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# Cardiorespiratory Response to Low-Intensity Walking in Water and on Land in Elderly Women

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**Abstract** The purpose of the present study was to determine whether or not the exercise intensity of water-walking for elderly women could be accurately prescribed by heart rate data obtained during treadmill exercise on land. Six healthy female volunteers, with a mean age of 62.2 ± 4.2 years, took part in this study. Walking on land was performed on a treadmill. Each subject completed three consecutive 4-minute walks at a progressively increasing velocity (40, 60 and 80 $m \cdot min^{-1}$), with a 1-minute rest after both the first and second walks. The room temperature and relative humidity were 24.5 ± 0.2°C and 54.8 ± 4.0%, respectively. Walking in water was performed in a Flowmill, which is a treadmill positioned at the base of a water flume. Each subject completed three consecutive 4-minute walks at a progressively increasing belt and water-flow velocity (20, 30 and 40 $m \cdot min^{-1}$), with a 1-minute rest after both the first and second walks. The water depth was at the level of the xiphoid process of each subject. The water temperature was 30.7 ± 0.1°C. The exercise intensity at the highest workrate was equivalent to 44.2 ± 10.3% of the heart rate reserve (HRR) during water-walking and 38.4 ± 4.7% of the HRR during land-walking. There was a highly significant linear relationship between heart rate (HR) and oxygen uptake ($\dot{V}O_2$) during both water-walking and land-walking. The relationship between HR and $\dot{V}O_2$ in both exercise modes was similar. Thus, the relationship of HR to $\dot{V}O_2$ derived from a treadmill-graded walking test on land may be used to prescribe exercise intensity for water-walking in thermoneutral water. *J Physiol Anthropol 20 (5): 269-274, 2001* http://www.jstage.jst.go.jp/en/

**Keywords:** cardiorespiratory response, water-walking, land-walking, elderly women

## Introduction

The effects of water buoyancy and resistance in water make it possible to expend high levels of energy while at the same time reducing strain and impact force on lower-extremity joints (Evans et al., 1978). For this reason, walking and jogging in water are effective exercises for individuals already suffering from hip, leg, or back problems as well as for the middle-aged and elderly whose physical fitness has decreased through aging and physical inactivity.

In Japan, the population of the elderly is rapidly increasing. When the quality of life for middle-aged and elderly people is being considered, exercise is likely to become an increasingly important way to keep the aged members of society healthy and vigorous. Water-walking can be practiced without having swimming skill and it is an easy, nonswimming, aerobic activity for middle-aged and elderly people who wish to begin water-exercise. However, there is less physiological data to support the prescription of water-walking for middle-aged and elderly people than there is for land walking.

Previous studies of walking and jogging in a pool (Evans et al., 1978; Whitley and Schoene, 1987; Town and Bradley, 1991) and on an underwater treadmill (Gleim and Nicholas, 1989; Hall et al., 1998) have been reported as feasible. The device used in the present study, called a Flowmill, has a treadmill at the base of a water flume. This device allows treadmill water-flow and belt velocity to be adjusted, and exercise intensity to be adjusted. Walking in the Flowmill is very similar to walking in a pool. Various studies have been carried out using the Flowmill (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, 2001).

Migita et al. (1994) compared the cardiorespiratory response of middle-aged men during Flowmill walking (water temperature: 34°C, water depth: 105 cm; where each subject held a handrail one on each side of the flume while walking) versus treadmill walking. These authors reported that the relationship between heart rate and oxygen uptake was similar in both walking conditions, and approximately double velocity was needed to walk on the treadmill in order to obtain the same level of physiological effort as during Flowmill walking. In general, the water in swimming pools in which water walking for health and fitness is carried out is about 30°C. As to walking in the Flowmill without water-flow, when the depth of water increased from the height of knee to waist, oxygen uptake decreased (Onodera et al., 1993). This result suggests that the effect of buoyancy offset the effect of water resistance. Since the average height of women is lower than that of men, women are more submerged than men at the same water depth. Also, women usually have more body fat than men. Therefore, owing to changing the relation between buoyancy and water resistance, the cardiorespiratory response of elderly women in chest-deep water may be different from that of middle-aged men in abdominal-deep water (Migita et al., 1994). In the present study, we compared the elderly women's cardiorespiratory response to Flowmill walking (water temperature: 30°C, water depth: the level of the xiphoid process), with arm-swinging, versus treadmill walking. The present study was designed to determine whether or not the appropriate exercise intensity of water-walking for elderly women could be accurately prescribed by monitoring heart rate during treadmill walking on land.

