福岡県立大学人間社会学部紀要
2007, Vol. 15, No. 2, 1 −12

# Blood pressure responses during walking in water in middle-aged and elderly women

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**Abstract** The purpose of this study was to investigate the effectiveness of physical activity in water from the perspective of blood pressure responses in middle-aged and elderly women for whom water exercise is recommended. Subjects comprised 22 middle-aged and elderly women who regularly go swimming or participate in water exercise in a sports club. A flowmill was used as the exercise stress device and water depth was adjusted to the height of the xiphoid process for each subject. Water temperature was controlled to 30℃. After resting by sitting on a chair for 5 min, each subject performed 4 sessions of walking in water. Each session lasted 4 min at different levels of difficulty (20, 30, 40 and 50 m/min), with a 1-min rest between each session. Oxygen uptake, ventilation and heart rate were monitored during walking and blood lactate concentration, blood pressure, and Ratings of Perceived Exertion (RPE) and Feeling Scores (FS) were measured immediately after exertion. Although no subject was receiving treatment for blood pressure-related problems, increased systolic or diastolic pressures were observed in 18 subjects (81.8%). Based on World Health Organization criteria, we classify the subjects into four groups (Group NN, normal systolic and diastolic pressures; Group NH, normal systolic and high diastolic pressures; Group HN, high systolic and normal diastolic pressures; and Group HH, high systolic and diastolic pressures). Blood pressure and double product were generally higher in Group HH than other groups who are high systolic and diastolic pressures, but RPE and FS scores were similar among all groups. Subjects whose blood pressure was so high that they could be categorized in the high blood pressure group may thus remain asymptomatic without any warning sign of risk caused by exercise. Individuals at risk of hypertension should therefore pay close attention to exercise load even when they feel well.

**Key words** blood pressure, walking in water, middle-aged women, elderly women

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## Ⅰ. Purpose

Exercise in water should differ from that on land. For example, bodyweight load is reduced by the effects of buoyancy in water, while the viscosity of water exerts resistance to movement, and water pressure increases central blood circulation during immersion. For these reasons, water exercise is recommended to individuals who need physical exercise, have poor physical abilities, or have difficulty in supporting their body during exercise.

In fact, water exercise is considered one of the most popular physical activities, particularly among middle-aged and elderly women [11]. Since the number of people participating in water exercise is expected to increase in future, identification of safe and effective methods of water exercise is very important.

Although water exercise is recommendable for the reasons mentioned above, central venous pressure increases and heart rate (HR) decreases with increased water depth [10], and cardiac output and stroke volume increase [2] even at neutral temperature (about 35℃) [8] during water immersion due to the abovementioned characteristics of water immersion. If the water temperature is lower, cutaneous blood vessels contract to restrict heat radiation, increasing central blood circulation and significantly increasing cardiac output. The mechanisms of blood pressure increases during water immersion have already been explained, but blood pressure responses during water exercise remain poorly understood, partially due to the difficulty of monitoring.

Since blood pressure actually increases during water immersion, understanding the relationships between level of exercise and blood pressure response is essential for maintaining safety during water exercise. In addition, investigations of how participants in such exercise can recognize and assess any physical responses during activity are important to determine the most suitable methods of water exercise.

The purpose of this study was to investigate the effectiveness of physical activity in water from the perspective of blood pressure responses in middle-aged and elderly women for whom water exercise is recommended.

## Ⅱ. Methods

### A. Subjects

Subjects comprised 22 middle-aged and elderly women who regularly go swimming or participate in water exercise in a sports club. Mean age was 59.6 ±5.8 years (range, 50-73 years), mean height was 153.4 ±3.6 cm, mean body weight was 54.6 ±5.7 kg, mean body mass index (BMI) was 23.3±2.8 and mean %FAT using by impedance method was 28.8±5.0%. Mean estimated maximal oxygen uptake ($\dot{V}O_2max$) was 1.5±0.32 l/min (range, 0.98-2.30 l/min). $\dot{V}O_2max$ was estimated using oxygen uptake ($\dot{V}O_2$) and HR obtained in an exercise test. Specifically, a regression equation was derived using 4-5 sets of $\dot{V}O_2$ and HR (including data obtained during rest) and estimated maximal heart rate ($HR_{max}$: 220 - age) was substituted into the equation to obtain $\dot{V}O_2max$. Prior to enrolment in the study, information was provided regarding the detailed purposes and methods of the study and written informed consent was obtained from each subject.

