

Original Article

Changes in foot pressure elicited by 3D air balance exercise and pelvic stability exercise for functional leg-length discrepancy in adult women

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Abstract. [Purpose] This study was conducted to examine the effect of pelvic stabilization exercise and 3D equipment exercise on adult women with Functional Leg-Length Discrepancy (FLLD). [Subjects and Methods] Twenty female students in their 20's having FLLD without Structural Leg Length Discrepancy were selected. Exercise was performed for 50 min per session, three times a week, for six weeks. The Pelvic stabilization exercise (PSE) group performed pelvic stabilization exercises for 50 minutes, and the 3D exercise (3DE) group performed 3D Air Balance exercise for 10 minutes after performing the pelvic stabilization exercise program for 40 minutes. [Results] The PSE group showed statistically significant differences in tape measure method (TMM) and maximum pressure between pre-test and post-test, and 3DE showed statistically significant differences in TMM, the difference in maximum pressure, the difference in average pressure, and the difference in support area. At the end of the 6-week intervention, TMM, difference in maximum pressure, difference in average pressure, and difference in support area showed significantly greater reduction in the 3DE group. [Conclusion] The results show that 3D stabilization exercise was more effective at improving the stabilization of the deep muscles surrounding the pelvis and left-right muscular balance. We consider that 3D exercise should be included in exercise programs for improving pelvic cavity and spinal stability in the future.

Key words: FLLD, 3D-exercise, Foot pressure

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INTRODUCTION

Leg-length discrepancy (LLD) is the term used to describe the condition when both legs are markedly different in length¹⁾. Leg-length discrepancy occurs in 40–70% of the total population and is reported to be more than 20 mm in one out of every 1,000 persons²⁾. LLD is also referred to as leg-length inequality. Generally, it is classified as structure leg-length discrepancy (SLLD) and functional leg-length discrepancy (FLLD)³⁾. SLLD is caused by actual length differences between the left and right sides' femur and tibia supporting the body due to fracture, tumor, infantile paralysis, or dysplasia. FLLD is caused by torsion occurring at the pelvis, knee, foot and ankle joints, and left-right imbalance due to fixed occupational position, daily life habits or poor posture⁴⁾.

LLD is known to cause diseases such as lumbar pain,

knee pain, scoliosis, ankle contracture, and degenerative arthritis^{5, 6)}. Furthermore, it is also known to cause impairment of standing balance ability and to change the gait pattern⁷⁾.

Pelvic stabilization exercise, one of the treatment methods used for patients with LLD, is an exercise program which strengthens the abdominal and pelvic floor muscles. The purpose of pelvic stabilization exercise is to reduce the stresses acting on the pelvic structure to the maximal extent to allow a humans to perform with optimal function⁸⁾. Inman⁹⁾ stated that once the hip joint is dislocated, the left-right height of the pelvis differs and the leg-length of both limbs becomes different. Thus, the balance of the pelvis becomes disarticulate due to leg-length discrepancy. Therefore, pelvic stabilization exercise is widely used to treat patients with lumbar pain¹⁰⁾, as well as athletes, and ordinary people¹¹⁾.

3D Air Balance is an instrument used for isometric exercise that can effectively strengthen deep muscles attached to the spine in order to stabilize the spinal structure. It induces the balanced development of muscles by making the user unconsciously use many muscles around the spine attached between spinal discs which are not usually used.

This study aimed to provide evidentiary material for a treatment program that can be used to treat patients with FLLD by comparing the treatment effects in female college students with FLLD of an existing pelvic stabilization exer-

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cise and a 3D stabilization exercise.

SUBJECTS AND METHODS

Subjects

This study was conducted after explaining the purpose and meaning of the study to 20 female students attending G University located in Gwangju. The subjects had FLLD of 10–30 mm without SLLD, and had not previously taken medication or received treatment for their condition. The subjects were selected from among those who understood the purpose of this study and were capable of understanding and complying with the examiner's instructions. The subjects were randomly divided into an experimental group of 10 subjects who performed pelvic stability exercise and 3D Air Balance exercise, the 3DE group, and 10 subjects who only performed the pelvic stabilization exercise, the PSE group (Table 1). This study conformed to the ethical principles of the Declaration of Helsinki, and all subjects provided their informed consent after being given information about the purpose of the experiment and exercise methods.