## Methods

*Subjects*

Six healthy female volunteers took part in this study. They belonged to the same sports club and regularly swam and exercised in water. The subjects usually swam or exercised in water for 91.7 ± 24.8 minutes, 3.8 ± 1.5 times a week, and had been training for an average of 6.7 ± 3.8 years. Since all of the subjects had previously walked in water using the Flowmill five times, they all seemed to be familiar with it. As for treadmill walking, since they practiced at the sports club, they seemed to be quite familiar with this too. Physical characteristics of the subjects are presented in Table 1.

This study was approved by the Ethics Committee of the Institute of Health Science, 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 to participate.

**Table 1** Physical characteristics of the subjects

| | Age (years) | Height (cm) | Weight (kg) | Body fat (%) |
|---|---|---|---|---|
| Mean | 62.2 | 154.6 | 58.9 | 25.5 |
| S.D. | 4.2 | 2.1 | 6.1 | 5.5 |

Body fat percent was estimated from triceps and subscapula skinfold measurements.

*Protocol*

After they arrived at the laboratory, each subject changed into her swimming suit, and surface electrodes were attached to her chest for an electrocardiogram record as the subject relaxed in a chair. Then they practised treadmill walking. After one treadmill walk, the subject rested in a chair for at least 10 minutes, until her heart rate recovered to its pre-exercise value. Flowmill walking was then practised.

Walking on land was performed on a treadmill (WOODWAY, Sakai Co., Ltd., Japan). A previous study (Migita et al., 1994) reported that approximately double the velocity was needed to walk on the treadmill in order to obtain the same level of physiological effort as during Flowmill walking. Thus, the velocity of the treadmill was double that of the Flowmill. Each subject completed three consecutive 4-minute walks in air at a progressively increasing velocity (40, 60 and 80 $m \cdot min^{-1}$), with a 1-minute rest after both the first and second walks. The grade of the treadmill was 0%. The room temperature and relative humidity were 24.5 ± 0.2°C and 54.8 ± 4.0%, respectively.

Walking in water was performed in the Flowmill (FM1200D, Japan Aqua Tech Co., Ltd., Japan), which has a treadmill at the base of a water flume. Each subject completed three consecutive rounds of walking for 4 minutes per round, each at a progressively increasing belt and water-flow velocity (20, 30 and 40 $m \cdot min^{-1}$), with a 1-minute rest after both the first and second rounds. Since blood lactate concentration (LA) when walking at 50 $m \cdot min^{-1}$ was significantly higher than at rest and during the other lower velocities used in a previous study (Shono et al., 2000), the fastest walking velocity in water was set at 40 $m \cdot min^{-1}$. The subject was instructed to swing both arms in order to maintain her balance while walking. The water depth was at the level of the xiphoid process of each subject. The water temperature was 30.7 ± 0.1°C.

*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. We used the HR reserve method to estimate the individual exercise intensity. Relative HR reserve (% HRR) was calculated using the following equations: % HRR = (HR exercise − HR rest / HR max − HR rest) × 100. HR max = 220 − age (years). We defined HR rest as the minimal HR during pre-exercise rest. Furthermore, metabolic equivalent (MET) was calculated from the individual $\dot{V}O_2$. Stride frequency (SF) was measured for 60 seconds in the third minute of each exercise round. A blood sample was taken from an earlobe immediately after each round. Blood lactate concentration (LA) was determined using a lactate analyzer (LT-1710, ARKRAY, Japan).

*Statistical analyses*

All values are expressed as means ± SD. The relationships between HR and $\dot{V}O_2$ and between SF and $\dot{V}O_2$ were analyzed by linear regression. The differences between water-walking and land-walking were evaluated by one-factor ANOVA, and then post hoc tests (Fisher's PLSD) were conducted. A value of $p<0.05$ was accepted as significantly different.

## Results

The relationship between walking velocity and $\dot{V}O_2$ during water-walking and land-walking are shown in Fig. 1. There were no significant difference between $\dot{V}O_2$ during land-walking at 80 m·min$^{-1}$ and water-walking at 40 m·min$^{-1}$; or between $\dot{V}O_2$ during land-walking at 60 m·min$^{-1}$ and water-walking at 30 m·min$^{-1}$. $\dot{V}O_2$ during water-walking at 20 m·min$^{-1}$, however, was significantly lower than that during land-walking at 40 m·min$^{-1}$ ($p<0.01$).

