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THE EFFECTS OF LEG LENGTH DISCREPANCY ON INTER-SEGMENTAL COORDINATION BETWEEN THE SPINE AND PELVIS DURING GAIT: A DYNAMICAL SYSTEMS APPROACH

Robert Needham, Nachiappan Chockalingam, David Dunning, Roozbeh Naemi and Aoife Healy
[1]CSHER, Faculty of Health Sciences, Staffordshire University, UK
r.needham@staffs.ac.uk

SUMMARY

There are assumptions that leg length discrepancy (LLD) may cause low back pain (LBP) by creating pelvic obliquity and lumbar scoliosis, although the exact means by which LLD causes or augments LBP is not clear. While it is evident individuals with LLD display compensatory movements in the lower limbs and pelvis, there is a scarce research regarding the effects of LLD on spinal motion. In this study LLD (1, 2, 3cm) was simulated and using a vector coding technique inter-segmental spine and pelvis coordination during gait was investigated. Circular statistics was used to average the coordination angles between trails and individuals. This investigation did not reveal any distinct differences in pelvis and lumbar spine coordination in the frontal plane during various phases of the gait cycle. High movement variability was related to changes in coordination patterns. Incorporating measures of coordination and movement variability may assist clinicians in the rehabilitation process for the purpose of restoring normal patterns of walking.

INTRODUCTION

Leg length discrepancy (LLD) is defined as a condition in which limbs are noticeably unequal [1] and has been implicated as a predisposing factor associated with low back pain [1,2]. While individuals with LLD develop compensatory strategies during gait, resulting in kinematic alterations in the lower limbs and pelvis [3], few investigations have attempted to investigate the effects of LLD on kinematic variables of the upper body, especially spinal motion.

Investigating the influence of simulated LLD on three-dimensional motion of the pelvis and spine during gait [4], this preliminary study reported minimal differences in pelvis and lumbar spine range of motion (ROM) values between barefoot and LLD conditions (1, 2, and 3cm). However, it was clearly evident that simulating LLD imposed asymmetrical movements. These observations represented mean data from 7 participants. However, further analysis revealed that not all of the participants demonstrated the same coordination / compensatory strategies to the task constraints imposed by simulating LLD.

Variability is inherent in all biological systems and prevalent in human gait patterns [5]. Traditional linear measures of analysis to evaluate variability do not account for the continuous dynamic interaction of inter-segmental coordination. Understanding variability in movement control strategies during gait and incorporating measures of coordination and movement variability could have major implications in the diagnosing process and may assist clinicians in the design of intervention programs during rehabilitation for the purpose of restoring normal patterns of walking. The aim of this study was to investigate the influence of simulated LLD on inter-segmental coordination between the spine and pelvis.

METHODS

Ten male participants with a mean age of 22.4 (±2.46) years, height of 180.3 (±7.18) cm and mass of 74.97 (±11.02) kg, with no history of musculoskeletal impairments participated in the study. Ethical Approval was sought and received from the University Research Ethics Committee.

Participants were required to walk barefoot at a preferred walking speed (PWS). Timing gates (Brower Timing Systems, USA) were also used during data collection for barefoot/LLD conditions to ensure PWS was achieved.

To simulate LLD individualized/modified pieces of high density EVA were attached to the fore/rear part of the right foot. There were three conditions of LLD (1, 2, 3cm). A pilot study using a multi-segment kinematic foot model [6] ensured the chosen method did not restrict normal foot motion during walking. An eight camera motion capture system (VICON, Oxford, UK) was used to record three dimensional coordinate data at 100 frames per second. Five trials for each condition were recorded. Marker coordinate data was processed in Visual3D (C-motion-Inc, MD) using a low-pass Butterworth filter with a cut-off frequency of 6Hz.

The kinematic spine model consisted of the following rigid segments: upper thoracic (UT T1-T6), lower thoracic (LT T6-T12) and lumbar (L1-S1). The validated spine model used is reported elsewhere [7].

A vector coding technique was used to quantify coordination between segments of the spine and pelvis [8], providing an outcome measure known as the coupling angle (CA). Mean CA and coordination angle variability (CAV) was calculated between all ten participants using circular statistics [9]. Mean coupling angles were classified into one of four coordination patterns [8].

