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Original Article

The effects of backpack loads and spinal stabilization exercises on the dynamic foot pressure of elementary school children with idiopathic scoliosis

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Abstract. [Purpose] The purpose of this study was to measure and observe the changes in dynamic plantar pressures when school children carried specific bag loads, and to determine whether improved physical balance after an eight-week spinal stabilization exercise program can influences plantar pressures. [Subjects] The subjects were 10 school students with Cobb angles of 10° or greater. [Methods] Gait View Pro 1.0 (Alfoots, Korea) was were based on to measure the pressure of the participants' feet. Spinal stabilization exercises used TOGU Multi-roll Functional (TOGU, Germany) training. Dynamic plantar pressures were measured with bag loads of 0% no bag and 15% of subjects' body weight. The independent t test was performed to analyze changes in plantar pressures. [Results] The plantar pressure measurements of bag load of 0% of subjects' body weight before and after the spinal stabilization exercise program were not significantly different, but those of two foot areas with a 15% load were statistically significant (mt5, 67.32±24.25 and 51.77±25.52 kPa; lat heel, 126.00±20.46 and 102.08±23.87 kPa). [Conclusion] After performance of the spinal stabilization exercises subjects' overall plantar pressures were reduced, which may suggest that physical balance improved.

Key words: Idiopathic scoliosis, Dynamic foot pressure, Backpack load

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INTRODUCTION

Scoliosis refers to three-dimensional deformations in which a more than 10° lateral flexion is formed in the spinal rotation in the coronal plane[1)]. This disease is accompanied by several symptoms, such as back pain, deformation of the thoracic cage, weakening of the respiratory muscles, and limited range of motion. Therefore, scoliosis subsequently results in a reduced quality of life[2–7)]. While the causes of idiopathic scoliosis have not been identified, various hypotheses exist, including genetic, biochemical, mechanical, neurological, myological, and hormonal factors[8)]. The most common types of idiopathic scoliosis are revealed during childhood and adolescence[1)]. Several complex problems result from this condition, including reduced control of balance, muscle imbalances, and gait asymmetry, which can exacerbate the symptoms during patients' growth phase. A previous study emphasized the importance of suppressing the progression of idiopathic scoliosis in adolescents through the early detection of the condition based on regular diagnoses and immediate treatment after diagnosis[9)].

An environmental factor that leads to scoliosis during childhood and adolescence is habitually incorrect posture. Asymmetrical gait patterns further change posture by influencing trunk balance and spinal movement. In addition, when school students carry a school bag with a weight greater than 10–15% of their body weight, they may experience reduced lung capacity and exhibit postural and gait changes, such as leaning the upper body forward and lowering the head. The continuation of these patterns puts pressure on the spine, causing musculoskeletal pain and structural spinal changes[10–12)]. In addition, when patients with idiopathic scoliosis symmetrically carry a bag with a load weight of at least 10% of their body weight on each of their shoulders while standing up, they experience changes in their physical balance and stability. Moreover, when they carry bags asymmetrically, it is recommended that they avoid carrying them on the convex surface of the shoulder[13)].

In an individual's normal gait, the ground reaction force must equal the body weight[14)]. However, abnormal gait patterns lead to the inappropriate distribution of force and pressure on the foot[15–17)]. The distribution of pressure is

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Table 1. Characteristics of the subjects

	N = 10 (M = 5, F = 5)
Age (years)	10.2±0.9
Height (cm)	144.6±7.5
Weight (kg)	38.5±6.0
Pre Cobb (°)	14.5±1.5
Post Cobb (°)	8.4±3.0
Pre load 15% (%)	5.8±0.9
Post load 15% (%)	6.0±0.9

influenced by several factors, including age, gender, weight, and ankle range of motion[16, 18, 19]. The weight of bags that students carry when they travel to and from school is added to their body weight, and the combined weight is likely to change the distribution of plantar pressures while school students are standing or walking, further exacerbating their abnormal gait patterns, back pain, foot deformations, or spinal disorders. Therefore, the purpose of this study was to measure and observe the changes in dynamic plantar pressures when the subjects carried specific bag loads, and to determine whether improved physical balance after an eight-week spinal stabilization exercise program influences plantar pressures.