The relationship between SF and $\dot{V}O_2$ during water-walking and land-walking are shown in Fig. 2. SF increased linearly with the increment of $\dot{V}O_2$ in both exercise modes. Since the $\dot{V}O_2$ value of the respective work rates was not equal, the SF at a given $\dot{V}O_2$ (at 11 and 14 ml·kg$^{-1}$·min$^{-1}$) was estimated from a regression equation of $\dot{V}O_2$ versus SF for each exercise mode. Stride frequencies during water-walking (at 11 ml·kg$^{-1}$·min$^{-1}$: 56 strides·min$^{-1}$; at 14 ml·kg$^{-1}$·min$^{-1}$: 62 strides·min$^{-1}$) were nearly half of those during land-walking (at 11 ml·kg$^{-1}$·min$^{-1}$: 105 strides·min$^{-1}$; at 14 ml·kg$^{-1}$·min$^{-1}$: 124 strides·min$^{-1}$).

The relationship between HR and $\dot{V}O_2$ during water-walking and land-walking are shown in Fig. 3. There was a highly significant linear relationship between HR and $\dot{V}O_2$ during both water-walking and land-walking. The relationship between HR and $\dot{V}O_2$ in both exercise modes was similar. For each subject, the relationship between HR and $\dot{V}O_2$ in both exercise modes was also highly linear (water-walking: $r=0.9934 \pm 0.0078$; land-walking: $r=0.9775 \pm 0.0328$).

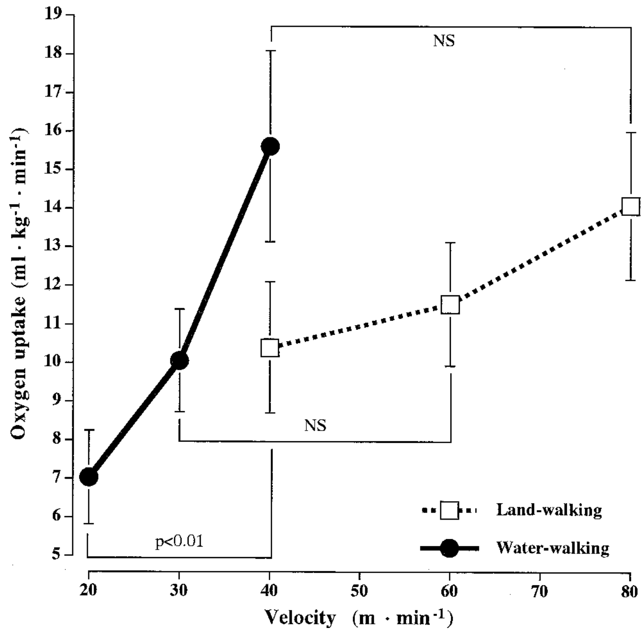


**Fig. 1** Relationship between walking velocity and oxygen uptake during water-walking and land-walking. NS: not significant.

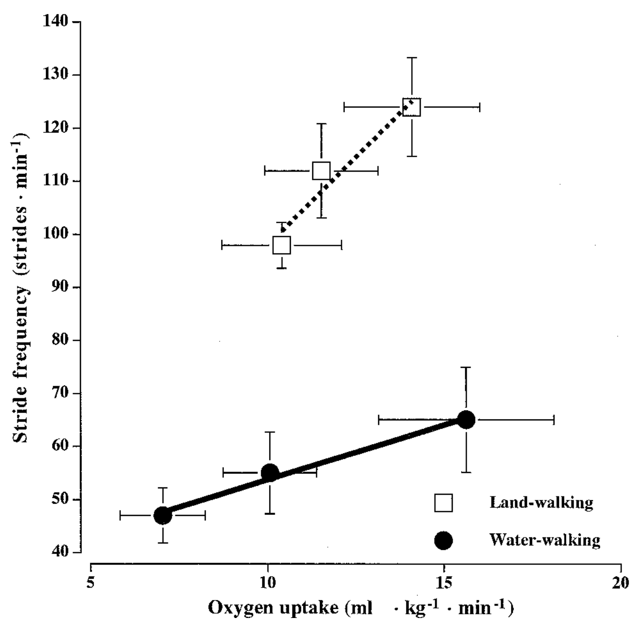


**Fig. 2** Relationship between stride frequency and oxygen uptake during water-walking and land-walking.

The group mean value of exercise intensity for water-walking at 40 m·min$^{-1}$ and land-walking at 80 m·min$^{-1}$ were 44.2 ± 10.3 and 38.4 ± 4.7% HRR, respectively. There was no significant difference between the two exercise modes. Also, the group mean value of MET for water-walking at 40 m·min$^{-1}$ and land-walking at 80

