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Effect of visual input on normalized standing stability in subjects with recurrent low back pain

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Although a number of studies have evaluated kinematic stability changes in subjects with low back pain (LBP), the combined sensitivity of normalized standing stability from the ground force and kinematic rotational angle of the body segment were not carefully examined for postural responses. The purpose of this study was to evaluate normalized standing stability in subjects with and without recurrent LBP while they stood quietly with the tested foot parallel to the other lower extremity at hip width. The subjects were then instructed to stand freely on one leg for 25 s with the contra lateral hip flexed 90° based on dominance side (dominant leg vs. non-dominant lower extremity) and visual condition (eyes open vs. eyes closed). A total of 42 subjects (27 subjects without LBP and 15 subjects with LBP) participated in the study. The dominant leg standing stability was significantly different during the eyes closed condition (0.68 ± 0.30 for control vs. 0.37 ± 0.32 for LBP, $T = -3.23$, $p = 0.002$) compared to the eyes open condition. The standing kinematic stability, especially of the dominant thigh, was greater in the control subjects than in the subjects with LBP ($T = -2.43$, $p = 0.02$). This sensitive detection of kinematic imbalance with postural stability is important for effective rehabilitation strategies and to understanding compensatory mechanisms in subjects with recurrent LBP.

1. Introduction

Low back pain (LBP) is one of the most common types of musculoskeletal pain, and it still remains a challenging problem which accompanies diverse impairments in individuals who suffer from this condition [1,2]. Clinical observations show that subjects with LBP often present impairments of postural control and dynamic stability [2,3]. Though several studies on postural control have supported decreased balance performance in subjects with recurrent LBP, there is a lack of understanding regarding the mechanism of increased postural stability and kinematic changes [1,2,4].

It is generally accepted that subjects with recurrent LBP have an altered body inclination that might be caused by anticipation of postural stability problem [2,4,5]. As a result, we established an objective way to evaluate lower extremity stability during one leg standing in previous studies [6,7]. The relative rotational angles of the body segments were calculated between two adjacent joints in three dimensions and then combined to quantify postural stability from the force plate to assess the stability index [8]. These studies reported valuable findings and began to establish movement patterns of the lower extremities; however, kinetic sensitivity on the ground is still lacking. It is necessary to assess valid results from a force plate considering the kinematic stability of the rotational angle for postural control.

Several reports indicated that the spine should not be considered in isolation from the lower extremities when trying to understand balance strategies in subjects with LBP [9]. Since altered lumbopelvic control and stability could affect the lower extremities, it is important to understand that a possible pelvic dysfunction might lead to different lower extremity movement patterns in subjects with recurrent LBP. Although these results demonstrated that subjects with recurrent LBP exhibit greater postural dysfunction than healthy controls [6–8,10], the relationship of visual feedback based on dominance side was not carefully considered.

This postural stability may provide additional information about fundamental mechanisms of standing balance since asymmetric postural responses related to the imbalances around hip joint [11]. This research further supports the need for the assessment and treatment of hip muscle imbalance in individuals with LBP. Therefore, balance stability of the proximal hip musculature is important in the prevention of lower extremity injuries [10,12]. In order to maintain postural stability within a

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certain range of motion (ROM), the body requires not only reliable sensory feedback from the ground reaction force (GRF) or muscle activation from all involved joints, but also the sensitive kinematic response of proprioceptive receptors to environmental changes.

The relative kinematic stability on the lower extremities has not been carefully considered in subjects with recurrent LBP. It has been frequently used for balance assessments based on the GRF. Since it is clear that subjects with recurrent LBP exhibit proprioceptive deficits, the kinematic changes for the stability of the pelvis could be affected in subjects with LBP as well [13,14]. These results could be due to the methodological issue that, in the absence of a standard method to quantify postural stability, the force measures were compared with functional balance tests. However, one other report has shown no significant correlations in force plate measures to reflect the performance of postural stability [15]. Therefore, this study evaluated both kinematic stability for the body segments and normalized stability from the force plate in order to objectively measure dynamic postural responses. Moreover, comparison of postural control between the normalized stability from the force plate and kinematic angular displacement measures may contribute to a further understanding of postural adjustability without visual input in relation to lower extremity movement.

Therefore, the purpose of this study was to investigate normalized standing stability and kinematic changes while considering visual input and dominance side between subjects with and without recurrent LBP. It was hypothesized that kinematic stability and standing stability on the force plate would be different in subjects with recurrent LBP. We expected that the normalized stability and kinematic angular displacement would be different for each specific region of the lower extremities between subjects with and without recurrent LBP.

2. Methods

2.1. Target population

Subjects were recruited from the greater city of Seoul, Korea. Subjects who expressed interest in the study became eligible for the study. Those subjects who met study inclusion criteria received information regarding the purpose and methods of the study and signed a copy of the Institutional Review Board approved consent form.

