

The Effects of Velocity and Gradient Changes on Cardiopulmonary Functions during Treadmill Walking

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Abstract. [Purpose] This study investigated the effects of velocity and gradient changes on cardiopulmonary functions during treadmill walking. [Subjects] The subjects were eleven physically fit female participants, 20 to 22 years of age. [Methods] Treadmill workload protocol was set at 4, 5, 6, 7 and 8 m/s and 0, 2.5, 5, 7.5, and 10% for velocity and gradient loading. A portable gas analyzer (COSMED K4b2, Italy) and portable heart rate analyzer (GBR. A, Finland) measured VO₂, VCO₂, EE, and HR. A treadmill with control of velocity and gradient was used for walking. Each of the average values used in the analysis was calculated from a 3 to 5 minute use of the treadmill. [Results] During treadmill walking, VO₂, VCO₂, EE and HR increased as the velocity increased. Also, as the gradient increased, VO₂, VCO₂, EE and HR increased. A comparison revealed that changes in velocity had a greater effect on VO₂, VCO₂, EE and HR gradient. [Conclusion] The results show that cardiopulmonary functions are affected by changes in velocity and gradient during walking. In particular, velocity has a greater effect on cardiopulmonary functions than gradient.

Key words: Treadmill, Cardiopulmonary functions, Walking velocity

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INTRODUCTION

Walking, a basic human movement, is the safest aerobic exercise, and it brings about changes in body composition, enhances motor performance by improving heart rate, blood pressure, and MVO₂ (myocardial oxygen consumption), and provides benefits for heart disease¹⁾. Walking is also known to improve flexibility and muscular strength, increase bone mineral density, and help psychological issues, for example, by improving cognitive performance²⁾.

Despite these many advantages, the energy expenditure of walking exercise is low compared to that of other types of exercise. Therefore, it is hard for a person with great physical strength to obtain results from walking exercise because the target HR cannot be reached by walking exercise³⁾. To remedy this shortcoming, studies using a treadmill that increases EE (energy expenditure) by applying various workload protocols during walking exercises have been conducted. Kwon Oh-Kyung⁴⁾ reported in his study, that the gradient and velocity of a treadmill have great effects on fat loss, while Jeong Il-Gyu et al.⁵⁾ noted that EE increases when walking with weights on the ankles. Walking exercise is a workload method that is commonly used for ambulation training of patients in hospitals. Nevertheless, not many studies have attempted to determine which variable, velocity or gradient, has the greater effect on changes in cardiopul-

monary function.

Accordingly, this study examined the effects of velocity and gradient, major variables of a treadmill, on cardiopulmonary function to determine the more effective variable. The study performed basic research that has not been previously performed.

SUBJECTS AND METHODS

For this study, 11 female subjects were recruited. The subjects were instructed to walk for five minutes under ten different conditions of velocity and gradient on a treadmill. We made repeated measurements of treadmill walking under each condition, and each measurement was conducted after subjects had rested until their heart rate (HR) had returned to the baseline level. Heart rate was measured using a portable gas analyzer, to ensure the effects of the preceding treatment had disappeared. The measurements of this study were conducted on a treadmill (h/p/Cosmos, Proxomed, Germany) with adjustable velocity and gradient. A portable gas analyzer (K4b2, COSMED, Italy), and a portable HR analyzer (GBR. A, Finland) were used.

First, the gradient was set at 0%, and walking was performed at 4, 5, 6, 7 and 8 km/h, based on the method employed by several previous studies. Then, the walking velocity was fixed at 4 km/h, and the gradient was set at 0,

Table 1. Verification of VO₂ and VCO₂ consumption, energy expenditure (EE) and heart rate

Variable		Grade1	Grade2	Grade3	Grade4	Grade5
O ₂ (ml/min)	Velocity	767.87 ± 183.04	875.43 ± 156.99	1030.13 ± 155.89	1261.94 ± 250.89	1599.98 ± 296.88
	Gradient	767.87 ± 183.04	867.08 ± 200.49	929.51 ± 174.38	1094.83 ± 251.84	1119.5 ± 200.66
	Within Group : F=68.986*	Between Group : 4.218		Interaction : F=11.901*		
CO ₂ (ml/min)	Velocity	613.94 ± 240.84	758.36 ± 176.04	916.15 ± 146.07	1118.49 ± 341.78	1603.65 ± 200.02
	Gradient	613.94 ± 240.84	711.57 ± 164.56	779.06 ± 166.33	815.43 ± 205.87	905.38 ± 168.53
	Within Group : F=43.573*	Between Group : 14.879*		Interaction : F=14.462*		
EE (kcal/min)	Velocity	3.70 ± 0.90	4.25 ± 0.80	5.03 ± 0.74	6.32 ± 1.18	8.03 ± 1.35
	Gradient	3.70 ± 0.90	4.16 ± 0.95	4.45 ± 0.86	5.15 ± 1.19	5.35 ± 0.93
	Within Group : F=82.631*	Between Group : 6.552*		Interaction : F=17.178*		
HR (bpm)	Velocity	106.51 ± 12.76	113.36 ± 11.70	121.52 ± 12.49	135.10 ± 17.56	157.27 ± 8.62
	Gradient	106.51 ± 12.76	111.64 ± 13.24	112.61 ± 9.87	116.45 ± 8.29	122.82 ± 9.34
	Within Group : F=46.256*	Between Group : 10.763*		Interaction : F=14.118*		

(Unit) *Statistically significant at the level of $p < 0.05$

2.5, 5, 7.5, and 10%, according to the method of previous studies. Velocity and gradient were divided into five levels. Each subject was instructed to walk on the treadmill at the five velocities and five gradients for five minutes⁶⁾.

