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Declined Treadmill Walking Eliminates Asymmetric Walking Pattern in Healthy Young Adults

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Background

Human locomotion is flexible for any kind of environment, and this fact has been widely approved by researches which instructed subjects to walk different walking speed in each leg on the split-belt treadmill (Choi et al., 2009; Malone and Bastian, 2010) or by putting an ankle weight on one leg (Mukherjee et al., 2011).

Only one study (Sombric et al., 2019) indicated that the flexibility of human locomotion indeed exists when walking on the inclined and declined surfaces by adjusting the step length symmetry on a split-belt treadmill. Importantly, walking on the inclined surface with two different walking speeds for each leg enhances the adaptation in comparison with walking on a declined and level surface due to the increased propelling force during the push-off phase of the gait cycle (Sombric et al., 2019).

However, when requiring a human to walk different walking speeds for each leg on the split-belt treadmill, their locomotor behaviors are passively changed by the motor-driven treadmill (feedback-driven).

Therefore, it is difficult to understand how participants adjust the flexibility of locomotion actively under physical and conscious demands by using the split-belt treadmill.

To address this gap, our current study investigated the flexibility of locomotion by using the 4-lb ankle weight on the dominant leg to induce the asymmetric walking pattern when walking on the inclined, declined, and level treadmill.

Hypothesis

We hypothesized that the level of active control would increase to adapt the asymmetric walking in all different kinds of inclinations.

Subjects

Twenty healthy young participants (age: 24.7 ± 2.2 years; height: 1.73 ± 0.08 m; mass: 68.92 ± 12.07 kg, 12 females and 8 males) were recruited for this study.

Participants were free from any neurological or musculoskeletal problems and no recent history of lower extremity injuries that might have affected their walking, such as having osteoarthritis, gout, neuropathy, vertigo, dementia, stroke, Parkinson disease, vestibular disorders, and any other diseases or circulation issues.

In addition, a Montreal Cognitive Assessment (MoCA) was given to all participants. The MoCA is a 30-point questionnaire that is used in the clinical and research setting to measure cognitive impairment. For those participants whose scores were above 26 out of 30 on the MoCA, they were included in this study.

Methods

Six conditions (walking on the level treadmill; walking on the 15% grade of inclined treadmill; walking on the 15% of declined treadmill; walking on the level treadmill with wearing 4-lb ankle weight on the dominant leg; walking on the 15% grade of inclined treadmill with wearing 4-lb ankle weight on the dominant leg; and walking on the 15% grade of declined treadmill with wearing 4-lb ankle weight on the dominant leg; Figure 1) were randomly assigned to participants.

An infra-red eight-camera Qualisys motion capture system (Qualisys AB, Gothenburg, Sweden) and spherical retro-reflective markers were used to collect three-dimensional kinematic data using Qualisys Tracker Manager (QTM) software (Qualisys AB) at 100Hz. Retro-reflective markers were placed on heels, and the second metatarsophalangeal joint (toe) of both legs to measure step length symmetric index (SLS) and step time symmetric index (STS).

$$\mathrm{SLS} = \frac{SL\_non\_dominant\_leg - SL\_dominant\_leg}{SL\_non\_dominant\_leg + SL\_dominant\_leg}$$

$$\mathrm{STS} = \frac{ST\_non\_dominant\_leg - ST\_dominant\_leg}{ST\_non\_dominant\_leg + ST\_dominant\_leg}$$

A two-way repeated measures ANOVA was used to investigate interaction between effect of unilateral limb loading and the effect of different locomotor conditions on SLS and STS. The significant level was set at 0.05.

