Changes of Normal Adult Physiological States and Gait Parameters with Treadmill Inclined

YongWoo Lee, PT, DC, MSc1, Oh Sung Kwun, PT, MSc1, DongWon Seo, PT, MSc1, SangWoo Jung, PT, MSc1, Young Jin Lee, PT, MSc1, Sejong Choi, PT, MPE1, SeungWon Lee, PT, PhD1

1) Department of Physical Therapy, Sahmyook University: 26-21 Gongneung2-dong, Nowon-gu, Seoul, 139-742, Republic of Korea. TEL: +82 2-3399-1630, FAX: +82 2-3399-1639, E-mail: swlee@syu.ac.kr

Abstract. [Purpose] The purpose of this study was to determine the standard alterations in normal adult physiological states and gait parameters resulting from changes in treadmill slope during the use of the treadmill as a medical reference. [Subjects] The subjects of this study were 12 normal, healthy volunteers without any orthopedic, respiratory or cardiovascular system problems. [Methods] The gait of subjects was measured using Optogait on an inclined treadmill for 3 minutes. Gait was measured at slopes of 0%, 9% and 18%. The subjects wore a Pansystolic murmur (PSM) training device over their xiphoid process in order to measure physiological changes. The speed of the treadmill was fixed at 5.0 km/h in order to maintain a constant walking speed. [Results] The subjects’ gait parameters were observed to change significantly between slopes of 0% and 18% and the physiological states which showed significant changes were average heart rate, recovery heart rate, average respiratory rate, and angular displacement of the trunk. [Conclusion] The results of this study may be used as a medical reference for gait training on a treadmill, especially for treadmills with adjustable gradients.

Key words: Gait, Physiological state, Inclined treadmill

INTRODUCTION

Beginning with the analysis by Marey, there have been numerous examples of research on the topic of gait in fields such as physiotherapy and biomechanics1. The early studies of body movement were dominated by kinematic analysis using image technology. In the 19th century, stride, foot angle or gait speed research were conducted through dynamic studies or footstep analyses outside the lab. Subsequently, many instruments have been developed which are capable of measuring various variables affecting gait, and human gait has been analyzed by investigating the characteristics of these variables. Recently, many studies comparing normal and abnormal gaits have been conducted5.

Gait disability of stroke patients is a major problem and 27–50% of these patients complain about the impact of stroke on their ability to walk3. In stroke rehabilitation, the ability to walk independently is the most frequently mentioned goal, but this goal has focused on walking inside the home as opposed to outdoors4). Nevertheless, the need of stroke sufferers to improve their ability to walk outdoors and participate more fully in society is a demand frequently presented to stroke rehabilitation therapists and researchers5.

Gait analysis of patients has been successfully used to measure treatment effects5. Gait analysis measuring devices have been effectively used by therapists for more than ten years7. Bovi et al.8 analyzed differences in kinematic, kinetic and EMG analyses according to age group to produce clinical references. Although the existence of specific lesions can be elucidated from gait analysis, some diseases in their early stages do not affect gait, but become manifest in the later stages9,10). Human gait speed is a basic factor to consider and an important indicator to assess11,12). Gait speed is useful as a clinical indicator for evaluation of COPD, MS, Parkinson’s disease and various cardiovascular diseases13). Disability related to gait is also closely related to movement limitation, increased risk of falls and potential mortality14). It has been shown that treadmill exercise, which is often used in stroke patient gait rehabilitation, produces better results than general gait exercise15. The treadmill is widely used in the study of the biomechanics of human gait and has the advantage of producing selective and stable gait in a controlled environment16. Van Ingen Schenau17, showed that gait achieved on a treadmill at a constant belt speed and gait observed on level ground are the same. The treadmill is used as an exercise device for cardiovascular patients because it is simple to operate and economical in its application18). As mentioned above, human gait is an important factor in measuring health conditions and treatment effectiveness. Moreover, many gait studies have focused on walking on level ground19,20) but fewer studies have investigated inclined surfaces21–24). Studies of inclined surfaces are important for understanding the causes of fall and for rehabilitation requirements21–24).

The purpose of this study was to investigate kinematic gait and physiological changes induced by changes of treadmill gradient.
SUBJECTS AND METHODS

The subjects of this study were 12 healthy students attending S college which is located in S town. Subjects gave their informed consent to participation in this study as required by our Institutional Review Board.

The study inclusion criteria included the following: subjects agreed with the purpose of this study, subjects had no existing neurologic problems, subjects had no existing orthopedic problems such as lower limb fracture or sprain/strain, subjects had no existing ROM of lower limb problems, and subjects had no existing respiration or cardiovascular system problems during walking.

The average age of the subjects was 35.4 ± 2.7 years, their average height was 173.5 ± 3.1 cm, their average weight was 71.5 ± 7.1 kg, and their average BMI was 24.3 ± 1.3.

A gait analysis device (Optogait, Microgate Inc., Italy, 2010) was used to measure the subjects’ gait parameters.

Kinematic gait variables measured included cadence, step time, stride time, step length, stride length, single limb support frequency, double limb support frequency, stance phase frequency and swing phase frequency.