### B. Procedures

An FM1200D Flowmill (Japan Aquatec, Nagasaki, Japan) was used as the exercise stress device. Water depth was adjusted to the height of the xiphoid process for each subject, and water temperature was maintained at 30℃. Following seated rest for 5-min, each subject entered the water of the Flowmill to undergo exercise test. The subject walked in water for 4 min each at 4 different exercise intensities, with a 1-min rest between each walking session. Exercise intensity increased by 10 m/min, starting at 20 m/min, for both water flow and treadmill speed (20, 30, 40 and 50 m/min). However, if exercise intensity at the 4th session was considered too difficult for the subject as judged by the condition of the subject at the end of the 3rd session, walking was discontinued at that point.

### C. Measurements

During walking, $\dot{V}O_2$ and ventilation ($\dot{V}_E$) were measured every 30s using an RM-300i automatic breath gas analyzer (Minato Medical Science, Osaka, Japan). HR was continuously monitored using telemetry (ST-30, DS-501; Fukuda Denshi, Osaka, Japan). Immediately after each stress session, blood was taken from the earlobe to determine blood lactate concentration (Bla) using a simplified LT-1710 blood lactate analyzer (Arkray, Tokyo, Japan). Blood pressure at rest was measured using a mercury sphygmomanometer. Blood pressure during walking was monitored using a mercury sphygmomanometer or HEM-401C semi-automatic portable blood pressure monitor (Omron, Kyoto, Japan) to determine systolic and diastolic pressures and the double product (DP; mean blood pressure×HR; mean blood pressure was calculated as (diastolic pressure+pulse pressure)/3 was then calculated.

During the 1 min rest for blood sampling, subjective level of exertion was assessed using the rating of perceived exertion (RPE) scale defined by Borg [3], Onodera and Miyashita [17] and also the category ratio 10 (CR-10; Table 1) scale designed to obtain exponential perceived exertion, which is similar to perceived exertion during actual exercise at different levels of stress [4, 5, 6]. The feeling scale (FS) described by Frijda [9] (Table 2) was used to assess feelings during exercise.

Table 1: Category Ratio Scale

| | | |
|---|---|---|
| 0 | Nothing at all | |
| 0.5 | Extremely weak | Just noticeable |
| 1 | Very weak | |
| 2 | Weak | Light |
| 3 | Moderate | |
| 4 | | |
| 5 | Strong | Heavy |
| 6 | | |
| 7 | Very strong | |
| 8 | | |
| 9 | | |
| 10 | Extremely strong | Almost max |
| ● | Maximal | |

Table 2: Feeling Scale

| | |
|---|---|
| 5 | Very good |
| 4 | |
| 3 | Good |
| 2 | |
| 1 | Fairly good |
| 0 | Neutral |
| -1 | Fairly bad |
| -2 | |
| -3 | Bad |
| -4 | |
| -5 | Very bad |

### D. Statistical analysis

Measured values at each stress level were expressed as mean ± standard deviation, and differences were tested using 2-way analysis of variance with replication. Values of $p<0.05$ were considered statistically significant, and multiple comparisons were performed if F-values were significant.

## Ⅲ. Results

In the current study, subjects were categorized in one of 4 groups depending on the comparison of systolic and diastolic blood pressures at rest, based on World Health Organization criteria (systolic, 140 mmHg; diastolic, 90 mmHg). Groups comprised: Group NN, normal systolic and diastolic pressures; Group NH, normal systolic and high diastolic pressures; Group HN, high systolic and normal diastolic pressures; and Group HH, high systolic and diastolic pressures. Table 3 indicates the distribution of blood pressures at rest for subjects.

