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The Comparison of Pressure of the Feet in Stance and Gait by the Types of Bags

WONTAE GONG, PhD, PT[1)], SANGYEOL LEE, PhD, PT[2)], BYUNGGON KIM, PhD, PT[3)]

[1)]*13 Department of Physical Therapy, Gumi College*
[2)]*17 Department of Physical Therapy, Gimhae College: Sanbang, Gimhae, Kyeongnam, Republic of Korea 612-908. TEL: +82 55-320-1735, FAX: +82 55-336-6222, E-mail: sjslh486@hanmail.net*
[3)]*Department of Physical Therapy, Daegu Health College*

Abstract. [Purpose] This study attempted to examine the imbalance between the left and right side in standing and during gait among college students according to the way they wore their bags and the weight of the bag. [Subjects] The subjects were forty healthy Korean undergraduate students who were divided into two groups: a shoulder pack group and a backpack group. Five different weights were used for the bags: 0, 2, 5, 10 and 15 kg. [Methods] A Zebris FDM-T Treadmill (Zebris, Germany) was used for measuring plantar foot pressure. The plantar foot pressures in standing and during gait were measured using different bag types and weights. The paired t-test was used to compare plantar foot pressure between the left and right side. [Results] The backpack group did not show a significant difference between the left and right sides in standing and during gait regardless of the bag weight. Meanwhile, the shoulder pack group began to show differing plantar foot pressures between the left and right sides at a bag weight of 5 kg. However, no difference in plantar foot pressure was observed at any bag weight during gait. [Conclusion] The study results show that the plantar foot pressure differs between the left and right sides in standing when wearing shoulder packs heavier than 5 kg, while no such difference was observed during gait. Thus, walking while wearing a shoulder pack heavier than 5 kg is likely to cause musculoskeletal disorder due to the overuse of the muscle on the contralateral side.
Key words: Backpack, Plantar foot pressure, Shoulder pack

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INTRODUCTION

Postural balance control refers to the ability to appropriately manage body stability in a spatial posture during exercise, rest, etc[1)]. For normal gait, the center of the body should be on the midline at stance, specifically at 55% of the height measured from the foot, i.e., the front of the second sacral vertebra body[2)]. The center of gravity supports the gait at minimum energy expense as it enables continuous change in joint angles in a regular pattern according to the gait cycle regardless of the walking speed[3)]. Hence, the energy expense decreases and the stability increases as the load is placed closer to the center of gravity[4)]. Studies about the foot associated with research into posture balance receiving have recently been receiving an increasing amount of attention. The foot is a complicated body part that consists of multiple joints, ligament, and muscle[5)]. A foot is an appropriate criterion for body balance since it supports the whole body weight with its narrow basis. As a result, plantar foot pressure has become the focus of attention in studies investigating body balance[6)].

When walking wearing a bag, the bag's weight

causes physical stress and dynamic balance and posture change under the physical and mechanical impact of the bag[7]. When weight is loaded on a single side, individuals unconsciously lift shoulder or tilt the body toward the side where the weight is loaded with the purpose of placing the center of the body at the center of gravity. However, too heavy a bag or an undesirable type, carrying way, or location of the bag are likely to cause abnormal posture as the weight is not appropriately distributed, resulting in muscle pain and spine disorder. Spine disorders can also cause psychological dysfunction in addition to physical dysfunction. Moreover, they result in inappropriate gait movement causing insufficient absorption of impact when the foot touches the ground. As a result, injuries are likely to be incurred due to excessive fatigue in the musculoskeletal system[7,8]. While balance in static posture can be maintained without losing much energy due to the absence of acceleration in the lower limbs and trunk, maintaining balance during gait requires higher energy due to acceleration in the lower limbs and trunk, increasing instability[9]. There have been a number of studies regarding the balance in static posture and in dynamic posture, as well as regarding balance according to the location of external load[2,10]. However, there has not been enough study of external load-carrying in static posture and during gait. Hence, this study attempted to investigate balance in static posture and during gait under differing locations and amounts of external load by comparing left and right plantar foot pressure. Based on the results, we suggest appropriate bag weights and ways to wear a bag which can contribute to prevent on of musculoskeletal disorder.