SUBJECTS AND METHODS

This study was conducted a gaining approval from the institutional review board (IRB) of Kangwon University (Project No. 2014-08-002-001). This study sent information about scoliosis to the fourth, fifth, and sixth graders of K Elementary School located in Gangreung City. The Adam's Forward Bend Test was performed to identify the students who showed rotational asymmetry. Then, X-ray images were obtained, and 10 students with Cobb angles of 10° or greater were invited to participate in the experiment After the procedures of the study had been explained, the consent of these individuals to participation in this study was obtained in accordance with the ethical standards of the Declaration of Helsinki. Exclusion criteria included: severe foot deformation, abnormal gait, or muscular weakness severe enough to prevent performance of the study's exercise program. The subjects were (mean±SD) 10.20±0.92 years of age, 144.58±7.52 cm tall, and weighed 38.50±5.96 kg. Most of the participants' spinal curvatures were located on the left side (Table 1).

The plantar pressure measuring instrument Gait View Pro 1.0 (Alfoots, Korea) was used to measure the pressure applied to the soles of the participants' feet. For an accurate test, the participants were provided with preliminary education about smooth, natural gaits and a full explanation of the test's purpose. The test was performed when the subjects were capable of adopting natural gaits and after repeating several rounds of practice.

Eight plantar areas of interest were established, and kPa was chosen as the unit of measurement. After measuring the target areas, the analysis was conducted. The subjects' heights and body weights were measured using a GL-150 (G-Tech International, Korea) height and weight measuring instrument, and a 15% calculation of the participants' measured body weights was performed. The weights of the bags that were used in the experiment were set using the SH-999 (Shibata Korea, China) digital portable baggage scale. The average weight of the subjects' bags was 15% of their body weight, which was 5.76±0.90 kg before the exercise program, and 6.00±0.93 kg after the exercise program (Table 1).

The spinal stabilization training exercise model was performed after reorganizing the exercise methods used in previous studies and basing them on the segmental stabilization exercise model[20, 21]. The study's spinal stabilization exercises were based on TOGU Multi-roll Functional (TOGU, Germany) training. Each subject performed upper- and lower-extremity separation in the supine position on an unstable base of support, axial rotation of the trunk while on their knees, and upper- and lower-extremity separation in the prone position. The participants were instructed to perform three sets of each exercise, and they maintained the position at the end of each motion for three seconds. They were then given a 60-second break after each set, so they relaxed a total of 12 times.

The participants' dynamic plantar pressures were measured with a bag load of 0% of their body weight, i.e. not carrying a bag, and a bag load of 15% of their body weight, when carrying a bag. This experiment used the bags the subjects carried when while they attended school. The participants began walking at a specific distance from the plantar pressure analysis plate. They were instructed to place their target foot on the plate with the fourth step they took. The participants kept looking forward, as if they were walking naturally. They were instructed to refrain from looking down at the plate as much as possible. After the initial plantar pressure measurements, an eight-week spinal stabilization exercise program was implemented. This program was conducted in three one-hour sessions each week. After the exercise program ended, the dynamic plantar pressures of the participants were again measured using the same method.

SPSS Statistics Version 18 was employed for statistical analyses, and all the data are presented as averages and standard deviations. The independent t-test was performed to analyze the changes in plantar pressures between the bag loads of 0% and 15% of the subjects' body weight before and after the spinal stabilization exercise program. The statistical significance level was chosen as $\alpha=0.05$.