Figure 1 demonstrates the correlation between $\dot{V}O_2$ and HR for each group. A linear correlation was observed between $\dot{V}O_2$ and HR for almost all groups and the regression lines were nearly collinear.

Table 3: Distribution of blood pressures at rest

| Subjects (n=22) | | Diastolic pressure | |
|---|---|---|---|
| | | Normal (<90 mmHg) | High (≥90 mmHg) |
| Systolic pressure | Normal (<140 mmHg) | Group NN 4 (18.2%) | Group NH 2 (9.1%) |
| | High (≥140 mmHg) | Group HN 11 (50.0%) | Group HH 5 (22.7%) |

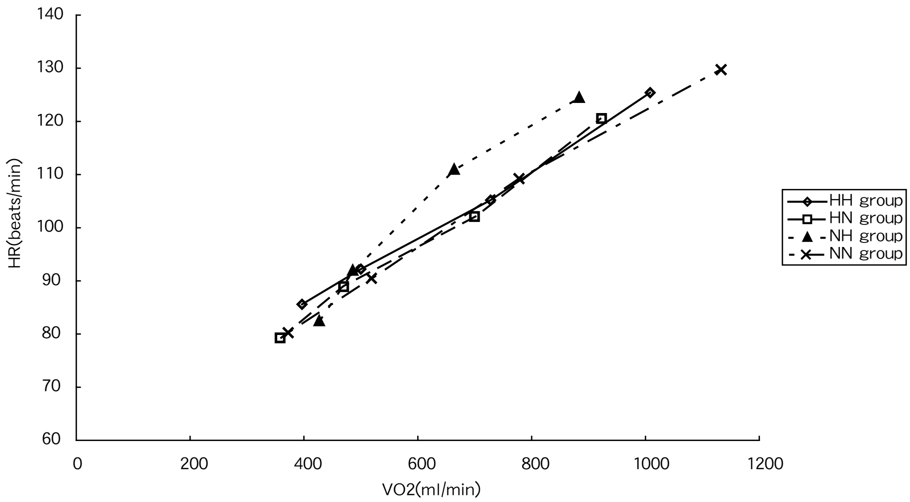


**Figure 1 Relationship between $\dot{V}O_2$ and heart rate (HR) for each group.**

However, a significant main effect of stress level (F(3,51)=428.277, p<0.01) and a significant interaction of group × stress level (F(9,51)=2.535, p<0.05) were observed for $\dot{V}O_2$, indicating wider variation of $\dot{V}O_2$with increased stress levels. A significant main effect of stress level (F(3,54)=192.786, p<0.01) was observed for HR.

Figure 2 and 3 show the correlation between $\dot{V}O_2$ and systolic and diastolic blood pressures for each group. A significant main effect of stress level (F(3,51)=4.798, p<0.01) was observed for systolic blood pressure (Figure 2) and a significant main effect of group (F(3,51)=4.652, p<0.05) was observed for diastolic blood pressure (Figure 3). Blood pressure was generally higher in Group HH than in other groups.

Figure 4 shows the correlation between $\dot{V}O_2$ and DP for each group. Significant main effects of group and stress level (group: F(3,51)=4.240, p<0.05; stress level: F(3,51)=20.500, p<0.01) were observed for DP, which was higher in Group HH than in other groups.

Figure 5 shows the correlation between $\dot{V}O_2$ and Bla for each group. As $\dot{V}O_2$ increased, Bla increased in a similar fashion in all groups.

Figure 6 and 7 show the correlation between $\dot{V}O_2$ and subjective stress level scores (RPE: Figure 6 and CR-10: Figure 7). A significant main effect of stress level (F(3,54)=49.195, p<0.01) and a significant interaction of group × stress level (F(9,54)=0.05, p<0.05) were observed for RPE score (Figure 6). RPE score varied widely when stress level was low, while linear correlations were observed for all groups as stress level increased, with regression lines being nearly collinear. Similar results were