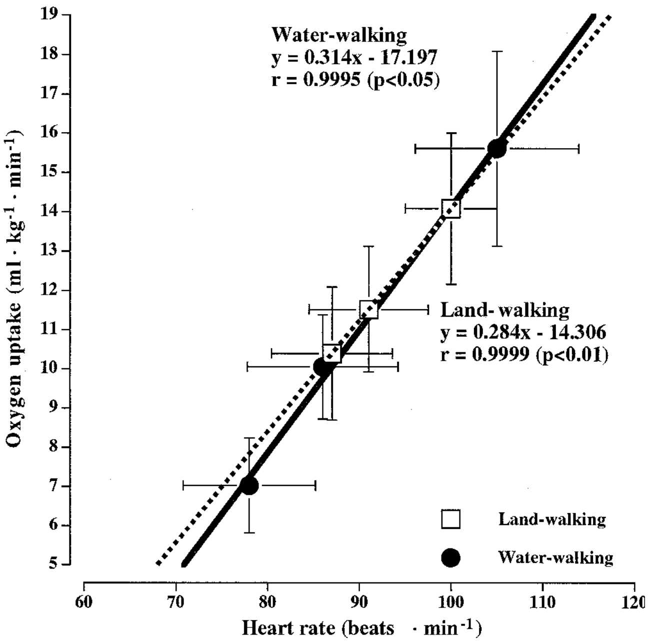


**Fig. 3** Relationship between heart rate and oxygen uptake during water-walking and land-walking.

m·min$^{-1}$ were 4.5 ± 0.7 and 4.0 ± 0.5 METs, respectively.

The LA during land-walking at 80 m·min$^{-1}$ and water-walking at 40 m·min$^{-1}$ were 1.0 ± 0.3 mmol·l$^{-1}$ and 1.1 ± 0.2 mmol·l$^{-1}$, respectively. There were no significant difference between these respective values and the value at rest (1.0 ± 0.2 mmol·l$^{-1}$).

## Discussion

There were no significant difference between $\dot{V}O_2$ during land-walking at 80 m·min$^{-1}$ and water-walking at 40 m·min$^{-1}$; or between $\dot{V}O_2$ during land-walking at 60 m·min$^{-1}$ and water-walking at 30 m·min$^{-1}$. This result is consistent with a previous study (Migita et al., 1994), in that approximately double velocity was needed during treadmill walking in air in order to obtain the same level of physiological effort as during Flowmill walking. This result suggests that the effect of water resistance offset the effect of buoyancy caused by water depth or body fat. This would be due to the effect of water-flow and arm-swinging. $\dot{V}O_2$ during water-walking at 20 m·min$^{-1}$, however, was significantly lower than that during land-walking at 40 m·min$^{-1}$ ($p<0.01$). These results suggest that during water-walking at a water depth at the level of the xiphoid process at 20 m·min$^{-1}$, buoyancy has a bigger reducing effect on energy expenditure than does resistance to movement. Water immersion to the xiphoid process reduce weight-load by 75% (Becker, 1997). Thus, water-walking at a lower velocity may be used as a part of rehabilitative program, and is considered to be particularly effective for people with lower-extremity injury. Previous studies (Hotta et al., 1993b; Kanaya et al., 1993) showed that water-walking using the Flowmill for low-physical-fitness patients who could not do self-walking on land was useful as an exercise treatment.

In the present study, the SF during water-walking was nearly half of that during land-walking. Previous studies (Town and Bradley, 1991; Hall et al., 1998) have reported a lower SF and higher $\dot{V}O_2$ cost per stride in water than on land. These results are attributed to the effects of water buoyancy and resistance, and clearly show that, compared to land-walking, water-walking enables more energy to be expended with relatively little movement or strain on lower-extremity joints.