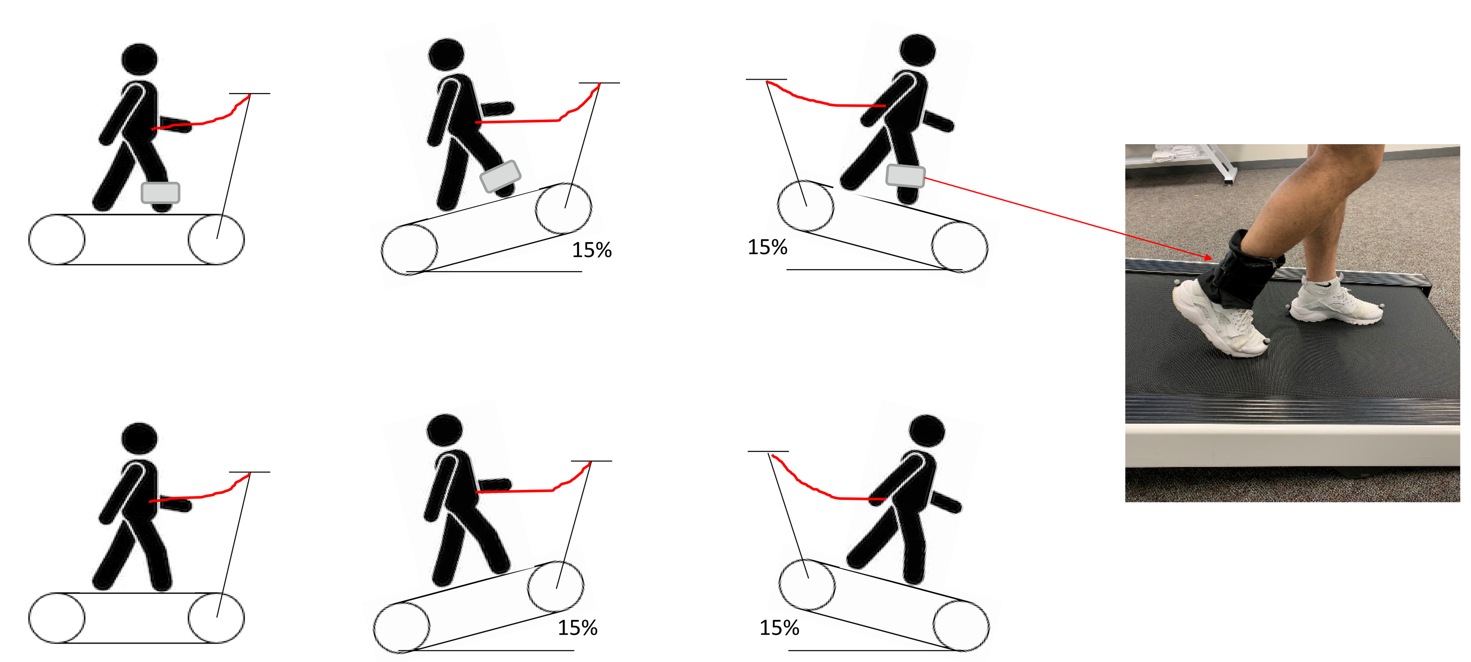

Figure 1 – The six condition of experimental diagram. The blue box represents the 4-lb weight. The angle of inclination and declination is 15% grade.

Results

A significant interaction was found between the effect of unilateral limb loading and the effect of conditions on SLS ($F_{2, 76}$ = 71.70, p < 0.0001) and on STS ($F_{2, 76}$ = 75.75, p < 0.0001). The post hoc comparisons revealed that wearing a 4-lb ankle weight significantly increased the SLS and STS values when walking on a level treadmill (p < 0.0001, p < 0.0001, respectively) and when walking on an inclined treadmill (p < 0.0001, p < 0.0001, respectively). In addition, among conditions which were wearing a 4-lb ankle weight, significantly higher SLS and STS values were found when walking on the level treadmill (p < 0.0001) and walking on the inclined treadmill (p < 0.0001) in comparison with when walking on the declined treadmill.

This phenomenon could be explained by that participants increased their active control of lower leg during declined treadmill walking to eliminate the effect of unilateral ankle loading by reducing the step length and step time.

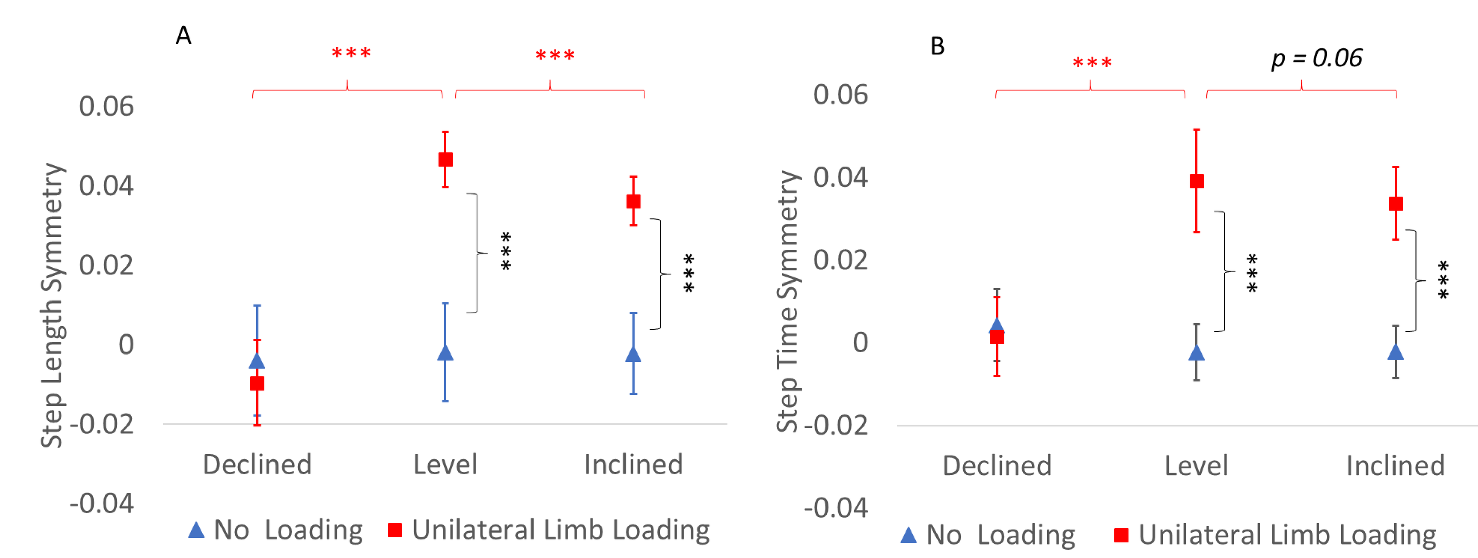

Figure 2 - The effect of different conditions (declined, level, inclined -- red arterisk) and the effect of unilateral limb loading (with/without loading – black arterisk) on step length symmetry and step time symmetry. *** represents p < 0.001

Conclusion & Clinical Relevance

Walking on the declined surface could induce a higher level of active control than walking on level and an inclined surface.

To our best knowledge, this is the first study to demonstrate that walking on the declined surface eliminated the asymmetric walking pattern in young adults. It has been shown that training patients with stroke on a split-belt treadmill reduced their asymmetric walking pattern during overground walking. However, this learning effect disappeared after approximately ten strides or less due to different levels of active control. The current result illustrates the possibility of training on the declined treadmill to regain symmetric walking pattern in patients who walk asymmetrically.

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