Methods

The PSE group and 3DE group exercised 3 times per week, 50 minutes per every session, for 6 weeks. The PSE group performed the pelvic stabilization exercise program for 50 minutes, and the 3DE group used the 3D Air Balance for 10 minutes after performing the pelvic stabilization exercise program for 40 minutes.

The pelvic stabilization exercise was modeled on the core exercise of Urquhart et al¹². And the exercise method of Stevens et al¹³.

3D Air Balance (3-Thera-Balance, Hanmed, Korea) is an apparatus that has been developed for the purpose of strengthening and correcting the muscles surrounding the pelvis and the spine. It reinforces the transversus abdominis, the external and internal oblique abdominal muscles, the gluteus medius, gluteus maximus, latissimus dorsi, rectus abdominis, erector spinae, hamstring muscle, quadriceps femoris, psoas major, and iliacus¹⁴.

The FLLD was measured using the tape measure method (TMM)¹⁵. The subjects lay on a bed and the distance from the anterior superior iliac spine (ASIS) to the medial malleolus¹⁶ was measured using a tape measure.

To measure the difference in weight bearing during gait, a SmartStep (Ver.2.23, Andante medical devices Inc., Israel) was used. This apparatus can perform evaluation and training of gait function simultaneously using a bio-feedback system. This system consists of a pressure sensor in the foot sole and a control device which is attached to the ankle of the subject. When weight is borne by the leg during gait, the pressure of the two pouches inside the insole increases and activates the pressure sensor linked to the control device. The control device stores the electric signal transmitted from the pressure sensor at the rate of 40 times/min¹⁷. A computer is linked to the control device, and the data from the sensor is processed and recorded in weight units (kg) or percentage¹⁸. The SmartStep measures the difference in the weight bearing (difference of total loading, difference of front loading, difference of rear loading) of both lower limbs during gait.

Table 1. Characteristics of the subjects

	PSE	3DE
Age (years)	21.5±3.57	23.5±4.18
Height (cm)	167.2±5.84	164.5±6.42
Weight (kg)	61.8±7.46	56.65±8.26

All data are expressed as Mean±SD. PSE: pelvic stability exercise group, 3DE: 3D balance exercise in addition to pelvic stability exercise group

The pressure difference between the legs was measured using Pedoscan (RSscan 1.0 m, Diers, Germany), which is an apparatus for measuring the pressure under both feet during standing. A 50-cm-wide mat containing 4,096 pressure sensors records the foot pressure. After dividing the pressure into foot sole areas using the DICAM program (Diers, Germany), a pressure map was displayed with colors for each sensor or each area¹⁹. In this study, measurement was taken while subjects stood still for 30 seconds on top of Pedoscan mat with both feet. The Pedoscan measures the difference in pressure (difference of maximum pressure, difference of average pressure, difference of support area) between both lower limbs during standing.

For data analysis, the PASW 18.0 statistics program was used. All data are reported as the mean and standard deviation. The paired t-test was used to determine the significance of know the change between pre-test and post-test. In order to examine group differences, the independent t-test was used. All statistical significance level was $p < 0.05$.

RESULTS

The PSE group, showed significant differences in TMM and maximum pressure between pre-test and post-test ($p < 0.05$), and the 3DE group showed significant differences in TMM, maximum pressure, average pressure, and support area ($p < 0.05$).

In the comparison of the groups after 6 weeks of exercise, there were statistically significant differences in TMM, difference in maximum pressure, difference in average pressure and difference in support area between the 3DE and PSE group ($p < 0.05$) (Table 2).

DISCUSSION

In LLD, it is assumed that the body alignment of the pelvis and spine is abnormal due to asymmetrical weight bearing of the lower limbs and chronic functional change²⁰. Defrin et al.²¹ asserted that LLD causes imbalances among the lower limb joints, spine and pelvis, which causes deformation of the soft tissue along with disturbance of biomechanical function. The posture of the feet in standing may have an influence on pelvic alignment and on spinal posture²².

Post et al.²³ stated that normal lower limb alignment is balanced during weight bearing, but abnormal alignment causes imbalance during weight bearing, due to structural imbalance causing overload of the ligaments, articular cartilage, bones, muscles, and tendons.

