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Body Temperature, Oxygen Uptake and Heart Rate during Walking in Water and on Land at an Exercise Intensity Based on RPE in Elderly Men

Kazutaka Fujishima[1] and Tomihiro Shimizu[2]

1) Institute of Health Science, Kyushu University
2) Joetsu University of Education

Abstract The purpose of this study was to clarify the characteristics of the physiological response that occurs while walking in water and on land at an exercise intensity based on the rating of perceived exertion (RPE) in elderly men. Nine elderly men ranging from 66–70 years of age participated in this study as subjects. The actual trials consisted of walking for 20 minutes in 31°C and 35°C water on an underwater treadmill. The water depth of the treadmill corresponded to the level of the xiphoid process in the subject. The same subjects performed on-land walking using a moving belt treadmill for 20 minutes at a room temperature of 27°C. The exercise intensity during walking in the two water trials and the on-land trial was the same "somewhat hard" measured on the basis of the subject's RPE rating of 13. There was no significant difference between the subjects' rectal temperatures among the three trials. The mean skin temperature and mean body temperature while walking for 20 minutes in 35°C water were significantly higher ($P<0.01$) than in 31°C water and on land. There were no significant differences in oxygen uptake and heart rate among the two trials in water and the on-land trial. The above results suggest that the exercise intensity based on a subject's RPE may be an effective index for the prescription of thermoneutral water walking in the same way that it is for land walking in the elderly. *J Physiol Anthropol 22 (2): 83–88, 2003*
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Introduction

Recently, walking and jogging in water have become popular nonswimming aerobic activities. These activities have been used as a part of rehabilitative, therapeutic and general conditioning programs, and are thought to be particularly useful for people with lower extremity injuries (Cureton, 1997). As indicated by Evans et al. (1978), the effects of water buoyancy and resistance make a high level of energy expenditure possible with relatively little movement or strain on the lower extremity joints. For this reason, water walking and jogging are also effective exercises for individuals with a body-weight problem as well as for people of middle or advanced age. Previous studies have reported metabolic and cardiorespiratory responses during walking or jogging in a pool (Evans et al., 1978). It has been difficult, however, to fix the physical and physiological intensity of walking and jogging in a pool.

Various studies of the cardiorespiratory and metabolic responses while walking on an underwater treadmill have been conducted (Migita et al., 1996; Hotta et al., 1993, 1994; Shimizu et al., 1998; Takaoka et al., 1999; Shono et al., 2000, 2001; Kato et al., 2002). Generally, heart rate (HR) and rating of perceived exertion (RPE) are used to establish the intensity of exercise in water (Pollock et al., 1994; American College of Sports Medicine: ACSM, 1998). HR during water exercise is lower than that during treadmill work on land (McArdle et al., 1976; Shimizu et al., 1998). Therefore, it is important to examine the relationship between HR while walking in water and HR while walking on land at an exercise intensity based on RPE.

Takeshima et al. (1997) reported the relationship of HR and oxygen uptake ($\dot{V}O_2$) during water-walking in 30°C water and land-walking at 28°C at an exercise intensity at level 13 on the RPE scale for the elderly. These researchers carried out the trial using one water temperature and a 6-minute exercise duration in a pool. Therefore, it is necessary to clarify the finding with respect to different water temperatures, a given walking speed and the exercise duration of a practical exercise prescription.

On the other hand, it is known that HR during exercise in water is influenced by body temperature (Holmér and Bergh, 1974; Galbo et al., 1979). However, no such study has been performed on the relationship of cardiorespiratory responses including body temperature while walking in water to those same responses while walking on land at an exercise intensity based on RPE for elderly people.

The purpose of this study was to evaluate the inter-relationships among body temperature, $\dot{V}O_2$ and HR while walking in water and on land in order to clarify the effectiveness of RPE for prescribing water walking for elderly people.

Methods

Subjects

Nine healthy male volunteers participated in this study. Their mean (SD) age, height, body mass, body mass index and percentage of body fat (%Fat) were 67.9 (1.7) years, 163.2 (9.0) cm, 61.6 (8.7) kg, 23.0 (1.5) $kg \cdot ht\ (m^2)^{-1}$ and 22.3 (4.8) %, respectively. %Fat was predicted based on the triceps and subscapula skinfold thickness of the subjects (Brozek et al., 1963; Nagamine and Suzuki, 1964).

This study was approved by the Ethics Committee of the Institute of Health Science, Kyushu University, and informed written consent was obtained from each subject.