RESULTS

Table 2 presents the dynamic plantar pressure data of the participants' left feet for each bag load before and after the spinal stabilization exercise program. The plantar pressure measurements of the bag load of 0% of subjects' body weight before and after the spinal stabilization exercise program showed that three of the eight plantar areas of the left foot exhibited decreases in dynamic plantar pressure; however, these differences were not statistically significant ($p>0.05$). The plantar pressure measurements of the bag load of 15% of the subjects' body weight before and after the spinal stabilization exercise program showed that seven of the eight plantar areas of the left foot showed decreases in dynamic

Table 2. Pre- and post-intervention foot pressure comparisons (unit: kPa)

	0%		15%	
	Pre-EX	Post-EX	Pre-EX	Post-EX
Hallux	71.7±32.7	71.9±32.0	75.3±47.7	70.0±43.0
2–5 toe	22.9±12.7	28.3±9.2	37.5±19.4	31.0±16.3
1 mt	71.5±37.6	70.0±34.0	77.3±40.4	78.9±42.7
2–4 mt	95.8±20.4	96.7±14.1	109.9±20.7	98.9±27.5
5 mt	54.2±20.7	62.8±21.6	67.3±24.3	51.8±25.5*
Mid foot	32.9±14.2	31.8±15.6	37.9±16.0	37.9±16.9
Med heel	110.8±19.4	112.1±16.2	122.3±23.9	102.8±26.0
Lat heel	107.8±25.7	103.4±30.2	126.0±20.5	102.1±23.9*

Mean ± SD, *p<0.05

plantar pressure, and the differences in two areas were statistically significant (mt5, 67.32±24.25 and 51.77±25.52kPa; lat heel, 126.00±20.46 and 102.08±23.87kPa) ($p<0.05$).

DISCUSSION

Human posture while standing upright is unstable by nature. Therefore, its balance is maintained by continuous physical responses to integrated information gathered by the visual proprioceptive senses, the vestibular system, and somatesthesia[22]. Balance in the standing position is affected by external factors or carrying external loads, such as bags. As this effect maybe a pathological factor for idiopathic scoliosis, it requires special attention[23].

The foot is the body region that has first contact with an external surface when an individual is in the standing position. To control posture, sensory information is gathered through the foot that contacts the ground[24]. The information gathered by the foot changes muscle activation patterns, affecting human posture and spinal and pelvic alignment. In addition, this information plays an important role in maintaining the mechanical functions of the lower extremities and establishing physical balance and stability during walking[15, 25]. The measurement of plantar pressure is widely used in pathological diagnoses of foot problems and can provide additional insight into various musculoskeletal diseases in the lower extremities[15, 18].

A study reported that differences in the patterns of movement in the center of the plantar pressure of both feet have a statistically significant correlation with the degree of scoliosis, which influences foot imbalance[26]. Therefore, this study measured the foot pressures of elementary school children with scoliosis when they carried bags weighing 0% and 15% of their body weight and compared them with those taken after an eight-week spinal stabilization exercise program had been performed.

A major function of exercise control is to maintain posture by minimizing disruptions to an individual's balance. In other words, this function stabilizes the line of gravity in the entire body by aligning the body based on its external environment[27–29]. Morphological changes and a damaged sense of movement, which are related to idiopathic scoliosis, cause problems with balance control[30, 31]. Therefore, exercises may be essential for improving neuromotor control, the stability of physical balance, and respiratory functions[32, 33].

After the spinal stabilization exercises had been completed in this study, the subjects' overall plantar pressure was reduced and their physical balance had improved. In addition, certain plantar areas exhibited statistically significant declines in plantar pressure at a bag load of 15% of the participants' body weight, which suggests that physical balance was improved by the spinal stabilization exercises eliciting effective spreading of the distribution of plantar pressures that increase when a load is carried.

This study had some limitations. First, it only compared the dynamic plantar pressures of 10 school children with idiopathic scoliosis; there was no control group. Moreover, it did not perform a direct analysis of the correlation between Cobb angle and plantar pressure. Therefore, it is unlikely that the study's results can be generalized. Future studies will be required to classify the subjects' major curvatures in detail, and to analyze the relationship between improved Cobb angles and plantar pressures, the results of which may contribute to the facilitation of spinal stabilization exercise programs for patients with idiopathic scoliosis.

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