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Original article

Trunk sway response to consecutive slip perturbations between subjects with and without recurrent low back pain

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ABSTRACT

Background: Trunk sway responses following perturbations are critical to develop adequate prevention strategies. It is unclear how postural responses with a handheld task can validly be transferred to treadmill-induced slip perturbations in subjects with recurrent low back pain (LBP).

Objective: To compare trunk sway angle, velocity, and reaction time following treadmill-induced perturbations while subjects with and without LBP held a tray.

Design: Cross-sectional study.

Methods: There were 30 subjects with LBP and 50 control subjects who participated in the study. Each participant stood on the treadmill while he/she held a tray to produce a functional task. Three levels of consecutive slips were introduced based on the specific duration, velocity, and displacement.

Results: The trunk extension angle was significantly different ($F = 4.22$, $p = 0.04$) and demonstrated a significant interaction with groups and levels of perturbation ($F = 6.83$, $p = 0.01$). However, the reaction time was not significantly different based on the levels of perturbation ($F = 0.43$, $p = 0.51$). The LBP group increased trunk extension only at level 1 slip perturbation ($t = 2.86$, $p = 0.005$).

Conclusion: The increased trunk extension following the first perturbation indicated a delay in adjusting trunk stability in the LBP group. However, there was no group difference with higher magnitudes of perturbations. These results indicated that the LBP group was able to minimize trunk sway with higher perturbations following the first perturbation.

1. Introduction

Low back pain (LBP) is the leading cause of disability in most countries according to the global burden of disease study in 2015 (Disease et al., 2016). Although LBP resolves in approximately 80%–90% of patients in about six weeks, at least 5% of patients develop persistent LBP after the initial injury (Manchikanti et al., 2014). Those who have recurrent LBP may experience a loss of trunk muscle strength and a lack of positional stability to compensate from injuries (Aleksiev, 2014; Granacher et al., 2013). These studies have concluded that subjects with recurrent LBP might be able to adopt proprioceptive postural control for optimal compensation strategies.

The potential causes for recurrent LBP frequently lead to repetitive micro trauma, limited functional mobility, and reduced lower limb muscle strength in addition to inadequate postural control (Fjeldstad et al., 2008; Lafortuna et al., 2005; Trainor and Trainor, 2004). The altered postural control might be related to a lack of proprioceptive postural control for optimal compensation strategies from the lower limbs in subjects with LBP (Brumagne et al., 2008; Sung and Danial, 2016). However, it is unclear whether these results can validly be transferred to treadmill-induced perturbations, especially with a hand held task.

The postural deficits following slip perturbations are frequently related to limited functional mobility, hip fractures, and reduced lower limb muscle strength in older adults (Liu et al., 2017; Pai et al., 2014). Although subjects with recurrent LBP demonstrate altered trunk control, the likelihood of slips or fall-related injuries might be caused by the individual's neuro-musculoskeletal capacity. This functional capacity might depend on trunk control within the capacity of treadmill-induced slips evoked when standing.

The fall risk can be raised based on adapted motor control with a number of external sources, such as various types of slips in daily activities. It is evident that external perturbations might differentiate fall-prone individuals (Lockhart and Liu, 2008) since local dynamic stability (i.e., greater sensitivity to local perturbations) may be used as a potential predictor to differentiate balance deficits. It is possible to

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decrease fall risk with adapted motor control even though such adaptations happen quickly as the central nervous system proportionately matches corrective responses with the motor errors resulting from a slip perturbation in older adults (Adkin et al., 2000; Marigold et al., 2003; Pai et al., 2010).

Other recent studies reported the effects of obesity on falls and dynamic stability control in young adults by the standardized treadmill-induced gait-slip (Yang et al., 2017a, 2017b). The results of their study indicated that obesity most likely influences the ability to recover from slip perturbations, and it is important to develop interventions to improve the capability of balance recovery among obese individuals. Therefore, anthropometric factors, such as age and body mass index (BMI), will be considered to compare outcome measures following consecutive slip perturbations between subjects with and without recurrent LBP.

The purpose of this study was to assess reaction times, trunk sway angles, and velocities following three levels of treadmill-induced slips between subjects with and without LBP. It was hypothesized that there would be significantly increased trunk sway angles and reaction times following the first slip perturbation in the LBP group.

2. Methods

2.1. Participants

Subjects were recruited from the University community through advertisement, and those subjects who met the study's inclusion criteria received information regarding the study design and signed a copy of the Institutional Review Board approved consent form.

