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Original Article

The effect of simulating a leg-length discrepancy on pelvic position and spinal posture

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Abstract. [Purpose] The purpose of this study was to examine how a leg-length discrepancy contributes to the pelvic position and spinal posture. [Subjects and Methods] A total of 20 subjects (10 males, 10 females) were examined during different artificially created leg-length inequalities (0–4 cm) using a platform. The pelvic tilt and torsion and the sagittal deviation of the spine were measured using the rasterstereographic device formetric 4D. [Results] Changes in platform height led to an increase in pelvic tilt and torsion, while no changes in the spinal posture were found with the different simulated leg-length inequalities. [Conclusion] Our study showed that a leg-length discrepancy may cause pelvic deviation and torsion, but may not lead to kyphosis and lordosis. Therefore, we consider that an artificially created leg-length discrepancy has a greater effect on pelvic position than spine position.
Key words: Leg-length discrepancy, Pelvic position, Spinal posture

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INTRODUCTION

If both of a person's legs are so different and asymmetrical in length that it can be observed with the naked eye, the person is said to have a "leg-length inequality"[1, 2)]. Leg-length inequalities can largely be divided into two different types[3)]. The first is structural leg-length discrepancies, which are innate or acquired differences in the actual lengths of the two legs. The second is functional leg-length discrepancies; there is no difference in the actual length, but the length can sometimes differ according to changed status in the lower extremity such as the contracture of joints, malalignment of the body, or when the difference in calcaneal eversion between the feet is more than 3 degrees. Leg-length discrepancies can cause functional problems like gait abnormalities and/or loss of balance[2, 4)], and many variations can be generated to compensate those inequalities[5, 6)].

Pelvis tilt in the frontal plane, flexion of the hip extensor and knee joint of the longer leg in the sagittal plane, and increased plantar flexion of ankle in the sagittal plane of the shorter leg are examples of compensations caused by differences in leg length[7)]. These unnecessary compensations caused by different leg lengths lead to balanced body alignment and minimize sway and energy cost during gait[5, 6)].

However, it is not clearly known what changes these unnecessary compensations will show according to different leg lengths[5)]. Most previous studies about different leg lengths have focused on lower extremity and pelvic changes, and the measurements have also been limited to those obtained with 3D equipment[7)].

Therefore, the goal of this study was to investigate how an artificially created leg-length discrepancy would immediately affect the pelvic position and spinal posture in healthy subjects with the rasterstereographic device formetric 4D.

SUBJECTS AND METHODS

The purpose and methods of the study were explained to all of the potential subjects of the study, and all voluntarily agreed to participate. This study was approved by the Catholic University of Pusan Institutional Review Board (CUPIRB-2014-007). Twenty subjects were selected with leg-length discrepancies of less than 0.5 cm, and no pathological issues related to the ankle joint, knee joint, hip joint and back (age, 20.10±1.91 years [mean±SD]; height, 172.4±8.55 cm; weight, 60±6.99 kg).

In this cross-sectional study, for the measurements, the subjects stood with a platform (+1 cm, +2 cm, +3 cm, +4 cm) below the right foot, the height of which could be controlled by the measuring device to simulate different leg lengths. The weight distribution between the left and right legs was quantified by the simulation platform prior to measurement to ensure an almost equal weight distribution between both legs. All subjects waited 2 min to adapt to the simulated leg-length discrepancies before performing measurement. After performing measurement, the subjects were given 5 min of normal walking time between measurements to return to a relaxed posture. We measured the pelvic position and spinal

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Table 1. Changes in pelvic position and spine posture for the different simulated platform heights

SPH	0	1 cm	2 cm	3 cm	4 cm
Pelvic tilt (°)	2.0±3.0*	5.7±4.5*	10.4±6.5*	14.2±6.9*	18.3±6.7*
Pelvic torsion (°)	2.2±1.4*	3.3±1.9*	4.0±5.3	4.7±2.0	3.8±1.7
Kyphotic angle (°)	45.5±9.5	45.2±9.7	44.9±10.0	44.7±10.7	41.0±14.3
Lordotic angle (°)	35.3±4.1	35.5±5.3	36.0±6.1	37.2±6.7	36.7±4.7

Each value represents the mean± SE. SPH: simulated platform heights.
*: Statistically significant, $p<0.05$

posture when subjects were standing in a relaxed posture with fully extended knees on the platform.