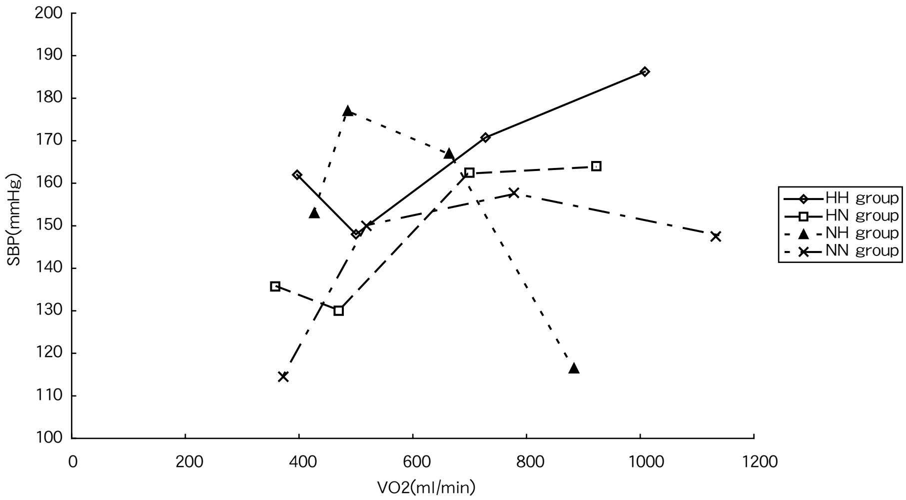


Figure 2　Relationship between $\dot{V}O_2$ and systolic blood pressure (SBP) for each group.

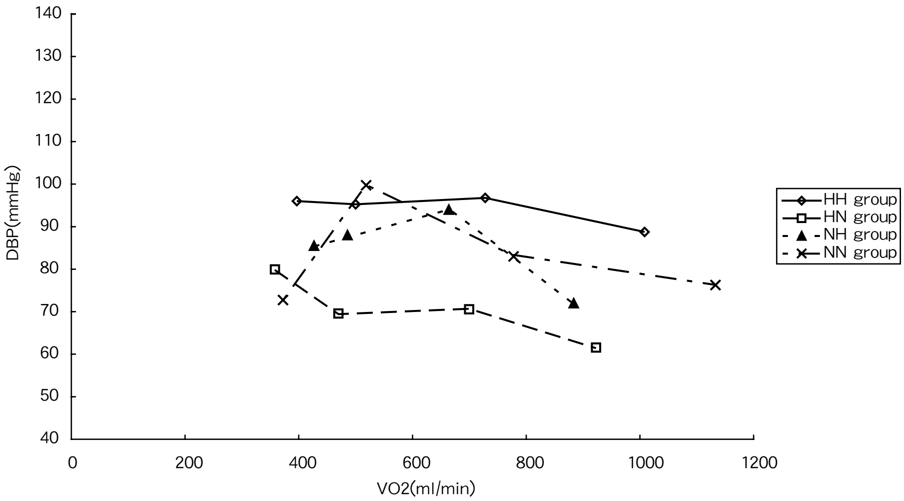


Figure 3　Relationship between $\dot{V}O_2$ and diastolic blood pressure (DBP) for each group.

observed for CR-10 (Figure 7), although only a significant main effect of stress level ($F(3,54)=55.744$, $p<0.01$) was observed.

Figure 8 shows the correlation between $\dot{V}O_2$ and FS for each group. FS score decreased with increased $\dot{V}O_2$ in Groups NN, NH and HN, although the decrease was delayed in Group HH compared to other groups. A significant main effect of stress level ($F(3,54)=18.155$, $p<0.01$) was observed for FS.