The subjects with LBP were eligible to participate if they: 1) were between 20 years and 65 years of age and right limb dominant, 2) had no current episode of acute pain referral into the upper/lower extremities at least one month prior to data collection, 3) had no structural dysfunction of the spine or lower extremities at the time of data collection, which was determined by the subjects' family physicians, and 4) had no conditions which would prevent them from standing without impaired balance (e.g., central nervous system disorder, neuromuscular disorder, vestibular disorder, diabetes, etc.).

The subjects with LBP 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. An episode of LBP is defined as a period of pain in the low back lasting for more than 24 h, preceded and followed by a period of at least 1 month without LBP (de Vet et al., 2002).

The control subjects were recruited with similar anthropometric factors as the subjects with LBP with the exception of pain for at least 1 month. Lower extremity dominance was also applied in this study since a previous study confirmed that dominance could be a confounding factor (Sung et al., 2004).

2.2. Experimental procedures

2.2.1. Measurement set-up

Upon arrival to the Motion Analysis Center, each participant completed the health questionnaire forms, which included anthropometric information. A visual analog scale (VAS) was utilized for the assessment of pain intensity in the LBP group. The scale was comprised of a 100 mm horizontal line labeled with scale anchors at each end (Huskisson, 1983). The two ends of the VAS scale were explained to patients as being “no pain” and “pain as bad as it could be,” and the scores ranged from 0 to 100 (mm). The subjects were instructed to mark the point that best expressed their pain at that moment.

The level of dysfunction for all participants was evaluated by the Oswestry disability index (ODI), which is one of the most frequently used tools for measuring chronic disability (Ciccone et al., 1996). A sum is calculated and presented as a percentage, where 0% represents no disability and 100% represents the worst possible disability.

The subjects were barefoot during the study. Following the instructions, participants walked at a speed of 1.7 m/sec for one minute to be familiar with the ActiveStep® treadmill device (Simbex, Lebanon, NH) without perturbation. The device delivers life-like perturbations that simulate real slips as the measurements of responses to the perturbations can augment quasi-static balance testing. The device measures and analyzes dynamic stability, step recovery, and trunk control movements that are related to the incidence of suffering a fall from postural perturbations.

The device consisted of a platform, which was mounted under a movable belt on top of a low-friction metal frame embedded in the treadmill. The belt consists of a black polyurethane top-layer and an under-layer made of a nylon-polyester weave covered on the platform and free to slide forward after being released by electronic locks. The subjects did not know when the belt would be released while standing on the platform, which would initiate a forward slip.

During the slip perturbation, the foot lift-off and the following touchdown were recorded by the synchronized vertical ground reaction force (GRF). The initial contact or step touchdown and toe-off or lift-off were identified from the GRF and verified from foot kinematic data. The platform could slide freely up to 150 cm (coefficient of friction < 0.05) and was supported by force plates (AMTI, Newton, MA) recording GRF at 600 Hz. Upon the subject's step from the force plate installed beneath the platform, a computer-controlled triggering mechanism would release the movable belt on the platform. This platform can slide freely in the anteroposterior direction, but cannot move in the medial-lateral direction.

The subjects were instructed to stand on the treadmill while holding a tray, and they were informed that they may or may not experience a slip in the forward direction at any time in order to produce real-life reactions to the treadmill-induced slips. However, they did not experience the levels of perturbation used in the study prior to data collection since information regarding the spatial and temporal predictability of the slips could influence the results.

If a slip occurred, the participants attempted to correct their posture and to recover a standing position while still holding the tray; they were not informed when, where, or how the slip perturbation would occur. During the test, all subjects wore a full-body safety harness system, which protected them from any potential injuries during falling while imposing negligible resistance.

2.2.2. Data collection

The reaction time (seconds) by step measure was between onset of perturbation and toe-off. The trunk measures were for the flexion/extension angle (degrees) and trunk flexion/extension velocity (degrees/second), which were compared between the groups while holding a tray. The trunk motion sensor (ActiveStep® Models GS) was attached to the chest of the participants and monitored trunk flexion, extension, and tilt while sampling at 120 Hz. A positive value indicates flexion with a positive rotation about the X axis. A positive value indicates a rotation to the patient's left with a positive rotation about the Z axis. A positive value indicates a tilt to the patient's left with a positive rotation about the Y axis. All three values were measured in degrees.

Fig. 1 indicates the experimental setup for inducing slips in standing while holding a 2.2-pound tray to mimic a functional task associated with daily living. The consecutive three levels of treadmill-induced slips were introduced at level 1 (duration: 0.10 s, velocity: 0.24°/s, displacement: 1.20 cm), level 2 (0.12 s, 0.72°/s, 4.32 cm), and level 3 (0.12 s, 1.37°/s, 8.22 cm).

The perturbations occurred in the order of level 1, level 2, and level 3 without changing the order of the trials. Trunk sway angles and velocities were measured during trunk flexion and trunk extension.