PSM training (Zephyr Technology Corp., New Zealand, 2010) was used to measure physiological changes. The average heart rate and breath rate of each subject was measured during a 3-minute gait test for physiological changes. After the 3-minute gait test, the subjects’ recover heart and breaths rate were measured during a 3-minute recovery period. In addition, anterior and posterior body sway was measured.

In order to prevent unnatural motions, subjects practiced walking on level ground with a PSM worn on their xiphoid process. The subjects wore shoes and walked on a treadmill for 3 minutes at incline grades of 0%, 9% and 18%. Subjects rested sufficiently between each gait test. The speed of the treadmill was fixed at 5.0 km/h to maintain a constant walking speed.

All collected data were analyzed using SPSS version 18.0. The average and standard deviation of all variables were calculated. One-way repeated ANOVA was used for comparisons between kinematic gait analysis and physiological changes at the different treadmill slopes. Fisher’s Least Significant Difference (LSD) was conducted for the post hoc evaluation. The level of statistical significance was chosen as α=0.05.

RESULTS

The results of kinematic gait versus treadmill slope demonstrated significant differences in cadence, step time, stride time, step length, stride length, single limb support, double limb support, stance phase and swing phase (p<0.01) (Table 1).

In the post hoc analysis results, significant cadence differences (p<0.05) were found between grades of 0% and 18% and between 9% and 18%. Step time between grades of 0% and 18% was found to be significantly different (p<0.05). Stride time between grades of 0% and 18% (p<0.05) and between 9% and 18% (p<0.05) were found to be significantly different. Step length between grades of 0% and 18% and between 9% and 18% were found to be significantly different (p<0.05). Single limb support between grades of 0% and 9%, between 0% and 18%, and between 9% and 18% were found to be significantly different (p<0.05). Double limb support between grades of 0% and 9% (p<0.05), between 0% and 18% (p<0.05), and between 9% and 18% (p<0.05) were found to be significantly different. Stance phase between grades of 0% and 9%, between 0% and 18%, and between 9% and 18% were found to be significantly different (p<0.05). Swing phase between slopes of 0% and 9%, between 0% and 18%, and between 9% and 18% were found to be significantly different (p<0.05).

In the post hoc results for the physiologic changes related to treadmill slope, the average heart rate was significantly different between grades of 0% and 9%, between 0% and 18%, and between 9% and 18% (p<0.05). The recovery heart rate was found to be significantly different between grades of 0% and 9% and between 0% and 18% (p<0.05). The average respiratory rate was found to be significantly different between grades of 0% and 9% and between 0% and 18% (p<0.05). The angular displacement of the trunk was found to be significantly different between grades of 0% and 9%, between 0% and 18%, and between

| Table 1. Kinematic gait analysis by treadmill grade |
|---------------------------------|----------------|----------------|
|                                 | 0 %            | 9 %            | 18 %           |
| Cadence (steps/min)             | 117.6 ± 2.6    | 118.2 ± 4.2    | 124.5 ± 5.5    |
| Step time (sec)                 | 0.5 ± 0.0      | 0.5 ± 0.0      | 0.5 ± 0.2      |
| Stride time (sec)               | 1.0 ± 0.2      | 1.0 ± 0.4      | 0.9 ± 0.4      |
| Step length (cm)                | 70.9 ± 1.5     | 70.9 ± 2.5     | 67.2 ± 2.9     |
| Stride length (cm)              | 142.1 ± 3.0    | 141.6 ± 5.0    | 134.3 ± 5.9    |
| Single limb support (%)         | 29.5 ± 0.7     | 29.1 ± 0.8     | 28.7 ± 0.7     |
| Double limb support (%)         | 40.9 ± 1.5     | 41.8 ± 1.5     | 42.6 ± 1.5     |
| Stance phase (%)                | 70.5 ± 0.7     | 70.9 ± 0.8     | 71.3 ± 0.7     |
| Swing phase (%)                 | 29.5 ± 0.7     | 29.1 ± 0.8     | 28.7 ± 0.7     |

Values are mean ± SD, * indicates comparison between 0% and 9%, 9% and 18% (p<0.05), † indicates comparison between 9% and 18% (p<0.05).
changes during level and incline walking, but our study only measured the angular displacement at the level of the xiphoid process (T9 level)\(^\text{29}\).

Usually, determination of exercise load in exercise prescription and training is made by heart rate or subjective evaluation of patient symptoms, but this approach produces risk factors for patient injury\(^2\). Therefore, therapists need to adjust the grade of the treadmill slope, as necessary.

In our study, the average heart rate and recovery heart rate increased significantly for subjects during use of the incline treadmill. Notably, their recovery heart rate decreased with use of the incline treadmill. Yanagisawa’s study noted that an abnormal heart recovery rate in elderly subjects was related to a higher mortality rate. Thus, therapists should evaluate heart recovery rate when creating an exercise program using a treadmill for elderly patients\(^1\).

Many virtual reality trainings have utilized a treadmill in the treatment of stroke patients\(^31\text{–33}\). If these virtual reality trainings utilize treadmill slope, it may increase the therapeutic effects for the patient.

ACKNOWLEDGEMENT

This study was supported by the Sahmyook University Research Grant, 2012.

REFERENCES