Exercise intensity

To determine the intensity of exercise for each subject, preliminary tests were conducted to standardize RPE rating of 13 (somewhat hard) for each subject while walking in water and on land using Borg's RPE scale (Borg, 1970). This rating scale was used because exercise of a moderate intensity was recommended by ACSM (1998), and Feriche et al. (1998) reported that the ventilatory threshold is equivalent to the intensity of RPE rating scale of 13.

Procedures

Subjects wore swimming trunks and rested in a sitting position for 40 minutes at a room temperature of 27 (0.9)°C before walking. The actual trials consisted of walking for 20 minutes in 31 (0.18)°C and 35 (0.33)°C water on an underwater treadmill (Aqua Ciser II, Model 100R, Ferno Washington Inc., USA). The depth of the water was the level of the subject's xiphoid process. Subjects wearing swimming trunks rested in a sitting position for 40 minutes and then performed on-land walking using a moving belt treadmill (Treadmill 8700, Landice, Inc., USA) for 20 minutes at a room temperature of 27 (0.5)°C. The exercise intensity achieved was the same "somewhat hard" measured on the basis of the subject's RPE while walking in water and on land. Three trials were performed at least one day apart at approximately the same time of day.

Measurements and instruments

Rectal temperature (Tre) and skin temperatures of the arm (Tarm), chest (Tchest) and thigh (Tthigh) were measured every minute with thermistor probes beginning with a pre-exercise rest period in air and continuing until the end of all the exercises. Tre was measured by inserting the thermistor probe 12 cm deep into the rectum of a subject. Adiabatic covers for the skin (Nihon Koden Co., Ltd., Japan) and transparent tape (3M Co., Ltd., USA) were used to prevent water infiltration into the sites of the skin temperature probes during each water-walking trial. A portable data recording machine (VMM-67, VINE Co., Ltd., Japan) was used to record the temperature minute-by-minute at the measurement site. Mean skin temperature ($\overline{T}sk$) was calculated as 0.25Tarm + 0.43Tchest + 0.32Tthigh (Roberts et al., 1977). Mean body temperature ($\overline{T}b$) was calculated from the equation (Gagge and Nishi, 1977) $\overline{T}b = 0.67Tre + 0.33\overline{T}sk$. $\dot{V}O_2$ was calculated every 15 seconds during the experiment by an automatic breath aeromonitor (AE-300S, Minato Medical Science Co., Ltd., Japan). This analyzer was calibrated against a known standard calibration gas before each experiment. HR was continuously monitored using a Life Scope 8 (BSM-7105, Nihon Koden Co., Ltd., Japan). The waterproof electrode (Vitrode; D-90, Nihon Koden Co., Ltd., Japan) was used to measure HR during each water-walking trial.

Statistical analysis

The difference between the mean values of the parameters measured in water and in air at 27°C was analyzed by one-way repeated-measures ANOVA. A value of $P < 0.05$ was taken as the limit for statistical significance. Descriptive statistics included means and standard deviations (SD).

Results

The changes in Tre during the two trials in water and the on-land trial are shown in Fig. 1. The value of Tre during walking for 20 minutes in 31°C water, 35°C water and on land did not change in the three trials. There was no significant difference in the value of Tre among the three trials. The changes in $\overline{T}sk$ during the two trials in water and the on-land trial are shown in Fig. 2. $\overline{T}sk$ and $\overline{T}b$ during walking for 20 minutes in 31°C water and during walking on land decreased slightly in both trials. $\overline{T}sk$ and $\overline{T}b$ during walking for 20 minutes in 35°C water increased significantly compared with that measured before walking. $\overline{T}sk$ and $\overline{T}b$ during walking for 20 minutes in 35°C water were significantly higher ($P < 0.01$) than in 31°C water or on land (Fig. 2 and Fig. 3).

$\dot{V}O_2$ during the three walking trials increased gradually during the first 5 minutes of each exercise and then maintained a steady level (determined by ANOVA) until the end of the exercise. $\dot{V}O_2$ for the two water-walking trials and the land-walking trial during a period from 5 minutes after the beginning of the the exercise to the end of the exercise was 903(149) $ml \cdot min^{-1}$ in 31°C water, 881(139) $ml \cdot min^{-1}$ in 35°C water and 794(80) $ml \cdot min^{-1}$ on land (Fig. 4). There was no significant difference in $\dot{V}O_2$ between the two trials in water and the on-land trial.