Table 2. The comparison of TMM, difference of foot loading, difference of foot pressure

	PSE		3DE	
	Pre	Post	Pre	Post
TMM (cm)	1.20±0.42	0.60±0.51*	1.30±0.48	0.40±0.51*
Difference of Total loading (%)	6.30±3.65	3.70±3.71	8.80±7.69	3.80±2.48
Difference of front loading (%)	9.40±5.21	7.00±3.85	9.70±6.56	6.70±6.73
Difference of rear loading (%)	7.20±5.53	6.10±6.22	9.90±9.71	6.10±4.84
Difference of Maximum pressure (N/cm ²)	3.27±2.81	1.19±0.83*	3.71±2.31	1.63±1.05*†
Difference of average pressure (N/cm ²)	0.40±0.37	0.16±0.15	0.41±0.34	0.12±0.04*†
Difference of support area (N/cm ²)	10.26±8.76	7.72±5.03	9.22±7.35	3.09±3.41*†

Values are Mean±SD. PSE: pelvic stability exercise group, 3DE: 3D balance exercise in addition to pelvic stability exercise group.

*: $p < 0.05$, paired t-test; †: $p < 0.05$, independent t-test

There are various ways of measuring leg-length discrepancy. Clarke²⁴) said the best measurement method is radiography. CT can precisely measure even the smallest discrepancy and make a comparison, and has the advantage of being able to take precise photos compared to radiography. Besides these, other methods being used include MRI and 3D ultrasound. While measurements using radiography or imaging have the advantage of being accurate, they have disadvantages in time and finance. Beattie¹⁵) reported that the tape measurement method which measures the distance from ASIS to the medial malleolus has high reliability and validity, and is easy to use in clinical practice.

In this study, the subjects were 20 female college students in their 20s with FLLD according to TMM. They were randomly and evenly allocated to the PSE and 3DE groups, both of which performed: three times a week, 50 minutes a session, for 6 weeks. PSE strengthens the muscular strength around the pelvis, and it was performed for 50 minutes for the purpose of increasing stability and improving bilateral muscular balance. The 3DE group performed the same pelvic stabilization exercise for 40 minutes which the PSE group performed, and deep muscle stabilization exercise for 10 minutes using a 3D Air-Balance.

The interventions were effective at reducing FLLD according to TMM in the PSE group and the 3DE group. In addition, the difference in pressure of both lower limbs during standing (difference of maximum pressure, difference of average pressure, difference of support area) was more greatly reduced in the 3DE group than in PSE group.

Kinser and Colby²⁵) suggested that pelvic stabilization exercise recovers the function of deep stabilizing muscles and abdominal muscles, strengthens the deep muscles, and improves the proprioceptive senses. Hicks et al.²⁶) reported that stabilizing exercise for 8 weeks was effective, and O'sullivan²⁷) said that the pelvis stabilization exercise is effective at transforming the functional posture. Adners¹⁴) reported that the exercising with 3D equipment was effective at 0° (erector spinae, multifidus, gluteus maximus), 45° (right erector spinae, multifidus, gluteus maximus, internal abdominal oblique), -45° (left erector spinae, multifidus, gluteus maximus, internal abdominal oblique), 90° (right multifidus, gluteus maximus, external abdominal oblique, internal abdominal oblique), 135° (right rectus abdominis,

external abdominal oblique, internal abdominal oblique), -135° (left rectus abdominis, external abdominal oblique, internal abdominal oblique) and 180° (rectus abdominis, internal abdominal oblique, external abdominal oblique) in the muscular strength test.

We consider that the deep muscular control ability was improved through gradually increasing the exercise intensity by tilting the 3D equipment in many different directions and planes to utilize gravitational force in fixing the joint improving muscular coordination and balance.

The limitations of this study were as follows. First, it is difficult to generalize the 20 female students with LLD. Second, we could not compare the results of study due to the lack of preceding studies on exercise with 3D Air-Balance equipment for LLD patients. Third, the gait habit, posture and life style of the subjects were not taken into account.

Nonetheless, this study revealed that the exercise program with 3D Air Balance equipment improved the lumbar stability, muscular strength and bilateral muscular balance of subjects with functional leg-length discrepancy due to posture and habit without structural problem. Consequently, we consider that studies of various population groups with LLD, and of patients with abnormal pelvic tilt and scoliosis, which can induce FLLD, are necessary.

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