Subjects wore the portable gas analyzer and walked for five minutes at each of the set velocities with the gradient fixed at 0%. They rested after each 5-minute walk, and then walked again for five minutes at the next level of velocity. While resting, their HR was measured before walking again to ensure that HR had returned to the stable condition. For the analysis, these measurements are referred to as the velocity-load group. Subjects took a one-week rest to recover from walking fatigue, and then repeated the procedure at each of the five gradients with the velocity fixed at 4 km/h. For the analysis, these measurements are referred to as the gradient-load group. For gas analysis and HR, the average values of respiratory gas and HR between the third and fifth minutes of walking, when the body reached a steady state, were used⁷⁾.

Repeated measures ANOVA was used to analyze the data for the effect of velocity and gradient.

RESULTS

The subjects of this study were physically fit female students of S University in Busan who had never been diagnosed with cardiopulmonary diseases. Their average age was 21.73 years old, and their average height and weight were 161.55 cm and 51.45 kg, respectively.

According to the measurement of VO₂ at each level of velocity and gradient during walking on the treadmill, in the velocity-load group, VO₂ was 767.87 mL/min, 875.43 mL/min, 1030.13 mL/min, 1261.94 mL/min, and 1599.98 mL/min at 4, 5, 6, 7, and 8 km/h, respectively ($p < 0.05$). In the gradient-load group, VO₂ was 767.87 mL/min, 867.08 mL/min, 929.51 mL/min, 1094.83 mL/min, and 1119.5 mL/min at 0, 2.5, 5, 7.5, and 10%, respectively ($p < 0.05$). The results indicate that VO₂ increased as the workload increased in both groups. According to the comparison of VO₂ change in the two groups, VO₂ in the velocity-load group increased more than in the gradient-load group. According

to the measurement of VCO₂ at each level of velocity and gradient during walking on the treadmill, in the velocity-load group, VCO₂ was 613.94 mL/min, 758.36 mL/min, 916.15 mL/min, 1118.49 mL/min, and 1603.65 mL/min at 4, 5, 6, 7, and 8 km/h, respectively ($p < 0.05$). In the gradient-load group, VCO₂ was 613.94 mL/min, 711.57 mL/min, 779.06 mL/min, 815.43 mL/min, and 905.38 mL/min at 0, 2.5, 5, 7.5, and 10%, respectively ($p < 0.05$). In both groups, VCO₂ increased as the workload increased. According to the comparison of VCO₂ changes in the two groups, VCO₂ increased significantly more in the velocity-load group than in the gradient-load group. According to the measurement of EE at each level of velocity and gradient during walking on the treadmill, in the velocity-load group, EE was 3.7 kcal/min, 4.25 kcal/min, 5.03 kcal/min, 6.32 kcal/min, and 8.03 kcal/min at 4, 5, 6, 7, and 8 km/h, respectively ($p < 0.05$). In the gradient-load group, EE was 3.7 kcal/min, 4.16 kcal/min, 4.45 kcal/min, 5.15 kcal/min, and 5.35 kcal/min at 0, 2.5, 5, 7.5, and 10%, respectively ($p < 0.05$). In both groups, EE per minute increased as the workload increased. According to the comparison of EE per minute in the two groups, it increased more in the velocity-load group than in the gradient-load group. According to the measurement of HR at each level of velocity and gradient during walking on the treadmill, in the velocity-load group, HR was 106.51 bpm, 111.36 bpm, 121.52 bpm, 135.1 bpm, and 157.27 bpm at 4, 5, 6, 7, and 8 km/h, respectively ($p < 0.05$). In the gradient-load group, HR was 106.51 bpm, 111.64 bpm, 112.6 bpm, 116.45 bpm, and 122.82 bpm at 0, 2.5, 5, 7.5, and 10%, respectively ($p < 0.05$). In both groups, HR increased as the workload increased. According to the comparison of HR in the two groups, HR increased significantly more in the velocity-load group than in the gradient-load group (Table 1).

DISCUSSION

In cardiovascular responses to exercise, the distribution of cardiac output changes, and cardiopulmonary function increases according to the changes in the metabolism of

each part of the body⁸⁾. In the present study, the velocity and gradient were divided according to the range that could be used for walking exercise on the treadmill in order to examine the effects of each level of the two variables on cardiopulmonary function and to determine which workload variable had the greater effect on cardiopulmonary function.

Jeong Il-Gyu et al.⁵⁾ reported in their study that oxygen intake increased as the velocity of the treadmill increased in both groups, and HR and EE showed statistically significant increases at 7 km/h. In the study by Jo Ki-Sun et al.⁹⁾, the effects of gradient on forward walking and backward walking were observed. Their results show that VO₂ and HR increased with increases in gradient regardless of the direction of walking.

In the present, all of the values measured to determine the effects of the velocity on cardiopulmonary function, namely VO₂, VCO₂, EE, and HR, increased as the velocity increased from 4 to 8 km/h. This result is in agreement with the results of previous studies in that the changes in cardiopulmonary function become greater as the velocity increased. As the gradient of the treadmill increased, all of VO₂, VCO₂, EE, and HR increased as the gradient increased from 0 to 10%. This result is also similar to the results of other studies in which tests were conducted with gradual increases in the gradient. However, in the comparison of the effects of velocity and gradient, VO₂, VCO₂, EE, and HR increased more with increases in velocity. In other words,

the changes of velocity had greater effects than those of gradient. However, there are limits to general comparisons of velocity and gradient, and standardized studies of velocity and gradient should be conducted in the future.

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