HR during the two trials in water and the on-land trial increased gradually during the first 4-5 minutes of each exercise and then maintained a steady level until the end of the exercise according to an ANOVA analysis (Fig. 5). The increases in HR from 5 minutes after the start of the exercise to the end of the exercise in comparison with the pre-exercise measurement were 20(7) $beats \cdot min^{-1}$ in 31°C water,

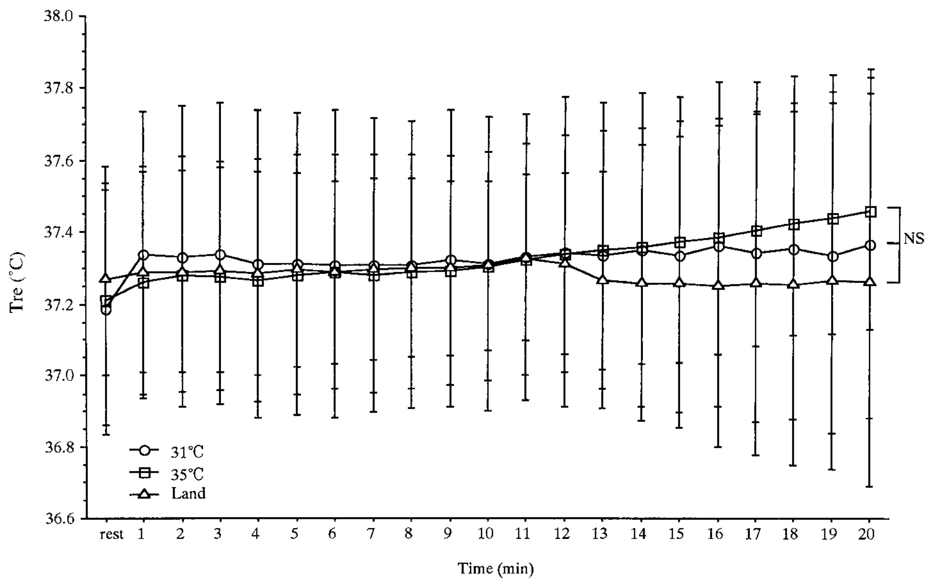

Fig. 1 Change in rectal temperature (Tre) between two trials, one in water and the other on land.

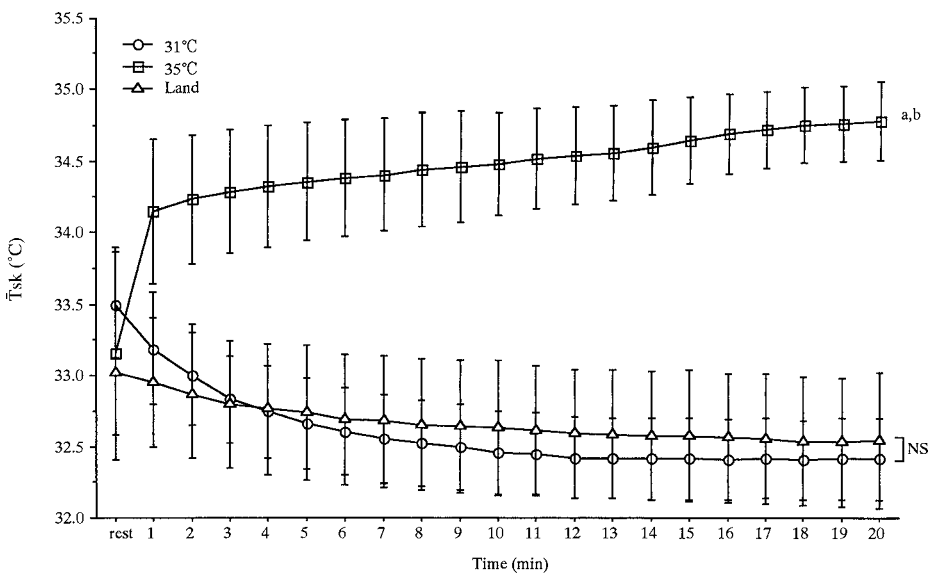

Fig. 2 Change in mean skin temperature (T̄sk) between two trials, one in water and the other on land. ᵃP<0.05 and ᵇP<0.05 show that the temperatures are significantly different from those recorded while walking in 31°C water and on land.

18(9) beats·min^{-1} in 35°C water and 15(10) beats·min^{-1} on land (Fig. 5). There was no significant difference in HR between the two trials in water and the on-land trial.

