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Physiological Responses to Water-Walking in Middle Aged Women

Tomoki Shono[1)], Kazutaka Fujishima[2)], Noboru Hotta[2)],
Tetsuro Ogaki[2)] and Takeshi Ueda[3)]

1) Beppu Women's Junior College
2) Institute of Health Science, Kyushu University
3) Fukuoka Prefectural University

Abstract The purpose of the present study was to examine the physiological responses to water-walking using the Flowmill, which has a treadmill at the base of a water-flume, in two groups of women. In the first group, the women were known to regularly swim and exercise in water (group A), while in the second, they did not routinely participate in water-exercise (group B). In both groups, twelve healthy female volunteers in their fifties participated in the study. All of the subjects walked in water using the Flowmill for the first time. Subjects completed four consecutive bouts of 4-minute duration at progressively increasing speeds (20, 30, 40, and 50 m · min^{-1}), with 1-minute rests between each bout. In addition, water-velocity was adjusted to the walking speed of each bout. The water-depth of the Flowmill was the level of the xiphoid process. The water and room temperatures were 30.3 ± 0.1°C and 24.9 ± 0.4°C, respectively. In both groups, the relationship between walking speed and oxygen uptake ($\dot{V}O_2$) as well as that between walking speed and heart rate (HR) changed exponentially as the walking speed increased, and the relationship between HR and $\dot{V}O_2$ was linear. The relationship between HR and $\dot{V}O_2$ was similar in both groups, and there was no significant difference between the predicted maximal oxygen uptake ($\dot{V}O_2max$) of the two groups. $\dot{V}O_2$ and HR of group B during water-walking, however, were significantly higher than those of group A at all walking speeds. The results of this study clearly showed that experience in moving through the water strongly affects physiological responses to water-exercise, even when fitness levels are equivalent. *J Physiol Anthropol 20 (2): 119-123, 2001* http://www.jstage.jst.go.jp/en/

Keywords: water-walking, physiological responses, middle aged women, trained and untrained women for water-exercise

Introduction

In recent years, water-walking and jogging have become popular non-swimming aerobic exercises at the swimming pool. Many previous studies have reported metabolic and cardiorespiratory responses during walking and jogging in a pool (Evans et al., 1978; Whitley and Schoene, 1987; Bishop et al., 1989; Ritchie and Hopkins, 1991; Town and Bradley, 1991; Gehring et al., 1992). Evans et al. (1978) have compared the energy expenditure during treadmill walking and jogging on land with that of water-walking and jogging. They found that approximately one-half to one-third of the speed is needed to walk or jog across a pool through waist-deep water at the same level of energy expenditure as treadmill-walking and jogging on land. Gleim and Nicholas (1989), however, have compared the energy expended during walking and jogging on a treadmill on land to that of walking and jogging on an underwater treadmill. They have suggested that walking on an underwater treadmill is quite different from walking in a pool, where the body must actually move through the water.

The device used in the present study, called a Flowmill, has a treadmill at the base of a water-flume. This device allows the water-flow and belt velocities to be fixed, and consequently the exercise intensity can be fixed. Various studies have been carried out using this device (Onodera et al., 1992, 1993; Kanaya et al., 1993; Migita et al., 1994, 1996; Hotta et al., 1993a, 1993b, 1994, 1995; Shimizu et al., 1998; Takaoka et al., 1999; Shono et al., 2000). However, there is still less cardiorespiratory and metabolic data related to water-walking for people of middle and advanced age than there is for land-walking.

Energy expenditure in water depends more on energy expended to overcome drag compared than does exercise on land. Holmér (1972) has found that elite swimmers are able to swim a particular stroke at a given velocity at a lower oxygen consumption than are relatively untrained or recreational swimmers, indicating that differences in swimming skills strongly affect energy expenditure. In water-walking, it has also been hypothesized that differences in skills for walking through the water strongly affect energy expenditure. However, there has been no study comparing physiological responses to water-walking using the Flowmill between trained and untrained people for water-exercise. The purpose of the present study was to examine physiological responses to water-walking using the Flowmill in two groups of women, one known to regularly swim and exercise in water and the other known to not exercise in water.

Methods

Subjects

Twelve healthy female volunteers in their fifties who regularly swam and exercised in water (group A) and twelve healthy female volunteers in their fifties who regularly practiced a gymnastic exercise called *jikyojutsu* for health, but did not swim and exercise in water (group B), participated in the study. This was the first experience all of the subjects had had with walking in water using the Flowmill. Subjects in group A had a mean age of 55.6 ± 2.6 years, a height of 153.7 ± 3.3 cm, a weight of 56.1 ± 5.8 kg, and a body-fat level of 25.6 ± 5.0%. Subjects in group B had a mean age of 54.9 ± 2.9 years, a height of 156.8 ± 5.3 cm, a weight of 51.9 ± 5.8 kg, and a body fat level of 22.4 ± 5.4%. Body fat levels were predicted based on the triceps and subscapula fatfolds. There were no significant differences in age, height, weight, and body fat levels between the two groups.