SUBJECTS AND METHODS

The subjects of this study, 20 male and 20 female undergraduate students at D University, were selected from those who voluntarily submitted their written consent to participate in this experiment after receiving sufficient explanation about the research. Those with orthopedic disorders, neurosurgical disorders, or functional or anatomical differences in lower limb length were excluded from the sample. The students who did regular exercise more than three times a week were also excluded. The subjects were assigned to the experimental groups by random selection.

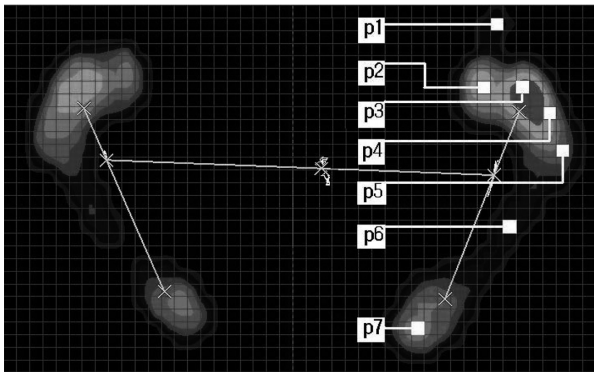

Fig. 1. Seven plantar foot pressure measurement points.

A Zebris FDM-T Treadmill (Zebris, Germany) was used for measuring the plantar foot pressure in standing and during the stance phase while walking. FDM-T Treadmill is composed of treadmill with sensors and software that conducts analysis after receiving data. The device is easy to use and it automatically examines the stance phase, center of pressure, pressure distribution, and power on each side of the foot with or without shoes.

The subjects were divided into two study groups: a backpack group who wore a backpack and a bag group who wore a bag on the right shoulder. Each group carried bags of five different weights: 0, 2, 5, 10, and 15 kg. The plantar foot pressure was measured in standing and during gait for each of the five weight. The measurement was conducted at seven points: the first interphalangeal joints (p1), the first metatarsophalangeal joint (p2), the second metatarsophalangeal joint (p3), the midpoint of the third metatarsophalangeal joint and the fourth metatarsophalangeal joint (p4), the fifth metatarsophalangeal joint (p5), the cuboid bone (p6) and the calcaneus (p7) (Fig. 1). The average value of the seven measured values was used in this study.

The measurement in standing was carried out for ten seconds while the participants maintained a standing posture on the device for 30 seconds while staring forward and resting their arms comfortably at their sides.

In order to measure natural gait while wearing the bags with different weights, the participants walked for about three minutes before the measurement procedure, looking forward and naturally swinging both arms.

To minimize data dispersion, the beginning and ending of the measurements of the plantar foot pressure in standing and during gait were not notified to the participants. The participants wore socks and short pants in order to decrease unfamiliarity with the treadmill and the resistance of trouser legs.

The order of the five different bag weights was chosen at random. Two minutes of rest were given between each measurement to prevent fatigue. Considering individual, variation, the gait rate was set at 2.5 km/h.

Statistical analysis was performed using SPSS (Windows version 12.0). A paired t-test was conducted to compare the plantar foot pressures between the left and right sides according to the way individuals wore the bag. To determine differences in the characteristics of the participants, the chi-squared test was used for gender, while the independent t-test was used for age, height, and weight. The level of significance (α) was set at 0.05.

RESULTS

The research subjects in this study were forty participants aged between 19 and 27 years old, with an average age of 21.28 ± 2.14 (mean ± SD). Their average height was 168.73 ± 8.62 cm and their average weight 64.45 ± 10.95 kg. There were 20 men and 20 women, giving equal gender proportion. The chi-squared test results for gender in the backpack and shoulder pack groups revealed statistically significant differences in height and weight, but no difference in age.