Discussion

In the present study, there was no significant difference in Tre among the two trials in water and the on-land trial. Shimizu et al. (1998) reported similar results, finding that there were no significant differences in Tre while walking in 30°C water, 35°C water and in air at 25°C with an exercise intensity equivalent to approximately 50% $\dot{V}O_2$ max for men. They found, however, that Tre during walking in 25°C water was lower than during walking in air at 25°C. Nadel et al. (1974) and Galbo et al. (1979) showed that core temperature increased in 33°C water at approximately 70% $\dot{V}O_2$ max. Therefore, core temperature during exercise in water obviously depends on the water temperature and exercise intensity.

In the present study, the value of T̄sk during walking in 35°C water was higher than that measured during walking in 31°C water and that measured in on-land trials (Fig. 2). These findings suggest that T̄sk during walking in water will be close to the water temperature. Nielsen and Davies (1976) reported similar results, finding that T̄sk during exercise in water at

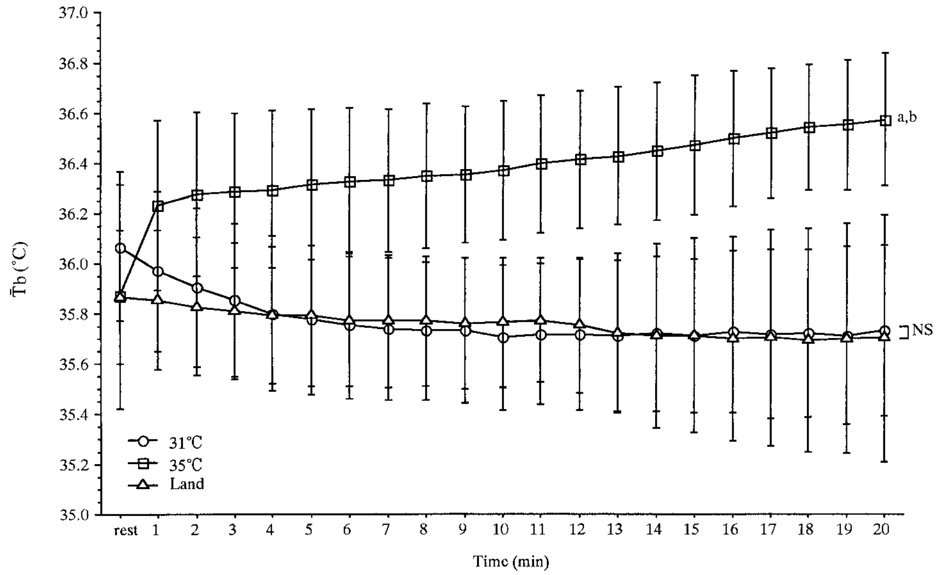

Fig. 3 Change in mean body temperature (T̄b) between two trials, one in water and the other on land. [a]$P<0.05$ and [b]$P<0.05$ show that the temperatures are significantly different from those recorded while walking in 31°C water and on land.

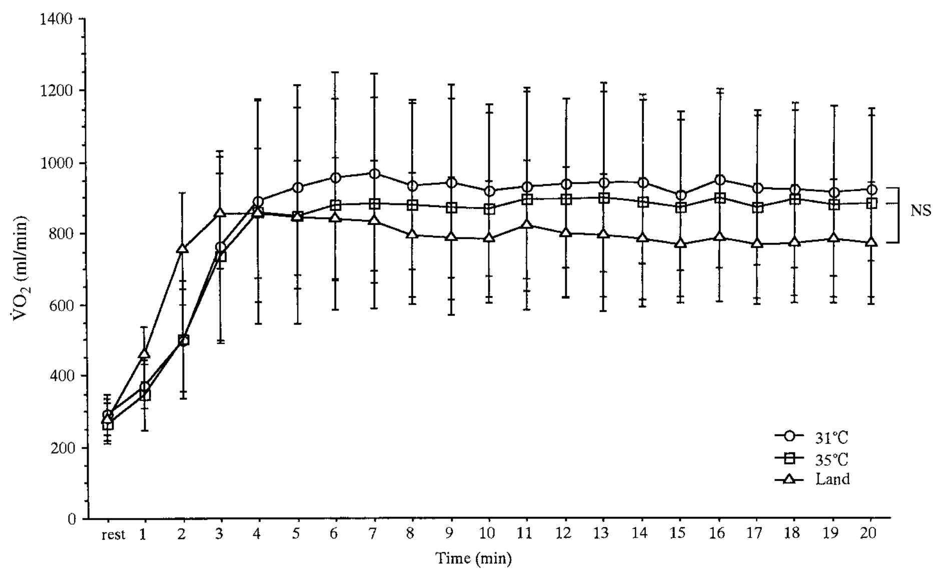

Fig. 4 Change in oxygen uptake ($\dot{V}O_2$) between two trials, one in water and the other on land.

