The effect of superficial trunk muscle exercise and deep trunk muscle exercise on the foot pressure of healthy adults

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Abstract. [Purpose] The purpose of this study was to analyze the effect of superficial trunk muscle exercise and deep trunk muscle exercise on the foot pressure of healthy adults. [Subjects] The subjects were 30 healthy females and males who agreed to participate in this study. There were two groups, a superficial trunk muscle exercise group and a deep trunk muscle exercise group, with 15 participants in each. [Methods] The exercises were conducted 5 times a week for 4 weeks for both groups. A gait analyzer was used to measure foot plantar pressure while walking on a plate. Participants were measured before starting the exercise and after 4 weeks. The paired t-test was used to analyze the pre-and post-test results. [Results] There were no significant differences in foot pressure in any region in the superficial trunk muscle exercise group. In the deep trunk muscle exercise group, there were statistically significant increases in F1, F4, F5, R1 and R3. In addition, there were significant decreases in R2 and R4. [Conclusion] After the 4-week deep trunk muscle exercise group decreases in foot pressure on the inner foot and increases on the outside of the feet indicate normal and overall even distribution of body weight on the feet.

key words: Superficial trunk muscle exercise, Deep trunk muscle exercise, Foot pressure

INTRODUCTION

Trunk stabilization exercises were developed in the late 1990s in order to improve the stability and mobility of the spine by strengthening the deep trunk muscles[1]. These stabilization exercises help to move the spine during posture changes while maintaining a balanced, neutral spine position by causing co-contractions and/or individual contractions of the deep trunk muscles[2]. These exercises can be prescribed as therapies or as preventive measures[3].

Trunk stabilization muscles are categorized as deep or superficial. The deep trunk muscles consist of the transversus abdominis, multifidus, quadratus lumborum, and rotatores muscles, which attach to individual lumbar vertebrae and provide control and rigidity for the spinal segments[4]. These muscles help prepare the body for sudden movements by coordinating proprioception and activating small muscles in the body[5]. A ball has been widely used as an exercise method to increase trunk stabilization[6]. The superficial trunk muscles consist of the rectus abdominis, internal oblique abdominal, external oblique abdominal, lateral quadratus lumborum, erector spinae, and iliopsoas muscles. They do not directly attach to the vertebrae, so they only stabilize pressurized spinal segments. These muscles respond to external loads which shift the trunk’s center of gravity and provide compression force upon strong contraction[7]. For normal walking, it is important to control trunk posture so that it maintains a stable body position against gravity. Trunk stability improves the functional stability of the physical body and improves balance and gait abilities, preventing physical injury[8].

This study aimed to assess changes in foot pressure elicited by 4 weeks of trunk stability exercises for the deep and superficial muscles, using a Swiss ball and tools, including bridge exercises, swimming posture, and unstable support surfaces.

SUBJECTS AND METHODS

The study participants were 30 healthy adults who voluntarily consented to take part and had no congenital deformity, orthopedic disorder, or neurological disorder. Before the start of the study, we received approval from Kangwon National University (KWNUIRB-2014-06-004-001). The participants were divided into a superficial trunk muscle exercise group and a deep trunk muscle exercise group, with 15 participants in each. The superficial trunk muscle exercise group had an average age of 22.2±1.93 years, an
average height of 170.5±10.5 cm, and an average weight of 78.1±23.64 kg. The deep trunk muscle exercise group had an average age of 21.3±1.84 years, an average height of 170.1±8.61 cm, and an average weight of 69.0±14.55 kg.

Participants started the exercises on the date they submitted a consent form. A gait analyzer (TechStorm Inc., Korea) was used to measure foot plantar pressure while walking and exercising. The gait analyzer system analyzes foot pressure in 10 regions of the plantar area while participants walk on a 384×1152 mm plate with a film-type pressure sensor consisting of a 2304-cell matrix array (Fig. 1). Pressure distribution data were analyzed using Gait Analyzer application software ver. 3.1. Pressure data by region were collected three times, and the mean values were used in the analysis

While exercising, participants wore comfortable clothes but not socks. They conducted the exercises on a mat after a demonstration and under the supervision of a physical therapist in an exercise therapy room at the Physical Therapy Department of Kangwon National University. The exercise routine consisted of 10 minutes of warm-up exercises, 40 minutes of main exercises, and 10 minutes of cool down, for a total of 60 minutes. Participants followed the routine 5 times a week for 4 weeks. For warm-ups, participants stretched the large joints in a standing position. The main exercise included 10 exercises for the deep and superficial trunk muscles. Each exercise was repeated for 3 sets, with 30 seconds of rest between sets.

One set of the hundred (straight) deep trunk muscle exercise was performed by lifting both legs 70–80 degrees off the ground while lying down and lifting the upper body and waving both arms 5 times while inhaling and exhaling. One set of the bridge (single leg straight) exercise consisted of lifting the pelvis while lifting and lowering each leg 5 times while lying down. In one set of the one-leg stretch exercise, one knee was lifted to the sternum 10 times while stretching the other knee in a diagonal direction in a supine position. One set of the quadruped alternate exercise was performed by gathering the right elbow and left knee in the center of the trunk and then stretching them in a quadruped position 10 times. One set of the swimming exercise consisted of stretching 4 limbs, like while swimming, and maintaining this position for 40 seconds in a supine position. One set of the side plank exercise included lifting the trunk and pelvis and maintaining this position for 40 seconds in a side plank position supported by the elbow. In 1 set of the gym ball plank exercise, both feet were placed on a Swiss ball with the elbows on the ground for 40 seconds. One set of the gym ball crunch exercise involved sitting up and lifting the upper body 20 times. One set of the gym ball crunch exercise was performed by rolling the shins on a Swiss ball while rolling it toward the upper body. One set of the gym ball kick forward exercise consisted of sitting on a Swiss ball, placing both feet on the red balance board, and maintaining knee extension for 40 seconds.