This study was approved by the Ethics Committee of the Institute of Health Sciences, Kyushu University. Before testing, each subject was informed of the purpose of the study and the testing procedures. Each subject gave her written informed consent.

Protocol

Walking in water took place in the Flowmill (FM1200D, Japan Aqua Tech Co., Ltd., Japan), which has a treadmill at the base of a water-flume. Subjects completed four consecutive bouts of 4-minute duration at progressively increasing speeds (20, 30, 40 and 50 $m \cdot min^{-1}$), with a 1-minute rest between each bout. In addition, water-velocity was adjusted to the walking speed for each bout. Subjects were instructed to swing both arms in order to maintain their balance while walking in water. The water-depth of the Flowmill was the level of the xiphoid process. The water and room temperatures were 30.3 ± 0.1°C and 24.9 ± 0.4°C, respectively.

Additionally, an obstacle-walking test of 10 m, in which subjects step over six obstacles (height: 20 cm, length: 10 cm, width: 50 cm) at 2-m intervals, including the start line and the goal, was carried out in order to examine the land-walking capabilities of each subject.

Measurements

Oxygen uptake ($\dot{V}O_2$) was determined every 30 seconds during the experiment by a mass spectrometer (WSMR-1400, WESTRON CORP., Japan) and an automatic breath-by-breath gas-exchange measurement system (RM-300i, Minato Medical Science Co., Ltd., Japan). Heart rate (HR) was monitored using a telemetry method (ST-30, DS-501, Fukuda-denshi Co., Ltd., Japan) and was recorded every 30 seconds. Blood samples were taken from an earlobe immediately following each bout. Blood lactate concentrations (LA) were determined by a lactate analyzer (LT-1710, ARKRAY, Japan). In the obstacle-walking test of 10 m, the walking time was measured.

Statistical analyses

All values are expressed as the mean ± SD. The relationship between HR and $\dot{V}O_2$ was analyzed by linear regression. The relationships between walking speed and $\dot{V}O_2$, and walking speed and HR were analyzed using exponential regression. The differences between group A and B were evaluated by the Student's t-test for unpaired data. The level of statistical significance was set at $p<0.05$.

Results

The relationship between HR and $\dot{V}O_2$ during water-walking is shown in Fig. 1. There was a highly significant linear relationship between HR and $\dot{V}O_2$ during water-walking in each group. The relationships between walking speed and $\dot{V}O_2$, and walking speed and HR in each group are shown in Fig. 2. Both $\dot{V}O_2$ and HR increased exponentially as the walking speed increased. The $\dot{V}O_2$ and HR of group B were significantly higher than those of group A at all walking speeds.

There was no significant difference in the respiratory exchange ratio (R) between the two groups at 20−40 $m \cdot min^{-1}$. At 50 $m \cdot min^{-1}$, however, the R of group B was significantly higher than that of group A (0.96 ± 0.05 in group A, 1.04 ± 0.09 in group B, $p<0.05$). The variations in LA are shown in Fig. 3. There was no significant difference in LA between the two groups at 20 and 30 $m \cdot min^{-1}$. The LA of group B at 40 (1.2 ± 0.2 $mmol \cdot l^{-1}$ in group A, 1.6 ± 0.6 $mmol \cdot l^{-1}$ in group B, $p<0.05$) and 50 (2.3 ± 0.8 $mmol \cdot l^{-1}$ in group A, 4.0 ± 1.8 $mmol \cdot l^{-1}$ in group B, $p<0.01$) $m \cdot min^{-1}$, however, were significantly higher than those of group A.

Exercise intensity (METs) was calculated from the $\dot{V}O_2$ for each subject at each walking speed. The exercise intensity of group A was 1.8 ± 0.3 METs at 20 $m \cdot min^{-1}$, 2.5 ± 0.6 METs at 30 $m \cdot min^{-1}$, 3.7 ± 0.7 METs at 40 $m \cdot min^{-1}$

