INFLUENCE OF DIFFERENCE IN BUOYANCY ON PHYSIOLOGICAL RESPONSES DURING TREADMILL WALKING IN WATER

FUJIKO YONEYAMA¹,³, HITOSHI WATANABE², MASANOBU ARAKI³ and KYONOSUKE YABE³

Abstract

The aim of this study was to clarify the influence of buoyancy on physiological responses during treadmill walking. Six subjects participated in this experiment. The water level was adjusted to the greater trochanter. Normal water (NW) and 1.135 kg/l of specific gravity (high buoyancy; HB) were set. Oxygen uptake (VO₂), heart rate (HR), and rating of perceived exertion were measured during exercise. VO₂ in HB at all walking speeds were higher than those in NW significantly. HR enhanced in HB over the walking speed of 70 m/min significantly. It was clear that the workload of walking in HB increased remarkably over the walking speed of 70 m/min. This suggested that the water resistance acted on the phenomenon of increase of the workload in HB. Furthermore, it was suggested that walking in HB was useful for rehabilitation and therapeutic exercise in the low-speed and for physical training in the high-speed.


key word: buoyancy, specific gravity, treadmill walking, greater trochanter

Introduction

It was well known that the physiological responses to water immersion have indicated differences from land by means of influence of buoyancy, water pressure and water temperature. Furthermore, the water resistance will affect the physiological responses during exercise in water. Walking in water has been applied as a means suitable not only for physical fitness training of ordinary healthy people and obese people but also rehabilitation with musculoskeletal ailments or surgically lesions. Changes in cardiopulmonary, metabolism, muscle activity have been analyzed for walking in water in relation to exercise speed, water depths and water temperature in previous studies. However, effect of buoyancy of water has not been clarified so far during walking in water.

The purpose of the present study was to determine the influence of buoyancy of water on oxygen uptake (VO₂), heart rate (HR), and rating of perceived exertion (RPE) during treadmill walking.

Subjects

Five men and one woman healthy volunteers served as subjects. The physical characteristics of the subjects were as follows: mean±SD age = 23.5±9.6 years; height = 169.9±5.7 cm; weight = 63.8±7.3 kg. They gave informed consent to the experiment protocol.

Setting of underwater environment

Water temperature was set at 32°C approximately through out the experiment, because this had least influence on the cardiopulmonary system, the oxygen transport system, and the metabolism system. The water level was adjusted to the greater trochanter. Two specific gravity of water which are normal water (NW) and 1.135 kg/l of specific gravity (high buoyancy; HB) by dissolving sodium sulfate (Na₂SO₄) were set in order to compare with the influence of buoyancy of water. There was no difference in water viscosity between NW and HB. The subjects wore a usual swimming suit.
Measurements

\( \text{VO}_2 \) was measured by breath-by-breath. HR was monitored by chest bipolar ECG. Score of RPE was determined subjectively. These parameters were recorded every 1 minute during exercise.

Experimental protocol

Treadmill walking in water was performed by incremental methods with each stage of treadmill walking lasting 3 minutes. After 5 minutes of control recording, treadmill walking continued starting from the speed of 40 m/min with 10 m/min increment until the point that was able to walk.

Statistical analysis

A paired t-test was used to study the effect of buoyancy of water at the same treadmill walking speed. Significance was accepted at the \( p < 0.05 \) level.

Result

Treadmill walking time in HD was shorter than those in NW subjectively. The changes of \( \text{VO}_2 \), HR, and RPE during treadmill walking in HB and NW are displayed in Fig. 1 and 2, respectively. \( \text{VO}_2 \) in HB and NW tended to enhance accompanied with increase of treadmill walking speed. \( \text{VO}_2 \) in HB at all treadmill walking speeds were higher than those in NW significantly (\( p < 0.05 \)). HR in HB and NW tended to enhance accompanied with increase of treadmill walking speed. HR increased in HB over the treadmill walking speed of 70 m/min significantly (\( p < 0.05 \)). RPE tended to increase accompanied with increase of treadmill walking speed, and both in HB and in NW were comparable approximately.

Discussion

To control buoyancy, we changed the specific gravity by dissolving sodium sulfate (\( \text{Na}_2\text{SO}_4 \)) in water because the solution of sodium sulfate did not affect the viscosity of water\(^4\). The specific gravity of water which is 1.135 kg l\(^{-1}\) of water (HB) was set in order to compare with NW. \( \text{VO}_2 \) in HB at all treadmill walking speeds were higher than those in NW significantly. The energy cost required in HB at the same treadmill walking speed in NW. Moreover, HR increased in HB over the treadmill walking speed of 70 m/min significantly. It was clear that the workload of treadmill walking in HB increased remarkably over the treadmill walking speed of 70 m/min compared with NW. It was suggested that the

Fig. 1. Changes in oxygen uptake in high specific gravity water and normal water to graded treadmill walking. Values are mean±SD. Significant different from the normal water values : * \( p < 0.05 \). The number over the walking speed of 100 m/min in figure shows the number of subjects who was able to walk.

Fig. 2. Changes in heart rate in high specific gravity water and normal water to graded treadmill walking. Values are mean±SD. Significant different from the normal water values : * \( p < 0.05 \). The number over the walking speed of 100 m/min in figure shows the number of subjects who was able to walk.
water resistance accompanied with an increase in
the specific gravity acted on the phenomenon of in-
crease of the workload during treadmill walking in
HB. Furthermore, we suggested that treadmill walk-
ing in HB by depth at the greater trochanter level
was useful for rehabilitation and therapeutic exer-
cise in the low-speed that can use buoyancy enough
and for physical training in the high-speed that can
use more water resistance.

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