## Ⅳ. Discussion

Measuring blood pressure during exercise by auscultation is difficult [12,

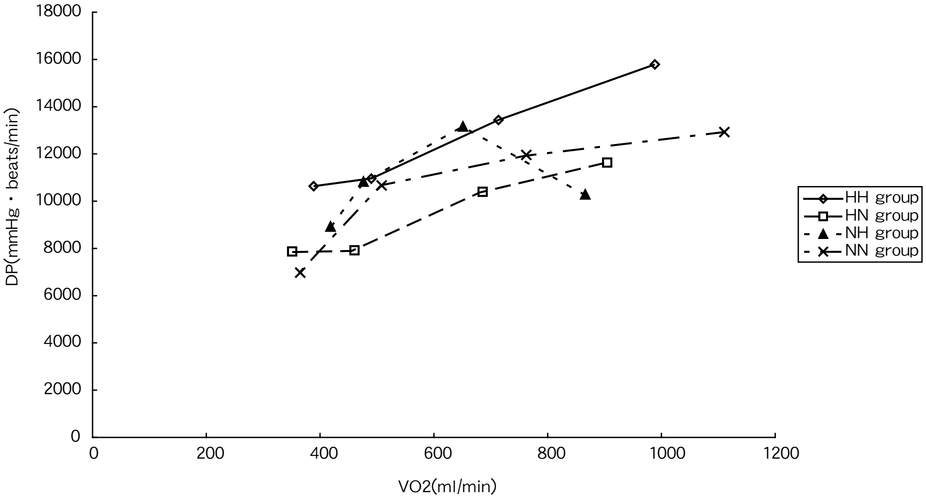


Figure 4　Relationship between $\dot{V}O_2$ and double product (DP) for each group.

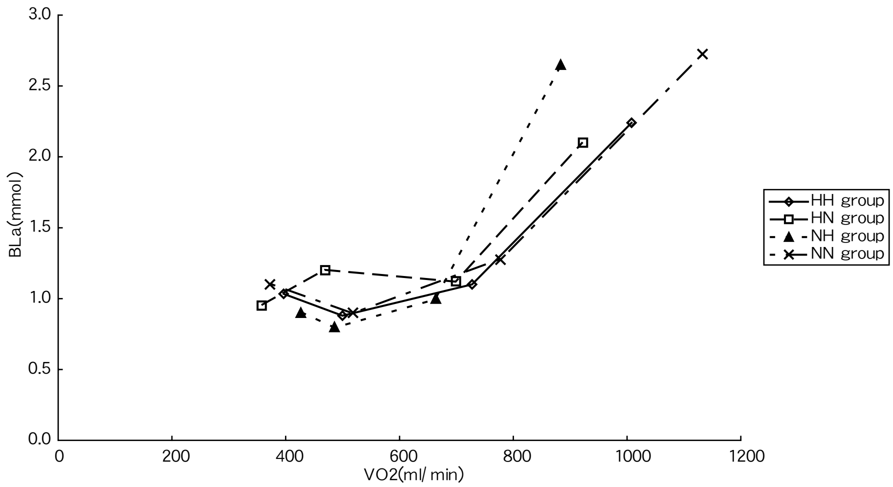


Figure 5　Relation between $\dot{V}O_2$ and blood lactate concentration (BLa) for each group.

18]. For instance, systolic blood pressure is measured using the height of mercury column when the first Korotkoff sound is heard. However, since the existence of an ausculatory gap has been reported [22], this method might not be accurate for determining systolic blood pressure during exercise [16]. Conversely, significant correlations have been reported between systolic blood pressure measured by auscultation and that obtained from invasive determination of intravascular pressure [12, 15, 20]. Since methods using auscultation are generally used for measurement of systolic blood pressure, this method was used for the present study