RESULTS AND DISCUSSION

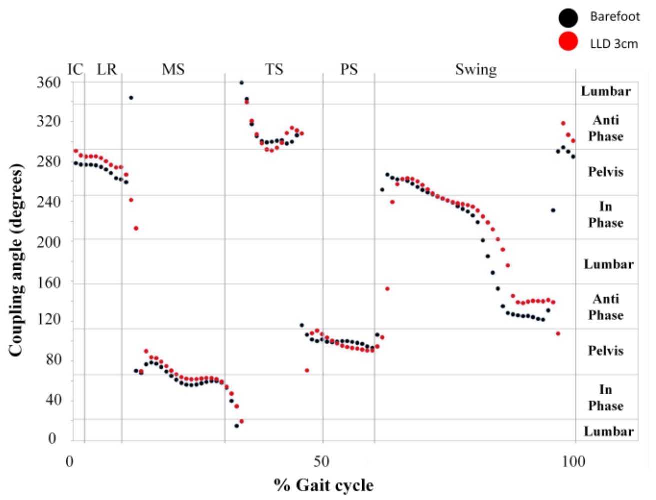

Figure 1: Mean coupling angle for all ten participants.

Figure 1 represents the mean CA across all ten participants for barefoot and the 3cm LLD condition and corresponds to frontal plane movement of the pelvis and lumbar spine during gait. Similar coordination patterns were highlighted between conditions during each phase of the gait cycle. At initial contact (IC), through loading response (LR) and during early mid-swing (MS) the pelvis was the predominant coordination pattern. A transition to in-phase coordination followed until the end of MS. Anti-phase was the predominant coordination pattern during terminal stance (TS) before progressing to pelvis dominancy during pre-swing (PS). The swing phase demonstrated transition from predominantly pelvis motion to in-phase then to an anti-phase coordination. Coordination in the frontal plane was predominantly pelvic dominated with equal distribution of in- and anti-phase coordination.

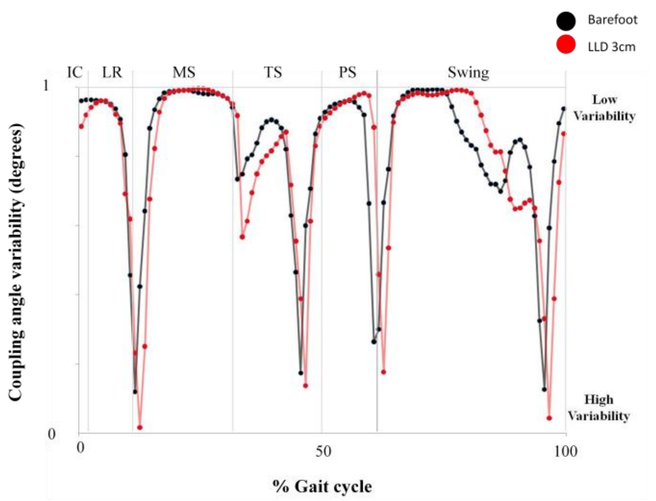

Figure 2. Mean coupling angle variability for all ten participants.

Figure 2 displays mean CAV across all ten participants. Consistent CAV between barefoot and 3cm LLD was exhibited during IC, LR, MS, PS and early swing phase. Higher variability was associated with changes in coordination pattern towards the end of LR, TS, PS and swing phase.

Small differences in ROM were observed in the frontal plane for the pelvis and lumbar spine and are in agreement with preliminary findings [4]. While the 3cm LLD condition created asymmetrical movement, with a noticeable shift in the angle-angle diagram (downward and to the left), pelvis and lumbar spine movement patterns were similar to barefoot. This may be a possible explanation for the similarities in the mean CA between barefoot and the 3cm LLD condition.

A recent study [10] reported that CAV values can be affected by walking speed. In the current study PWS was matched between conditions and this may be a reason for the similarities observed for CAV for barefoot and the 3cm LLD condition. Whilst high variability may not be associated with coordination pattern changes, the present findings suggest that high CAV is related to changes in coordination patterns between known phases of gait.

CONCLUSIONS

Altered lower limb kinematics during walking may be one possible explanation for the observed similarities in frontal plane pelvic and lumbar spine motion for barefoot and 3cm LLD condition. Therefore, further in-depth investigation into the coordination between the lower limbs and spine using vector coding is required.

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