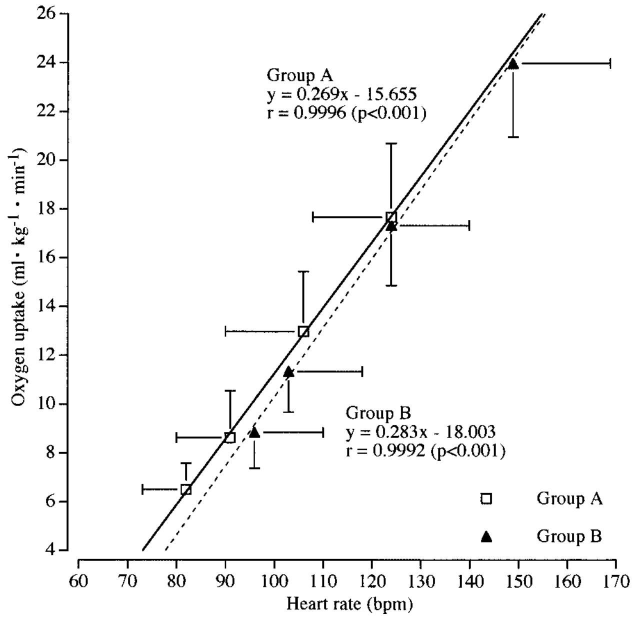

Fig. 1 Relationships between heart rate and oxygen uptake in each group during Flowmill walking.

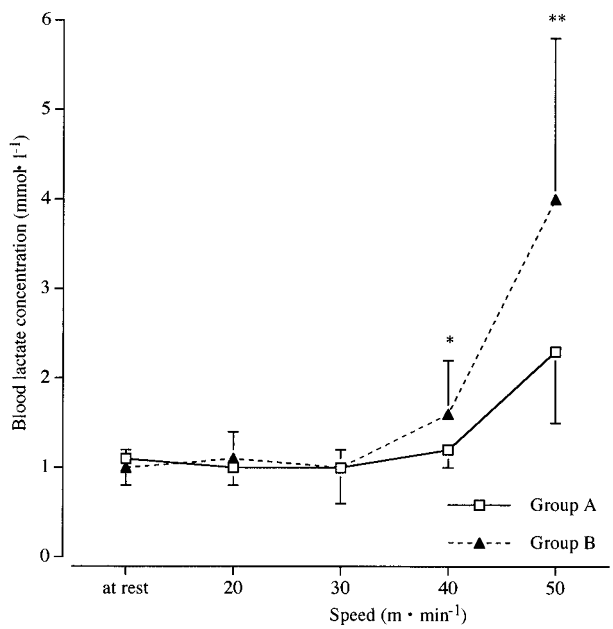

Fig. 3 Responses of blood lactate in each group to Flowmill walking. *p<0.05, **p<0.01, group A vs. group B.

and 5.1 ± 0.9 METs at 50 m · min^{-1}. The exercise intensity of group B was 2.5 ± 0.5 METs at 20 m · min^{-1}, 3.3 ± 0.5 METs at 30 m · min^{-1}, 5.0 ± 0.7 METs at 40 m · min^{-1}, and 6.9 ± 0.9 METs at 50 m · min^{-1}. At all walking speeds, the exercise intensity of group B was significantly higher than that of group A (p<0.0001–0.01).