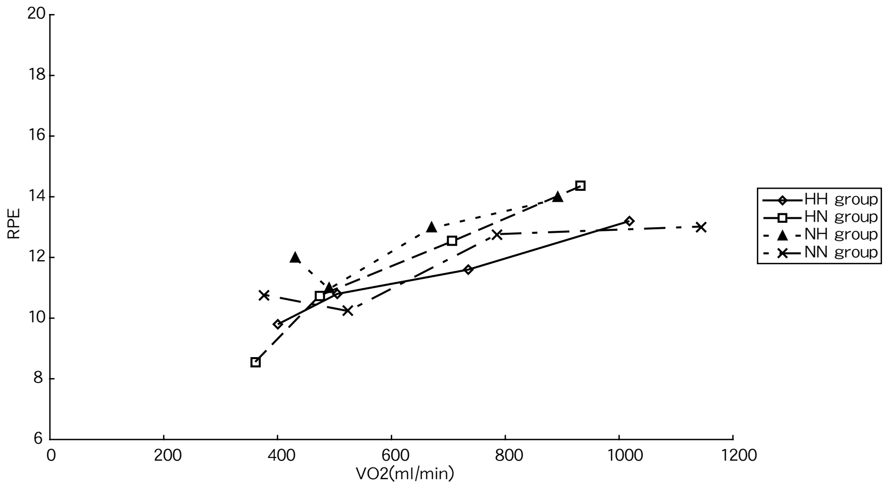


Figure 6　Relationship between $\dot{V}O_2$ and rating of perceived exertion (RPE) for each group.

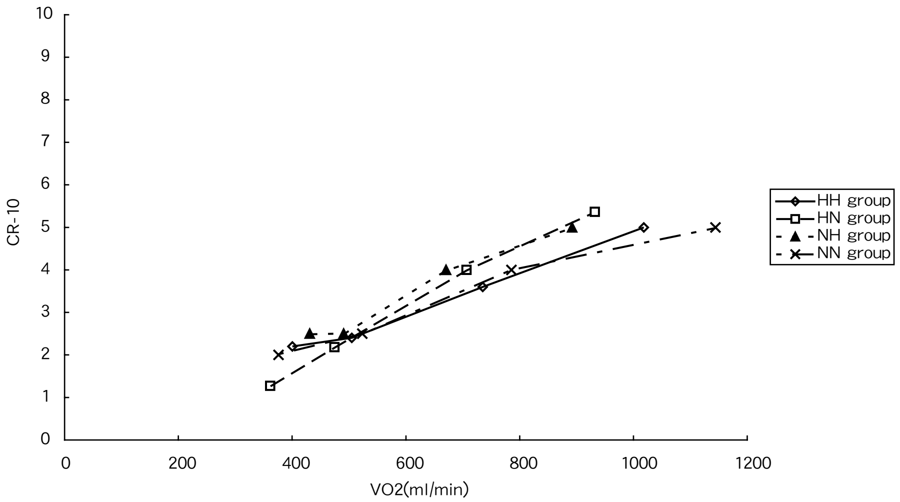


Figure 7　Relation between $\dot{V}O_2$ and category ratio 10 scale (CR-10) for each group.

despite potential problems in accuracy.

The percentages of women who can be categorized as having high blood pressure at the same age as subjects in the current study are reportedly 40.9% (age, 50-59 years), 56.7% (age, 60-69 years) and 64.9% (age, ≥70 years) [14]. However in the current study, either systolic blood pressure at rest, diastolic blood pressure at rest, or both were high in 18 women (81.8%). The frequency of subjects with high blood pressure was thus higher in the current study, but no subjects were receiving any treatment for hypertension. All subjects were middle-aged and elderly women who regularly go swimming or participate in water exercise in a sports club. Among middle-aged and elderly individuals who

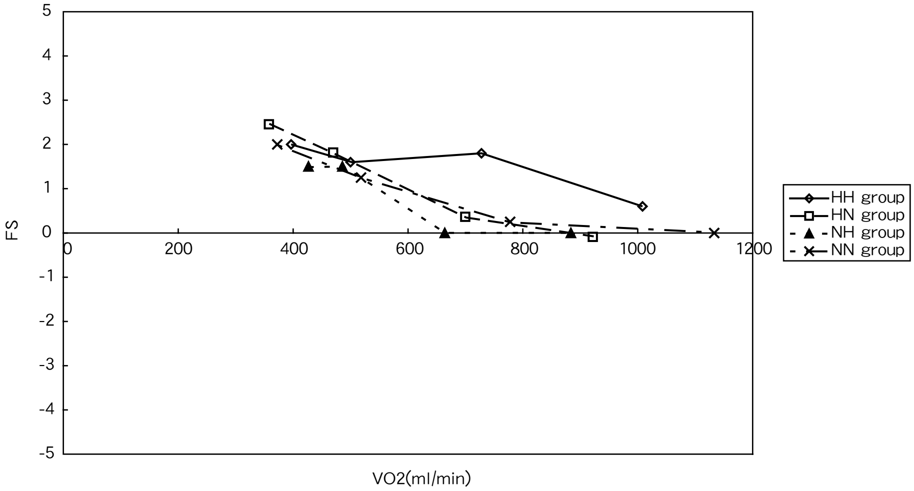


**Figure 8 Rrelation between $\dot{V}O_2$ and feeling scale (FS) for each group.**

exercise regularly, some can be assumed to potentially have high blood pressure. In order to reduce the risk of illness during exercise, safety considerations should be made, such as medical examination using interviews, physical observation or physiological and clinical testing [1].