As shown in Table 1, the comparison of plantar foot pressures between the left and right sides in standing and during gait while wearing the backpack show that there were no statistically significant differences among any of the backpack weights.

Table 2 contains the results of the comparison of left and right plantar foot pressures in standing while wearing the shoulder pack and reveals statistically significant differences from 0 kg for weights of 5, 10 and 15 kg. No significant differences were found during gait for any of the shoulder pack weights.

Table 1. Comparison of plantar foot pressures during backpack wearing

	Weight	Right	Left
Stance	0	5.12 ± 3.59	5.01 ± 3.60
	2	5.26 ± 3.68	5.21 ± 3.71
	5	5.32 ± 4.02	5.26 ± 3.97
	10	5.70 ± 4.27	5.69 ± 4.53
	15	5.89 ± 4.79	5.78 ± 4.77
Walking	0	8.31 ± 3.43	8.21 ± 3.91
	2	8.53 ± 3.97	8.44 ± 3.90
	5	8.73 ± 3.98	8.74 ± 4.25
	10	9.28 ± 4.18	9.27 ± 4.80
	15	9.76 ± 4.41	9.85 ± 4.90

mean ± SD

Table 2. Comparison of plantar foot pressures during shoulder pack wearing

	Weight	Right	Left
Stance	0	5.24 ± 3.46	4.93 ± 3.98
	2	5.21 ± 3.99	4.95 ± 3.81
	5*	5.73 ± 4.43	4.77 ± 3.97
	10*	6.34 ± 5.44	4.50 ± 3.65
	15*	6.99 ± 6.50	4.12 ± 4.33
Walking	0	8.20 ± 3.92	8.10 ± 4.34
	2	8.39 ± 4.13	8.50 ± 4.56
	5	8.57 ± 4.00	8.73 ± 4.71
	10	9.03 ± 4.14	9.21 ± 4.97
	15	9.55 ± 4.43	9.97 ± 5.72

mean ± SD, * : statistically significant with $p<.05$

DISCUSSION

This study examined the plantar foot pressures during gait while carrying shoulder packs and backpacks of different weights. Due to global fashion trends, the types of bag available are more diverse than ever. However, wearing a bag on one side results in a higher weight load on that side and the body imbalance can eventually result in musculoskeletal disorders[7]. Despite the fact that it causes imbalance of the body, many people, including growing children, wear a shoulder bag for convenience.

Recent studies have argued that using backpacks causes higher abdominal muscle activation and changes in lower limb muscle activation since the body tries to bring forward, to the center of the body, the weight which tends to move to the rear[10]. Moreover, the center of gravity moves forward

when the load is placed on the front, causing higher back muscle activation for compensation[2,11]. In this study, the plantar foot pressures placed upon the left and right sides were measured when there was loading on the rear side due to a backpack. The study results show no significant difference in plantar foot pressure between the left and right sides both in standing and during gait. Moreover, no difference the between left and right sides was found among the different weights, which can be attributed to the fact that the weight load was placed on the rear side.

Previous studies regarding asymmetric load-carrying similar to the shoulder pack have argued that the range increases for maximum trunk lateral flexion to the contralateral side, maximum head lateral flexion to the contralateral side, and maximum upper arm elevation to the contralateral side during gait as load increased from 0, to 3 and 8 kg[7]. This result is consistent with the results of the present study show no difference in plantar foot pressure between the left and right sides during gait irrespective of the weight of the shoulder pack. Biomechanical balance control brings the center of gravity in to the midline through adjusting the angles of the trunk, neck, and upper limbs during gait. However, as the shoulder pack's weight increased, the weight on the side wearing the pack in standing also increased. This can be attributed to the fact that the participants did not feel instability despite the asymmetric center of gravity in standing different from during gait. However, the asymmetric activation of the trunk and back muscles increased as the weight increase in order to move the center of gravity to the middle during gait, increasing the probability of incurring musculoskeletal disorders such as muscle pain.

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