 7 were significantly different between the normal group and the overweight slightobesity, moderateobesity groups. The plantar foot pressures of area 2, 3 and 6 were significantly different between the normal group and moderateobesity group, overweight group and moderateobesity group, and the slightobesity group and moderateobesity group (Table 1) ($p<0.05$).

At an obstacle of 10 cm, significant differences in pressure were shown in areas 1, 3 and 7. The post-hoc test showed that the plantar foot pressure of area 1 and 7 were significantly different between the normal group and moderateobesity group, overweight group and moderateobesity group, a slightobesity group and moderateobesity group (Table 1) ($p<0.05$).

At an obstacle height of 20 cm, no significant differences were shown between any of the degrees of obesity (Table 1) ($p>0.05$).

DISCUSSION

Safety must come first in walking, but obstacles are an unavoidable situation in daily life. A study of walking speed and stride showed that the walking over an obstacle is more carefully performed by older persons than by young ones[8]. Recent reports have shown that the center of the plantar pressure is moved toward the forefoot as the obstacle height increases[9], and the obese lack positional stability are limited in their motion because their foot structure and plantar foot pressure distribution are different from those of normal person[6]. It was also reported that increased body weight can serve as an internal factor affecting the foot pressures in addition to quantitative changes, primarily in abdomen and lower limb size[5].

In this study, we investigated the effect the degree of obesity has on the plantar pressure when middle-aged women walked over an obstacle height of 0 cm, the

Table 1. Comparison of plantar foot pressures while crossing obstacles of different heights

Obstacle height	Area	Normal	Overweight	Slightobesity	Moderateobesity
0 cm	area 1*	88.57 ± 11.90[a]	184.35 ± 19.76[b]	182.71 ± 35.04[b]	233.17 ± 36.64[b]
	area 2*	13.53 ± 6.29[a]	17.48 ± 2.16[a]	20.34 ± 1.79[a]	41.62 ± 11.88[b]
	area 3*	81.53 ± 7.21[a]	106.26 ± 18.66[a]	134.57 ± 22.20[a]	183.27 ± 30.96[b]
	area 4	146.41 ± 15.85	169.64 ± 11.86	196.01 ± 26.27	226.27 ± 23.62
	area 5	105.92 ± 22.42	96.63 ± 14.01	115.40 ± 14.97	140.10 ± 21.88
	area 6*	45.28 ± 9.01[a]	70.22 ± 13.25[a]	64.49 ± 15.95[a]	122.67 ± 19.18[b]
	area 7*	119.86 ± 12.08[a]	174.90 ± 15.87[b]	190.31 ± 22.05[b]	194.60 ± 16.35[b]
10 cm	area 1*	99.14 ± 6.35[a]	166.44 ± 21.75[a]	168.21 ± 89.66[a]	281.30 ± 72.93[b]
	area 2	24.04 ± 10.38	12.03 ± 7.76	17.80 ± 7.03	31.70 ± 7.69
	area 3*	123.27 ± 18.36[a]	128.46 ± 14.55[a]	113.58 ± 19.11[a]	182.98 ± 19.63[b]
	area 4	164.72 ± 23.29	199.16 ± 14.71	153.06 ± 37.15	229.97 ± 37.04
	area 5	112.44 ± 45.47	123.70 ± 15.32	82.10 ± 27.17	133.07 ± 27.33
	area 6	67.98 ± 23.71	87.74 ± 74.78	74.78 ± 11.93	149.72 ± 18.67
	area 7*	156.26 ± 17.82[a]	177.58 ± 15.68[a]	149.72 ± 18.67[a]	228.52 ± 12.17[b]
20 cm	area 1	150.49 ± 38.13	179.90 ± 30.77	223.80 ± 35.27	238.79 ± 39.54
	area 2	51.51 ± 18.88	27.79 ± 5.26	26.60 ± 9.24	25.69 ± 5.77
	area 3	91.45 ± 25.60	137.30 ± 30.19	112.74 ± 17.07	179.48 ± 44.63
	area 4	162.00 ± 28.55	195.03 ± 16.97	204.56 ± 21.07	238.71 ± 30.71
	area 5	88.46 ± 17.15	129.62 ± 24.73	156.93 ± 18.16	166.58 ± 21.43
	area 6	59.16 ± 27.12	77.74 ± 16.99	70.11 ± 12.67	130.24 ± 16.59
	area 7	178.71 ± 17.57	206.32 ± 19.04	171.86 ± 16.37	205.34 ± 27.03

$p<0.05$, mean ± SE. area1, Hallux; area2, 2nd~4th toe; area3, 1st metatarsal; area4, 2nd metatarsal; area5, 3th~5th metatarsal; area6, Midfoot; area7, Heel.
NOTE. Each value represents the mean ± SE. The values with different superscripts in the same column are significantly different ($p<0.05$) according to Turky's test.

pressure at the hallux and heel was significantly higher in the overweight group, the slightobesity group, and moderateobesity group than in the normal group. This may be because an excessive pressure was imposed on the heel at the initial contact even by the weight of slightly obese persons, and a lot of pressure was imposed on the hallux for the rapid movement of the weight and the provision of driving force at the time of toe-off. Additionally, the pressures at the second to fourth toes, the first metatarsal, and the midfoot were significantly higher in the moderateobesity group than in the normal group, the overweight group, and the slightobesity group. This result indicates that, the pressure was high at those regions due to the pressure passing through the midfoot being not rapidly transferred because the ability to maintain balance while walking was lower in the moderateobesity group. This result was similar to the result of a previous study which reported that the pressure increased at the midfoot on the less-affected side during the terminal swing of the affected side when hemiplegic patients walked over an obstacle[10]. This indicates that a lack of stability is shown by increased plantar pressure at the midfoot. At the obstacle height of 10 cm, the pressure at the hallux, the first metatarsal, and the heel in the moderateobesity group was significantly different from those of the normal group, the overweight group and the slightobesity group. This was the same as the result for the obstacle of 0 cm except for the pressure at the midfoot regions. At the obstacle height of 20 cm, there were no significant differences among any of the obesity groups in any of the regions. This may be because walking over an obstacles 10 cm or higher affects the walking stability of even normal middle-aged persons, showing no significant difference in the midfoot plantar pressure. The result that there were no significant differences among the obesity groups in any of the regions at the 20 cm obstacle height may be because of a strategy to increase the base area in order to support the weight load and maintain the balance due to the weakened muscle strength and lower proprioceptive sense in the middle-aged subjects.

The present results show, that in walking over obstacles of 10 cm or higher, the body weight increase of middle-aged women causes increased plantar foot pressure at specific regions. Also, when walking over an obstacle of 20 cm, all groups increased foot pressure at specific regions. Because of aging, middle aged women need to pay attention to balance when walking over obstacles. Especially, moderately obese subjects have postural imbalance when walking on flat ground. Therefore middle-aged subjects need to balance more carefully when walking over an obstacle on flat ground.

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