30°C and at 33°C was close to the two respective water temperatures. T̄b during the two water trials showed the same patterns of change as shown by T̄sk. These findings suggest that T̄sk was directly affected by the water temperature, and consequently a higher T̄b resulted in 35°C water.

In this study, $\dot{V}O_2$ based on each subject's RPE was approximately the same between the two trials in water and the on-land trial. These findings were consistent with the report of Takeshima et al. (1997) with respect to $\dot{V}O_2$ level during walking in water and on land based on RPE rating of 13.

In this study, HR for the two water-walking trials and the land-walking trial during a period from 5 minutes after the beginning of the exercise to the end of the exercise was 97(7) beats$\cdot$min^{-1} in 31°C water, 94(14) beats$\cdot$min^{-1} in 35°C water and 92(10) beats$\cdot$min^{-1} on land (Fig. 5). No significant difference in HR was recorded in the two trials in water and the on-land trial. The results were not consistent with the result that HR during walking in 30°C water was significantly lower than HR during walking on land (Takeshima et al., 1997). This inconsistency might be caused by the differences in the water depth; that is, the depth of water in the present study was at the level of a subject's xiphoid process, and the study of Takeshima et al. (1997) was performed with the subjects immersed to the level of the axilla.

It seems reasonable that a lower HR during water exercise may have caused a greater venous return, a higher stroke

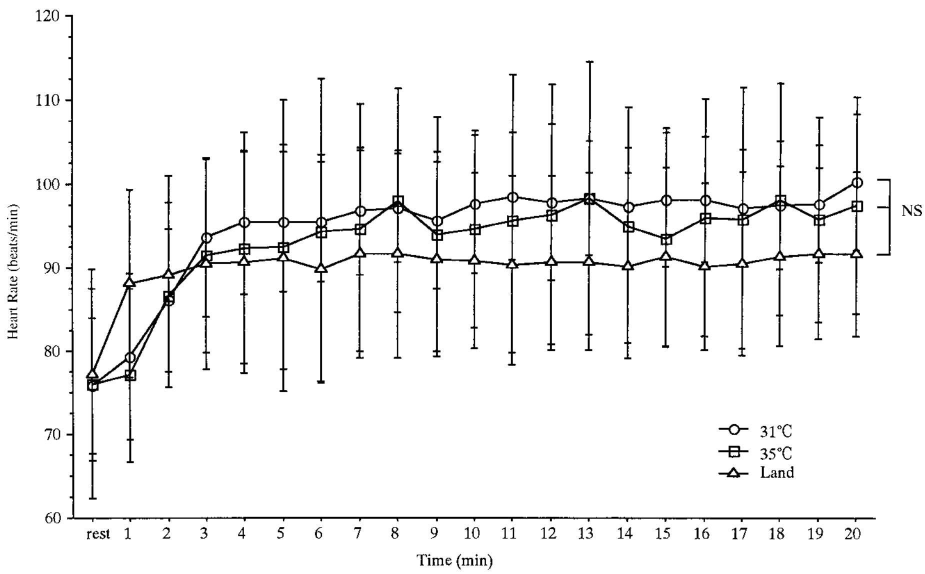

Fig. 5 Change in heart rate (HR) between two trials, one in water and the other on land.

volume and a higher cardiac output in water immersion (Farhi and Linnarsson, 1977). Furthermore, many studies (Holmér and Bergh 1974; McArdle et al., 1976; Gleim and Nicholas, 1989; Shimizu et al., 1998) have indicated that HR during exercise in water decreased with decreasing water temperature. The results in the present study were not consistent with other studies, which may be due to the thermoneutral water temperatures used (31°C and 35°C). As is the standard, the values of the RPE scale (Borg, 1970) were chosen to be as close as possible to one-tenth of the corresponding HR. In the present study, the exercise intensity was conducted so as to use RPE rating of 13 (somewhat hard); however, HR during each exercise trial was lower than 130 beats $\cdot$ min^{-1} (Fig. 5). It appears that the reason for the lower HR may be the decrease in maximal HR with aging. Therefore, caution should be exercised when using RPE with elderly people.

In conclusion, the above results suggest that the exercise intensity judged on the basis of the subject's RPE may be an effective index for the prescription of thermoneutral water walking in the same way that it is for land walking.

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Correspondence to: K. Fujishima, Institute of Health Science, Kyushu University 11, Kasuga 816–8580, Japan
Tel. & Fax: +81–092–583–7849
e-mail: fujisima@ihs.kyushu-u.ac.jp