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Determining the effect of leg length discrepancy simulation on pelvic alignment by using digital photography

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SUMMARY
Leg length discrepancy (LLD) has been reported to influence pelvic alignment. Because the pelvis is composed of the right and left innominate bones and sacra, the effect of LLD on the pelvis cannot be solely induced by pelvic tilting. Therefore, to clarify the relationships between low back pain (LBP) and LLD, the motions of innominate bones need to be individually captured. The present study aimed to examine the effect of simulated LLD on pelvic alignment by using digital image analysis. A total of 30 healthy men participated in this study. The subjects were randomly divided into 2 groups: one underwent LLD simulation (LLD group) and the other did not (control group). The lateral pelvic tilt, innominate inclination, and pelvic asymmetry were measured. The LLD group showed significant differences for lateral pelvic tilt to the right, forward inclination of the innominate bone, and pelvic asymmetric increase. The pelvic alignment changes induced by LLD occurred in the frontal plane as well as the sagittal plane. Differences in inclination between the right and left innominate bones may influence the inclination and rotation of the sacrum located between the innominate bones, leading to changes in the dynamics of the lumbar vertebra and possibly influencing the development of LBP.

INTRODUCTION
Leg length discrepancy (LLD) has been implicated in the development of low back pain (LBP). The occurrence of LLD thus needs to be considered during LBP therapy. Several researchers have described various therapy options for LBP in patients with LLD. The study demonstrated that shoe sole height correction reduced pain and dysfunction [1, 2]. However, the low back pain reduction mechanism by the correction of LLD remains unidentified. LLD has been reported to influence pelvic and lumbar alignments. Generally, the influence on the human body by LLD was reported as pelvic inclination and lumbar vertebra being scoliotic towards the shorter leg in the frontal plane. On the other hand, Timgren J *et al.* reported that innominate bones on the side of longer and shorter legs inclined backwards and forward, respectively, in scoliosis [3]. LLD may thus cause not only changes in the frontal plane but also relative changes in right and left innominate bones in the sagittal plane. Because the pelvis is composed of right and left innominate bones and sacra, of the effect of LLD on the pelvis cannot be solely induced by pelvic tilting. To clarify the relationships among LLD, LBP, and the use of shoe inserts, the motions of innominate bones need to be individually captured.

The present study aimed to examine the effect of simulated LLD on pelvic lateral tilting, innominate inclination and pelvic asymmetry by using digital image analysis.

METHODS
The subjects included 30 young, healthy men (age range: 21–24 years). The inclusion criteria were as follows: normal BMI (BMI 18.5–25) and LLD was <1 cm. The subjects were randomly divided into 2 groups: one group underwent LLD simulation of 3 cm (LLD group) and the other underwent no simulation (control group). The purpose of the study was verbally explained to the subjects prior to participation; the consent of each study participant was acquired before allowing them to engage in the investigation. This study was approved by the Ethics Committee of Seirei Christopher University.

The pelvis was photographed using a digital camera (Canon PowerShot G12); images were used to measure pelvic alignments. The digital camera was positioned 2.5 m away from the subject to during imaging of front, right, and left views of each subject. The camera was positioned at a height at the level of the pelvic region. A weighted string hanging from the ceiling was used as reference line for the measurement of pelvic alignments. A reflection marker with a 4-mm diameter was attached to the pelvis. Digital photography was performed at a standing posture. During static standing in which LLD was not applied, the arms of the subject were crossed in front of the thorax, feet were set apart to shoulder width, and knees were extended. During static standing in which LLD was applied, a 3-cm high platform was inserted underneath the left sole. The subjects were instructed to apply equal weight distribution on the right and left legs.

First, the reflection markers were placed on the right and left anterior superior iliac spines (ASISs), posterior superior iliac spines (PSISs), and iliac crests (ICs) of the subjects in the both groups during static standing and photographed from the front, right, and left directions (pre measurement). After the photography, the markers were temporarily removed and the subjects were allowed to rest. Next, the markers were placed again on ASISs, PSISs, and ICs of the subjects in the LLD group for simulated LLD and in the

control group during static standing and photographed (post measurement).

