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RELIABILITY OF WALKING SPEED, STRIDE TIME AND STRIDE LENGTH VARIABILITY USING FEEDBACK-CONTROLLED TREADMILL

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The purpose of this study was to evaluate the test-retest reliability of walking speed, stride time and stride length variability using a feedback-controlled treadmill. Ten subjects performed 3 trials of walking experiment for 5 min with a feedback-controlled treadmill. To check the reliability of gait parameters such as walking speed, average and variability (i.e. coefficient of variance, CV) of stride time and stride length, those parameters were compared in this study. Results showed that all gait variables were confirmed the reliability within-trial (walking speed: intra-class correlation, ICC=0.996, standard error of measurement, SEM=0.03, average stride time: ICC=0.989, SEM=0.01, stride time variability: ICC=0.680, SEM=0.18, average stride length: ICC=9.994, SEM=0.01, stride length variability: ICC=0.830, SEM=0.25). This feedback-controlled treadmill can be used for various gait dynamics study using spatio-temporal variables.

KEY WORDS: feedback-controlled treadmill, gait variability, reliability, spatio-temporal variable.

INTRODUCTION: There are many advantages using a treadmill for gait study, such as saving experimental duration and space and minimizing equipment required to measure. Experimental environment also can be easily controlled according to the purpose of study, including various inclinations of the walkway and constant walking speed (Alton et al., 1998). In addition, it is known that treadmill walking is very similar to overground walking from the perspective of kinematics and kinetics (Alton et al., 1998; Riley et al., 2007). In the study of gait variability, it, however, has reported that stride time and stride length variability during treadmill walking were reduced than those during overground walking (Dingwell et al., 2001). Thus, it may affect human's natural gait control, which consists of stride time and stride length.
In several researches, feedback-controlled treadmill, which can be tuned treadmill belt speed to walker's speed as quickly as possible, have been tried to apply gait research (Bonnard & Danion, 2000; Minetti et al, 2003). Since a treadmill belt speed can be changed frequently by the subject while walking per each trial, it is necessary to confirm the reliability of walking speed and spatio-temporal variables. Therefore, the purpose of this study was to evaluate the test-retest reliability of walking speed, stride time and stride length variability using a feedback-controlled treadmill.

METHODS: Ten male subjects without any disorder on lower limb extremities were participated in this experiment (age: 22.1±1.2 years, height: 174.8±3.1 years, weight: 70.1±8.8 kg). This experimental procedure was explained to all subjects prior to experiment, and written consents were received. All experiment was performed using a feedback-controlled treadmill (RX9200S, TOBEONE, Korea), which can be tuned treadmill belt speed to walker's speed. It controls belt speed by walker's anterior-posterior location by using installed-loadcell under treadmill floor. In other words, treadmill belt speed increases when walker's location is in advance of the centre of treadmill, whereas treadmill belt speed decreases when walker's location is in posterior to the centre of treadmill. Treadmill belt speed was transmitted to PC with 10 Hz through RS232 cable and recorded. All subjects were walked 3 trials for each 5 min on the feedback-controlled treadmill with gazing in front.

To detect gait events, reflective markers were attached at subject's right toe and heel. 3D motion analysis system (Motion Analysis Corps, USA) was used with sampling frequency of 120 Hz. Based on heel strike (HS), which was detected by Foot velocity algorithm (O'Connor et al., 2007), stride time and length, duration and distance between sequential heel strikes, respectively, were calculated. Subject's walking speed is defined as the average of the treadmill belt speed recorded at PC and gait variability was represented by using coefficient of variance (CV = SD/mean*100).
To compare the reliability of walking speed, average and variability of stride time and stride length between trials (i.e., the value of each trial was represented by calculating the average of all subjects), intra-class correlation (ICC) and standard error of measurement (SEM) were used. SPSS Statistics ver. 19 (SPSS Inc., USA) were used for statistical analysis with a significant level of .05.

RESULTS: Results of the reliability with 3 trials were shown in Table 1. There was no significant difference in the average of walking speed, stride time and stride length. However, there were significant differences in those reliabilities. There also was significant reliability in stride time and stride length variability. All SEM were significantly small.

Table 1
Results of Walking Speed, Average and Variability of Stride Time and Length

Variables	Trial 1	Trial 2	Trial 3	ICC	p-value	SEM
Walking speed (m/sec)	1.44 (0.14)	1.44 (0.16)	1.43 (0.16)	0.996	0.000	0.03
Stride time (sec)	1.05 (0.05)	1.06 (0.06)	1.05 (0.06)	0.989	0.000	0.01
Stride time variability (%)	1.41 (0.23)	1.46 (0.42)	1.43 (0.29)	0.680	0.025	0.18
Stride length (m)	1.17 (0.11)	1.17 (0.11)	1.16 (0.12)	0.994	0.000	0.01
Stride length variability (%)	2.37 (0.47)	2.49 (0.81)	2.27 (0.56)	0.830	0.001	0.25

DISCUSSION: Human gait consists of a complex system. Locomotor system generally controls muscles and limbs by using integration of inputs from the motor cortex, cerebellum, and basal ganglia and sensory feedbacks from visual, vestibular and proprioceptive sensors (Hausdorff, 2007). By using stride time and stride length which are the results from this complex process, gait variability can be used to compare changes of gait pattern by various walking conditions (Hausdorff, 2007; Dubost et al., 2008). The most fundamental factor for gait variability study is natural walking condition during the experiment. It has been reported that traditional treadmill walking decreased the variability than an overground walking (Dingwell et al., 2001), and it can restrict the control of natural walking speed which consists of stride time and length due to constant belt speed (i.e. traditional treadmill) (Danion et al., 2003). Thus, it is necessary to use a feedback-controlled treadmill during gait variability study since gait reflects the relationship among neuromuscular-skeletal system. This was a preliminary study to apply feedback-controlled treadmill to gait variability research. To acquire this purpose, the reliability of walking speed, average and variability of stride time and stride length using a feedback-controlled treadmill were tested within-trials. Results showed significantly small SEM and large ICC, such as walking speed: ICC=0.996, SEM=0.03, average stride time: ICC=0.989, SEM=0.01, stride time variability: ICC=0.680, SEM=0.18, average stride length: ICC=9.994, SEM=0.01, stride length variability: ICC=0.830, SEM=0.25. In other word, feedback-controlled treadmill those belt speeds can be changed by subject's demand showed constant walking speed for all subjects, and reliability of the average and variability of stride time and stride length within-trial, respectively. It showed that feedback-controlled treadmill can be used in gait variability research.

CONCLUSION: This was a preliminary study to apply feedback-controlled treadmill to gait variability research. Results showed that feedback-controlled treadmill those belt speeds can be changed by subject's demand gave constant walking speed for all subjects, and reliability of the average and variability of stride time and stride length within-trial, respectively. In further study, this feedback-controlled treadmill can be used for various gait dynamics study using spatio-temporal variables.

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