The leg-length discrepancies were simulated by lifting the platform prior to the rasterstereographic examination by the following amounts: +1 cm, +2 cm, +3 cm, and +4 cm. The rasterstereographic device formetric 4D (Diers International GmbH, Schlangenbad, Germany) measured pelvic tilt, pelvic torsion, inclination, the spinal kyphotic angle, and the lordotic angle. Rasterstereography is a method for stereophotogrammetric surface measurement of the back that was developed in the 1980s by Hierolzer and Derup[8]. Based on the principle of triangulation, it allows a radiation- and contact-free method of detecting and measuring the human posture[9–11]. Two cameras record the back shape. In rasterstereography, a projector that projects the raster containing the grid on the object under investigation replaces one of the cameras. Parallel white light lines are projected on the back surface of the subject by the slide projector. The three-dimensional back shape leads to deformation of the parallel light lines, which can be detected by the camera[12].

Data were processed using SPSS 18 for Windows. To compare pelvic tilt, pelvic torsion, inclination, the spinal kyphotic angle, and the lordotic angle between 0 and +1 cm, +2 cm, +3 cm, and +4 cm leg-length discrepancies, one-way ANOVA was used. To identify differences for each muscle, Bonferroni's post hoc test was performed. Statistical significance was accepted for values of $p<0.05$.

RESULTS

The pelvic position showed significant differences among leg-length discrepancies ($p<0.05$) and tended to increase as the leg-length discrepancies increased. The spinal kyphotic and lordotic angles at the five different leg-length discrepancies did not show significant differences (Table 1).

DISCUSSION

The present study aimed to investigate how an artificially created leg-length inequality would affect the pelvic position and spinal posture. The study used the rasterstereographic device formetric 4D, which can observe pelvic position and spinal posture together by overcoming limitations of the previous studies on leg-length inequalities.

If X-ray, CT, or MRI are used to diagnose pelvic position and spinal posture, some negative effects can be generated by radiation exposure that can be measured with radiation measuring devices. On the other hand, the formetric 4D is strongly beneficial, since it does not lead to radiation exposure and thus can be easily applied to most patients, from children to adults. It is particularly convenient to measure of pelvis torsion, lordotic and kyphotic angles of the pelvis, and vertebral rotation[13]. Several studies have shown the high reliability and accuracy of this method[14–16].

Some significant changes were found in pelvic position as a result of an artificially created leg-length inequality. Pelvic tilt is an indicator for observing pelvic changes in the coronal plane according to leg-length inequalities, and it can be considered the most sensitive factor subject to change due to leg-length inequalities, since it shows significant increases as the length of the inequality increases in 1-cm increments.

Pelvic torsion is an indicator used to observe pelvic changes in the sagittal plane. As the leg-length inequality increased from 0 to 1 cm, there was a significant difference, but there was no significant difference for the leg-length inequalities of 2 cm, 3 cm, and 4 cm. Pelvic torsion is also likely to increase as a leg-length inequality increases, but the change is highest for a 1-cm gap, and the range of the change decreases as the leg-length inequality increases. Therefore, it seems like the pelvic torsion reacts the most for the first 1-cm gap, and even though pelvic torsion can still be observed a little bit thereafter, a compensation tactic is more likely to be generated as a result of pelvic tilt than by a change in torsion. These findings are similar to that of the study of Young et al.[17], who found a significant increase in pelvic tilt and pelvic torsion resulting from a leg-length inequality of 1.5 cm.

There was no significant difference in spinal posture resulting from the leg-length inequalities. There appeared to be no significant changes in the trunk resulting from the temporal leg-length inequalities, but spinal changes were observed with different leg lengths for short periods of time in healthy adult male and female groups. The temporal changes in the pelvis and the trunk resulting from leg-length inequalities seem to show more of a compensation mechanism in the pelvis than the trunk.

Therefore, it is necessary to perform further research to observe the changes in the pelvis and trunk resulting from leg length-inequalities in selected subjects with real leg-length inequalities, not with artificially created ones.

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