Subjects were eligible to participate if they: (1) were 18 years of age or older, (2) had a current episode of recurrent LBP for more than two months without pain referral into the lower extremities, and (3) had no dysfunction of the pelvis or lower extremities.

Subjects were excluded from participation if they: (1) had a diagnosed psychological illness that might interfere with the study protocol, (2) had overt neurological signs (sensory deficits or motor paralysis), and/or (3) were pregnant. Participants were withdrawn from the study if they requested to withdraw. The control group was age- and gender-matched in order to eliminate concurrent effects between groups.

2.2. Outcome measures

Pain/disability was inferred from self-reported scores on the Oswestry Low Back Pain Disability Index (ODI). The ODI is one of the most frequently used tools for measuring chronic disability [16]. A sum is calculated and presented as a percentage, where 0% represents no disability and 100% the worst possible disability [17].

The effect of visual condition was investigated by having subjects open or close their eyes during the test. Subjects performed three trials each of the lower extremity test with eyes open and then with eyes closed during dominant and non-dominant leg standing. In order to avoid learning effects, the tested legs were alternated between subjects. Limb dominance was applied in this study since the previous study confirmed that handedness could be a confounding factor for a back muscle study [10]. The right lower extremity was regarded as the dominant side for all subjects since they preferred to use the right limb to kick a ball [18,19].

The subjects were instructed to stand quietly in the upright position with their eyes open and bilateral hips and knees fully extended with both feet shoulder width apart. They were allowed to practice before testing and were free to choose which leg they preferred to lift first. All tasks were performed three times to test for reliability. The order of the tasks was randomly assigned to each participant. The participants stood barefoot on the force plate, and the initial position was standing relaxed with eyes open and weight evenly distributed between both feet. The subjects were then instructed to stand freely on one leg for 25 s with the contra lateral hip flexed 90° and to keep their arms along the side of the body during initial standing and task performance. However, compensatory arm movements were accepted, and the investigator stood close to the subject throughout the experimental session to prevent falls or injuries.

The subjects had the Helen Hayes full body (with head) reflective marker set attached to specific sites on their bodies with adhesive tape rings [20,21]. Before the experiment, data were collected from the unloaded platform to determine the zero offset. All kinematic data were filtered and time synchronized within the test cycle. Digital video data was collected and tracked using EVA 5.20. Digital video and force plate data were then imported into Orthotrac 5.2 (Motion Analysis Corporation, Santa Rosa, CA). In Fig. 1, the core axis was used as a reference for the necessary kinematic angles to compare three-dimensional rotational displacement angles. This axis was calculated based on the perpendicular coordinate on the second sacrum level, which included the pelvic plane from the sides of the anterior superior iliac spine (ASIS) for the three-dimensional spinal angles.

Synchronized kinematic data were recorded and processed by six digital cameras capturing three-dimensional full body kinematic motions sampling at 120 Hz (Motion Analysis Corporation, Santa Rosa, CA). The AMTI OR6-5 (Advanced Mechanical Technology, Inc., Newton, MA) force plate was used to record the GRF (F_x, F_y, and F_z) and the force moments (M_x, M_y, and M_z) in orthogonal directions at a sampling frequency of 50 Hz. The signals were low pass filtered with a cut-off frequency of 10 Hz to reduce the measurement noise. Balance changes imposed

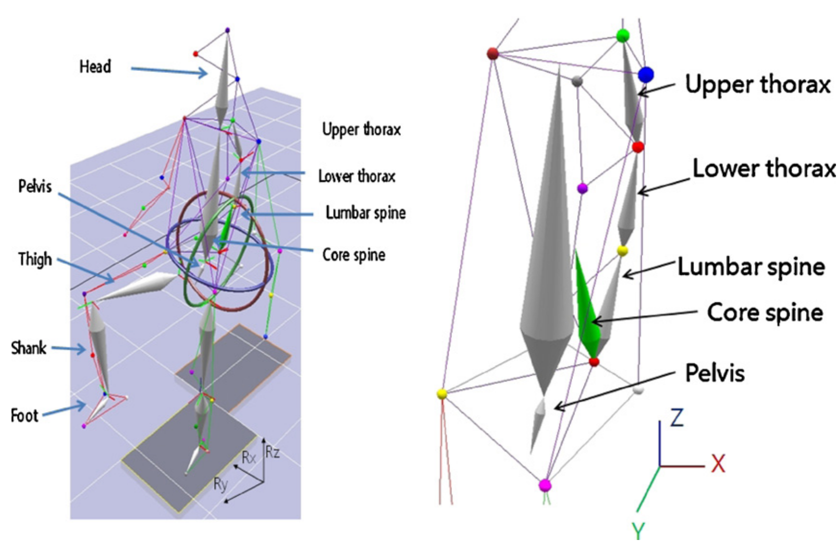

Fig. 1. One leg standing balance test. A subject stands on one leg with the contra lateral hip flexed 90° for 25 s. During the test, the subject maintains stability while the reflective markers collect kinematic data from the three axes (R_x, R_y, and R_z).