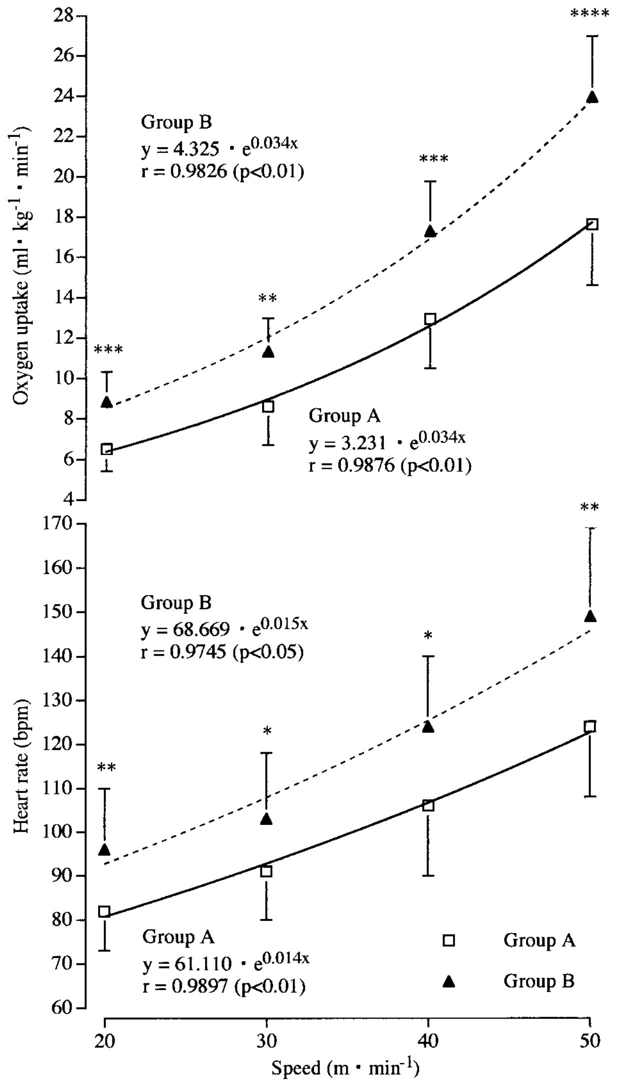

Fig. 2 Relationships between walking speed and oxygen uptake, and walking speed and heart rate in each group during Flowmill walking. *p<0.05, **p<0.01, ***p<0.001, ****p<0.0001, group A vs. group B.

There was no significant difference in the walking time for the obstacle-walking test of 10 m between groups A and B (6.2 ± 0.5 seconds versus 6.3 ± 0.5 seconds).

Discussion

In both groups, the relationships between walking speed and $\dot{V}O_2$, and walking speed and HR changed exponentially as the walking speed increased, and the relationship between HR and $\dot{V}O_2$ was linear. These results are similar to those obtained in previous studies using the Flowmill (Migita et al., 1994; Hotta et al., 1993a, 1993b, 1994, 1995; Shono et al., 2000). Since the relationship between HR and $\dot{V}O_2$ in both groups was linear, Flowmill walking with arm-swinging could be prescribed for the people who regularly swim and exercise in water and for those who do not, as with land-walking.

$\dot{V}O_2$ and HR of group B were significantly higher than those of group A at all walking speeds. The relationship between HR and $\dot{V}O_2$ in both groups, however, was similar. The relationship between HR and $\dot{V}O_2$ in each subject also showed a highly significant linear relationship (group A: r=0.9632−0.9997, p<0.001−0.05, group B: r=0.9750−0.9999, p<0.001−0.05). Therefore, the predicted maximal oxygen uptake ($\dot{V}O_2max$) of each subject was estimated from the assumed maximum heart rate (220− age) using the regression equation for each subject. The mean values for group A and B were 29.0 ± 5.0 and 28.4 ± 5.2 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. There was no significant difference between the two groups, suggesting that the subjects' aerobic capacity was comparable in the two groups. There was no significant difference in the walking time for the obstacle-walking test of 10 m between the two groups, suggesting that the subjects' land-walking capability was identical. There were no significant differences in height, weight, and body fat levels between the two groups. Thus, the subjects' fitness levels were equivalent.

The exercise intensities of the two groups for each speed were classified on the basis of the five-level classification of physical activity (McArdle et al., 1986). In group A, the exercise intensity appeared to be light at 20 and 30 $m \cdot min^{-1}$, moderate at 40 $m \cdot min^{-1}$, and heavy at 50 $m \cdot min^{-1}$. In group B, the exercise intensity at 20 $m \cdot min^{-1}$ was light, that at 30 $m \cdot min^{-1}$ was moderate, that at 40 $m \cdot min^{-1}$ was heavy, and that at 50 $m \cdot min^{-1}$ was very heavy. These results suggest that the rate of increase in exercise intensity with walking speed for group B was greater than that for group A. Unlike walking on land, the range of speed that can be controlled becomes very narrow in water-walking because of water-resistance. This may be particularly true when water-resistance becomes greater because of unskilled movement through the water. We therefore presume that the higher intensity of exercise at a given walking speed in group B than in group A was due the lack of experience in water-exercise. In contrast, it seemed that the subjects of group A had learned movements that could reduce water-resistance through experience in water-exercise.

In the comparison of LA between the two groups, there was significant difference at 40 and 50 $m \cdot min^{-1}$, the magnitude of difference being greater at 50 $m \cdot min^{-1}$. In the comparison of R between the two groups, there was a significant difference at 50 $m \cdot min^{-1}$, and the R of group B was above 1.0. These results suggest that water-resistance strongly affects untrained people in water-exercise. Unskilled movement may increase the energy, via anaerobic glycolysis, required to overcome the resistance to movement through the water.

The results of the present study clearly indicate that experience in moving through the water strongly affects the physiological responses to water-exercise, even though the fitness level is equivalent. We therefore recommend that exercise prescriptions for Flowmill-walking for the people who have no experience in water-exercise begin with milder loads, such as walking while holding the handrails and walking with the water-flow stopped, with the load gradually increased afterward with experience.

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Correspondence to: Tomoki Shono, Beppu Women's Junior College, Chuo-machi, Kamegawa, Beppu, Oita 874-8567, Japan
e-mail : t_shono@mizobe.ac.jp