One set of the crunch exercise in the superficial trunk muscle exercise involved lifting the trunk until both shoulder blades were off the ground from a supine position 20 times. One set of the crunch side exercise was performed by rolling the upper body toward the side in a side plank position supported by one arm 15 times. One set of the crunch oblique exercise included lifting the upper body obliquely from an oblique lying position 15 times. In 1 set of the sit-up exercise, 2 people together rolled up the upper body as much as possible for 60 seconds. One set of the leg raise exercise consisted of lifting and lowering both legs from a lying-down position 20 times. One set of the twist crunch exercise was performed by placing 1 leg on the knee and lifting the upper body obliquely toward the knee from a supine position 15 times. In 1 set of the V sit-up exercise, participants maintained the body in a position looking the like letter V while sitting for 30 seconds. One set of the side band exercise included holding a dumbbell with 1 hand and bending the upper body toward the dumbbell while standing 15 times. One set of the seated knee-up exercise involved pulling the knees up to the sternum supported by both hands and releasing the knees while in a sitting position 20 times.

For the cool down, whole body stretches were done in a lying-down position. After the participants had performed these exercises for 4 weeks, their foot pressure while walking was measured using a gait analyzer in the manner described earlier.

The collected data were analyzed using SPSS 21.0 statistical software (SPSS, Chicago, IL, USA). The average and standard deviation of participants’ general characteristics were calculated. The paired t-test was conducted to analyze the pre- and post-test results. The statistical significance level was chosen as α=0.05.

RESULTS

There were no significant differences in foot pressure in any region in the superficial trunk muscle exercise group (p>0.05).

In the deep trunk muscle exercise group, there was a statistically significant increase from 0.04±0.65%N/cm² to 0.25±0.20%N/cm² in the F1 region, which corresponds to the fourth and fifth toes of the forefoot (p<0.05). There was a statistically significant increase from 2.06±1.19%N/cm² to 4.49±0.75%N/cm² in the F4 region, which corresponds to the outside of the forefoot (p<0.05). There was a statistically sig-
significant increase from 7.53±1.33%N/cm² to 8.71±1.54%N/cm² in the F5 region, which corresponds to the middle of the foot (p<0.05). There was a statistically significant increase from 1.42±2.06%N/cm² to 4.51±3.19%N/cm² in the R1 region, which corresponds to the outside of the midfoot (p<0.05). After exercise, there was a statistically significant increase from 1.22±0.19%N/cm² to 2.06±1.19%N/cm² in the F1 region, which corresponds to the outside of the hindfoot (p<0.05). In addition, there was a significant decrease from 8.71±1.54%N/cm² to 3.75±1.33%N/cm² in the F2 region, which corresponds to the inner side of the hindfoot (p<0.05). There was also a significant decrease from 1.19±0.34%N/cm² to 0.34±0.35%N/cm² in the R4 region, which corresponds to the inner side of the midfoot (p<0.05) (Table 1).

### DISCUSSION

Deep trunk muscle exercises have been used to improve the mobility of athletes and patients with lower back pain and to prevent physical injury during exercise[13]. Deep trunk muscle exercises using a Swiss ball have been reported to have a positive effect on the prevention of falls among elderly women by improving their balance and gait abilities[15]. As deep trunk muscle exercise can affect the body in various ways, this study aimed to determine the effect of the trunk muscle exercises on foot pressure.

After the 4-week exercise program, the superficial trunk muscle exercise group showed no significant differences in any region of the foot. However, the deep trunk muscle exercise group showed increases in foot pressure on the outside of the forefoot, midfoot, and hindfoot and decreases on the inner hindfoot and midfoot. The decrease in foot pressure on the inner foot and the increase on the outside of the feet indicates normal walking and overall even distribution of body weight on the feet. Consistent with these results, a study by Lim et al.[14] reported that hemiplegic patients who performed trunk stabilization exercises for 8 weeks showed a significant increase in pressure on the hindfoot. In addition, Jang et al.[15] reported that balanced incline shoes decreased foot pressure by 15% compared to flat shoes, thereby reducing loads on the feet, ankles, and knees by distributing pressure to the outside of the feet. The present study, too, found an increase in pressure on the outside of the feet, resulting in a positive effect on the body.

The present study did not specify a walking velocity when foot pressure was measured and limited participants to adults in their 20s, so the results cannot be generalized to all ages. The elderly may exhibit a decrease in foot plantar fat pad thickness and lowering of the height of the longitudinal arch, along with structural changes, such as a claw or hammer toe[16–18]. In consideration of these changes, future studies should compare the foot pressures of young and elderly adults after deep trunk muscle exercises.

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