Regarding pressure response during exercise, systolic blood pressure increased in Groups HH and HN, while the profile of pressure response was an inverted U-shape in Groups NN and NH with increased $\dot{V}O_2$. However, diastolic blood pressure decreased in Groups HH and HN and the profile was an inverted U-shape in Groups NN and NH. In the general population, systolic blood pressure reportedly continues to increase in proportion to $\dot{V}O_2$ until maximum exercise level is reached, whereas diastolic blood pressure does not change or slightly decreases during exercise [21]. In our study, DP increased with increases in $\dot{V}O_2$ in Groups HH, HN and NN, and taking into consideration that data obtained for Group NH was derived from only 2 subjects and the accuracy of the method to measure blood pressure used in the study, the result obtained for walking in water seems consistent with the above report. In Group HH, systolic blood pressure further increased with increases in $\dot{V}O_2$.

In the current study, maximum stress level for walking in water ranged from 61.3 ± 10.9% $\dot{V}O_2$max (Group HN) to 74.6 ± 21.8% $\dot{V}O_2$max (Group NN). If DP is regarded as indicating stress on the cardiovascular system, maximum DP ranged from $10.3 \times 10^3 \pm 3.6 \times 10^3$ (Group NH) to $15.8 \times 10^3 \pm 2.5 \times 10^3$ (Group HH). Regarding Bla as a stress on the muscular system, Tanaka et al. [23] reported that DP at lactate threshold (LT) was 14.7×103 ± $2.5\times10^3$. In the current study, Bla at the highest stress ranged from 2.1 ± 0.6 mmol/l (Group HN) to 2.7 ± 0.8 mmol/l (Group NN). Maximum stress level used in this study may thus be at or slightly higher than ventilatory threshold (VT) and LT. In addition, although relative stress level was higher in Group NN than in other groups, stress on the cardiovascular system was higher in Group HH.

Regarding RPE, score at the highest stress ranged from 13.0 ± 1.4 (Group NN) to 14.4 ± 2.0 (Group HN). Boutcher et al. [7] reported that RPE score at LT ranged from 9.0 ± 2.6 to 10.6 ± 3.0 during pedaling, and from 10.4 ± 2.4 to 12.0 ± 3.7 during running. Purvis and Cureton [19] found that RPE score at VT in men was 14.2 ± 0.9 during pedaling. Mahon et al. [13] also reported that RPE score at VT in men was 11.5 ± 2.6 during pedaling. The RPE score obtained thus also indicates that highest stress level in the current study was at or slightly higher than LT and VT.

Regarding perceptions in the stress test, the relationship between $\dot{V}O_2$ and RPE and FS scores demonstrated that RPE and CR-10 scores in each group were aligned on the same regression line and increased with increasing $\dot{V}O_2$. This means that the assessment of stress level was almost equal among groups and no differences existed in assessment between groups with different blood pressure. Although FS scores decreased with increased stress levels, Groups NN, NH and HN rated "0: Not good, not bad", while the score was relatively higher in Group HH than in other groups, at around 700 ml/min $\dot{V}O_2$. Even individuals displaying blood pressure levels so high that they could be categorized in the high blood pressure group may remain asymptomatic. Subjects with high blood pressure instead reported feeling better. This clearly suggests that no sign warning of potential risk caused by exercise is likely to appear. Individuals with blood pressure risk should thus pay attention to level of exercise, even when feeling good during exercise.

Acknowledgement

This study was supported by the research fund of the Kyushu Society of Physical Education and Sports.

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