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Dynamic evaluation of simulated leg length inequalities and their effects on the musculoskeletal apparatus

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ABSTRACT

Background: Leg length inequalities (LLI) are a common problem in medicine. So far, the diagnosis and treatment are performed under static conditions. Surface Topography (ST) is an optical, non-invasive technique that uses the principle of triangulation to measure spinal posture and pelvic position. This technique offers the opportunity to detect and treat LLIs and their effects under dynamic conditions.
Research: question The aim of the study is to show that ST can detect simulated LLIs under dynamic conditions and to prove if there are differences between the effects on the human body under static and dynamic conditions.
Methods: In the clinical study a total of 30 test subjects were examined with a ST measuring device. LLIs (1 to 4 cm) were simulated using a custom- built sandal and insoles of various thickness. The pelvic obliquity, the surface rotation and lateral deviation of the spine were detected on a treadmill under static and dynamic conditions (3 km/h).
Results: Under static and dynamic conditions LLIs lead to a significant increase of all measured parameters. The pelvic obliquity reaches a significant level of $p < 0.0001$ under static and $p = 0.0001–0.0421$ under dynamic conditions. However, for all examined parameters the magnitudes of the parameters under dynamic conditions were smaller than under static conditions.
Significance: The study showed that simulated LLIs also have a significant effect on the human pelvis and spine under dynamic conditions, but with a smaller magnitude than under static conditions. The human individuum is a dynamic one. Because of that, for the future it should be of great interest to use dynamic measurements to detect and treat LLIs to provide an over correction of LLIs.

1. Introduction

Leg length inequality (LLI) is a condition in which paired limbs are noticeably unequal [1]. They can be found in 40–70% of the population and they may be greater than 2 cm in about 0.1% [1]. LLIs can be a predisposing factor for sacroiliac joint disorders, lumbar back pain, functional scoliosis as well as for symptoms in various joints due to the kinematic joint chain [2]. LLIs can affect all age groups and are categorized into anatomical and functional LLIs [1].

So far, the clinical diagnosis and treatment of LLIs is still performed mostly under static conditions, while patients are standing upright in front of the examiner. The amount of LLI is measured by palpating the height of the iliac crests and their position to each other. Larger LLIs lead to pelvic obliquity, which is then corrected by placing small blocks under the short leg until the pelvis is levelled. In multiple studies, the static effects of LLIs on the musculoskeletal system have been evaluated [3–5]. Hackenberg et al. [5] showed that there is a direct effect of simulated LLIs on the pelvic position and spinal posture [5]. Betsch et al. established a non-invasive method to simulate and examine LLIs and their effects on the musculoskeletal apparatus using a simulation platform [3,4]. The results of these studies confirmed a correlation between increasing LLIs and pelvic obliquity, torsion and changes of the spinal posture [3,4].

The human being is a dynamic individual [6] and therefore, we believe that the diagnosis and treatment of LLIs should also be carried out under dynamic conditions. With the development of surface topography there is a fast, reliable and radiation-free method available to diagnose and treat LLIs under dynamic conditions. In previous studies, the reliability and validity of this system under static and dynamic conditions was shown [7–10].

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Fig. 1. We constructed a custom sandal in three different sizes. To simulate the different LLIs, three insoles with varying thickness, were added to achieve a maximum LLI of 4 cm.

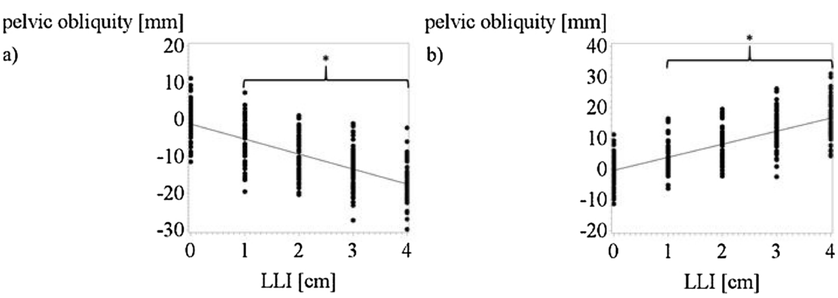

Fig. 2. Pelvic obliquity in mm. a) shows the effect of a simulated LLI on the left side. b) shows the effect of a simulated LLI on the right side. Negative values indicate a pelvic obliquity to the left side and positive to the right side. The brackets mark the LLIs, which reach the level of significance [$p < 0.05$] in relation to the reference LLI (0 mm). The pelvic obliquity was directed towards the longer leg side. The reported dots shown in this figure represent one single trial.