The relationship between HR and $\dot{V}O_2$ during exercise in water compared with exercise on land is important, because HR is commonly used to prescribe and regulate the intensity of exercise. The relationship between HR and $\dot{V}O_2$ is variable and depends on exercise intensity (Sheldahl et al., 1984, 1987; Connelly et al., 1990; Cureton, 1997), exercise mode (Cureton, 1997), water depth (Gleim and Nicholas, 1989; Cureton, 1997) and water temperature (Craig and Dvorak, 1969; McArdle et al., 1976; Gleim and Nicholas, 1989; Cureton, 1997; Hall et al., 1998; Shimizu et al., 1998). In the present study, the relationship between HR and $\dot{V}O_2$ during water-walking, with a water temperature of 30°C and water depth at the level of the xiphoid process, was similar to that during land-walking. Evans et al. (1978) studied the circulatory responses to walking and jogging across a pool in waist-deep water at a water temperature of 30–31°C. These authors found that there was essentially no difference between water walking and jogging and land walking and jogging in terms of the relationship of HR to $\dot{V}O_2$. In the present study, the water temperature was similar to that in the above study, but in the present study the water was deeper. However, both studies had similar results.

Several studies have compared the relationship between HR and $\dot{V}O_2$ during cycling in the upright posture on land and head-out water immersion. Sheldahl et al. (1984) reported that although mean heart rate in water and on land at rest and at the same level of $\dot{V}O_2$ during moderate exercise was similar, during heavy exercise mean HR was lower in water. The water temperature in the latter study was 31.0 ± 0.5°C. The authors explained that this temperature is considered thermoneutral for exercise but is below thermoneutrality for immersion at rest. Sheldahl et al. (1987) also studied the effect of head-out water immersion on cardiorespiratory response to graded dynamic exercise. Healthy middle-aged men cycled upright at 40, 60 and 80% $\dot{V}O_2$max on land and in shoulder-deep water (31.0 ± 1.0°C). They reported that HR did not differ significantly at 40 and 60% $\dot{V}O_2$max but was significantly lower in water at 80% $\dot{V}O_2$max. In the present study, the exercise intensity of the highest workrate were equivalent to 44.2 ± 10.3% HRR during water-walking and 38.4 ± 4.7% HRR during land-walking. The water temperature in this study was similar to that in the studies mentioned above. The relationship between HR and $\dot{V}O_2$ during walking in water at the depth of the level of xiphoid process and land-walking respectively were similar to the results obtained in those studies.

The relation of HR to $\dot{V}O_2$ during walking at a progressively increasing intensity on land and in water (using the Flowmill or another underwater treadmill) has also been compared to using water-depths or water temperatures that differed from those in the present study. Migita et al. (1994) compared the cardiorespiratory response to treadmill and Flowmill walking (water temperature: 34°C, water depth: 105 cm; where each subject held a handrail one on each side of the flume while walking) in middle-aged men. They reported that the relationship between HR and $\dot{V}O_2$ was similar in both walking conditions. The water in the present study was cooler and deeper, and in this study the subjects swung their arms while walking. The relationship between HR and $\dot{V}O_2$ during water-walking and land-walking, however, was similar in the two studies. Hall et al. (1998) compared the cadiorespiratory responses of healthy women (mean age 30.25 years) to submaximal exercise on land and water treadmill in chest-deep water. In addition, the effect of two different water temperatures (28.2 and 35.8°C) was examined. Although the water depth was similar to that in this study, the relationship between water-walking velocity and $\dot{V}O_2$ or HR was different from that in the present study. This reason was due to using underwater treadmill without water-flow. The relationship between HR and $\dot{V}O_2$, however, was linear. For a given level of $\dot{V}O_2$, HR was similar during walking on land or in water at 35.8°C. However, in water at 28.2°C the relationship was different. At the same level of $\dot{V}O_2$, HR was lower than on land or in water at 35.8°C. It is common observation that exercise in water colder than approximately 30°C reduces HR at all intensities (Craig and Dvorak, 1968, 1969; McArdle et al., 1976; Cureton, 1997).

In summary, the relationship between HR and $\dot{V}O_2$ during water-walking, at a water temperature of 30°C and at a water depth at the level of the xiphoid process, was similar to HR and $\dot{V}O_2$ during land-walking. Thus it is suggested that when the low-intensity water-walking is prescribed for middle-aged and elderly people, under Flowmill and pool conditions in which the water depth is at the level of the xiphoid process and the water temperature is 30°C, the relation of HR to $\dot{V}O_2$ derived from a treadmill-graded walking test on land may be used to prescribe exercise intensity for water-walking. Furthermore, these results in the present study and previous studies (Evans et al., 1978; Migita et al., 1994; Hall et al., 1998) suggest that the relationship between HR and $\dot{V}O_2$ during water-walking in waist- to chest-deep water at 30°C to 35°C is similar to HR and $\dot{V}O_2$ during land-walking regardless of sex.

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