The images were retrieved on a PC and measurements of lateral pelvic tilt in frontal plane and innominate inclination in the right and left sagittal planes were conducted using ImageJ 1.43u software. The lateral pelvic tilt in the frontal plane was defined as the angle formed by a line between ICs and a line vertical to the floor. Innominate inclination in the sagittal plane was defined as the angle formed by the line between ASIS and PSIS and the line vertical to the floor. Pelvic asymmetry was calculated by subtracting the left innominate inclination from the right innominate inclination. A 90 degree lateral pelvic tilt indicates that the line between ICs is parallel to the floor. Values <90 degree indicate tilting to the right. A decrease and increase of the values of innominate inclination represents forward and backward inclinations of innominate bone, respectively. A positive value for pelvic asymmetry indicates forward inclination of the left innominate bone in relation to the right pelvic bone, whereas a negative value suggests backward inclination of the left innominate bone relative to the right pelvic bone.

To verify the effect of simulated LLD on pelvic alignments, two-way analysis of variance was applied to the groups (application and non-application of simulated LLD) and measurements (pre and post). If an interaction was detected, the main effect on each group was also verified. Statistical differences were considered significant when $p < 0.05$.

RESULTS AND DISCUSSION

Table 1 shows the mean angles (and standard deviations) of the pelvic alignments. An interaction between group and measurements was found for lateral pelvic tilt, innominate inclination (right) and pelvic asymmetry ($p < 0.01$, respectively). In addition, main effects of each variable were also observed ($p < 0.01$, respectively). In terms of lateral pelvic tilt, a significant tilting to the right is attributable to the insertion of a platform under the left lower limb. This result was similar to previous reports. In terms of innominate inclination, the innominate bone on the opposite side of the insertion of a platform showed significant forward inclination in simulated LLD. On the other hand, the left innominate bone on the same side showed no significant change. Earlier studies reported that the innominate bone on the side of longer leg inclined backwards. This study showed that the innominate bone did not necessarily incline backwards due to the forward inclination or sacroiliac joint upslip. Pelvic asymmetry was initially measured at -0.8 degree, whereas this was measured at -5.4 degree in simulated LLD. It has been previously reported that pelvic asymmetry during LLD progressively increases peak stress and contact load on the sacroiliac joint [4]. Therefore, differences in inclination between the right and left innominate bones may influence the inclination and rotation of the sacrum, leading to changes in the dynamics of the lumbar vertebra and possibly influencing the development of LBP.

CONCLUSIONS

The present study examined the effects of simulating LLD on the pelvic alignments in the frontal and sagittal planes and pelvic asymmetry. The results confirmed that LLD causes lateral tilting of the innominate bones and pelvic asymmetry. Future studies should investigate whether LLD improvement can revise the pelvic alignment in cases of low back pain with LLD.

REFERENCES

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Table 1: Mean and standard deviation values of the lateral pelvic tilt, innominate inclination, and pelvic asymmetry in pre- and post-measurements

Group	lateral pelvic tilt* (degree)		innominate inclination (right)* (degree)		innominate inclination (left) (degree)		pelvic asymmetry* (degree)	
	pre	post**	pre	post**	pre	post	pre	post**
LLD	89.7	82.7	78.4	75.3	79.2	80.7	-0.8	-5.4
	(2.4)	(2.6)	(4.3)	(4.1)	(3.9)	(3.5)	(1.7)	(2.4)
control	88.4	88.5	78.7	78.4	80.9	80.5	-2.2	-2.1
	(1.2)	(1.2)	(4.6)	(4.8)	(3.5)	(3.6)	(2.1)	(2.5)

Mean (SD)

*: The interaction of Group with measurements ($p < 0.01$)

**: The main effect of measurements ($p < 0.01$)