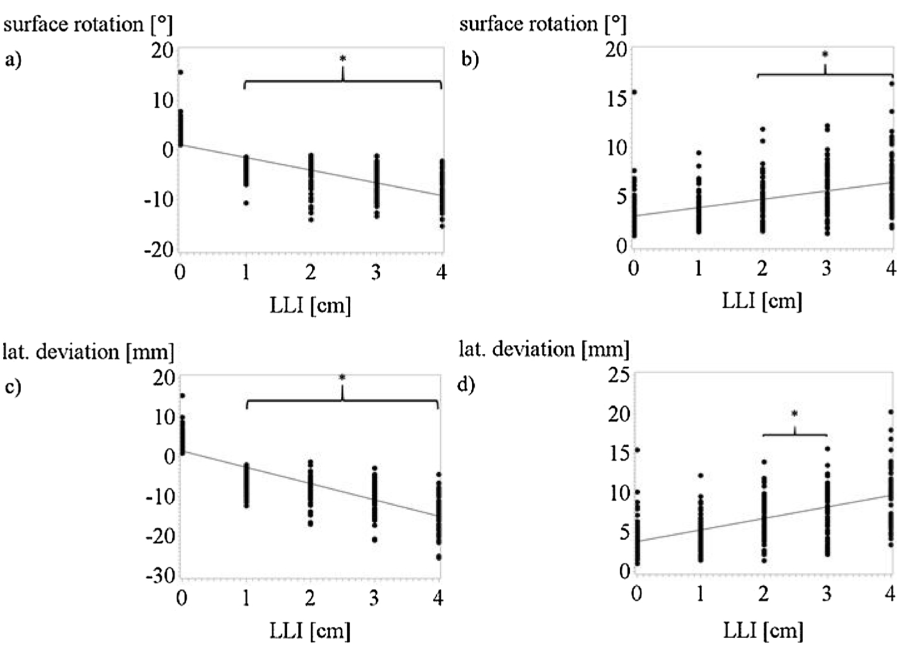

Fig. 3. Surface rotation in ° and lateral deviation in mm. a) and c) shows the effect of a simulated LLI on the left side. b) and d) shows the effect of a simulated LLI on the right side. Negative values indicate a surface rotation to the left side and positive to the right side. The brackets mark the LLIs, which reach the level of significance [$p < 0.05$] in relation to the reference LLI (0 mm). The surface of the back is rotated and laterally deviated to the side of simulated LLI. The reported dots shown in this figure represent one single trial.

Aim of this study was to develop a method for simulating and evaluating LLIs and their effects on the pelvis and spine under dynamic conditions.

2. Materials and methods

30 test subjects without pre-existing leg or spinal abnormalities were included in this study. Exclusion criteria of this first pilot study were a pelvic obliquity due to a functional or anatomical leg length discrepancy greater 10 mm and obesity with a body mass index (BMI) of greater 35 kg/m^2, which could impede the detection of anatomical landmarks by the measuring system. Another exclusion criterion was back pain during the previous year lasting longer than 2 days. Mean age of the subjects was 24.4 years (± 2.2 years), mean height was 1.77 m (± 0.08 m) and mean weight was 70.5 kg (± 7.2 kg). The subjects gave their oral and written consent to participate in this study. The protocoll of this study was approved by the local ethic commity (Study number: 111-15).

All measurements were conducted with a surface topography measuring system (Formetric 4D motion, Diers International GmbH, Germany). This system allows a radiation- and contact-free examination of the pelvic position and spinal posture [11]. It consists of a light projector and a digital video camera, which work together as a stereooptical pair [8]. The method of surface topography is based on the mathematical principle of triangulation, which uses the projection centers of the stereooptical pair to measure the 3D coordinates on an object's surface [12]. The projector generates a raster image on the back, which is captured by a digital camera [12]. The computer unit