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# Gender Differences in Metabolic Responses During Water Walking

Koichi Kaneda, Yuji Ohgi, and Chiaki Tanaka

The purpose of this study was to compare metabolic responses between men and women during water walking. Japanese men (27–73 yr,  $n = 26$ ) and women (33–70 yr,  $n = 14$ ) performed water walking at 25 m/min, 30 m/min and 35 m/min. Oxygen consumption ( $VO_2$ ),  $VO_2$  per weight ( $VO_2/W$ ), respiratory ventilation (VE), heart rate (HR), energy expenditure (EE), EE per weight (EE/W), and actual walking speed were analyzed at each velocity.  $VO_2/W$  and EE/W were higher in women compared with men.  $VO_2$  and EE showed similar values between men and women. HRs were significantly higher for women than those of men at all speeds. The regression analysis with third-ordered polynomial equation by actual walking speed showed high correlation coefficients for  $VO_2$  and  $VO_2/W$ . In relative terms, exercise intensity was higher for women than men; however, absolute intensity was similar in both men and women during water walking. Moreover, analysis using third-ordered equations found that absolute intensity during water walking was dominated by walking speed.

*Keywords:* energy expenditure, walking speed, gender difference, regression model, water walking

Water exercise has become popular in therapeutic, rehabilitative, and health care programs (Assis et al., 2006; Kaneda, Sato, Wakabayashi, Hanai, & Nomura, 2008a; Sato, Kaneda, Wakabayashi, & Nomura, 2007). In an aquatic environment, gravitational stress at lower extremity joints can be reduced (Nakazawa, Yano, & Miyashita, 1994) while requiring greater exertion when exercising in water due to increased fluid density when compared with movement through air (Miyoshi, Shirota, Yamamoto, Nakazawa, & Akai, 2005). In addition, hydrostatic pressure gradient causes blood to shift from the lower limbs to the thoracic region as a result of immersion, and if water temperature is less than body temperature, the high thermal conductivity of water causes an additional blood shift as well. This results in an increase in cardiac output and a decrease in sympathetic nervous system activity (Bonde-Petersen, Schultz-Petersen, & Dragsted, 1992). For these reasons, water exercise is widely accepted by practitioners for disabled and aged people for rehabilitation, body-function and fitness training (Gappmaier, Lake, Nelson, & Fisher, 2006; Kaneda et al., 2008a; Sato et al., 2007).

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To date, metabolic responses during water walking (WW) have been investigated (Evans, Cureton, & Purvis, 1978; Gleim & Nicholas, 1989; Masumoto, Shono, Hotta, & Fujishima, 2008; Shono, Fujishima, Hotta, Ogaki, & Masumoto, 2001; Shono et al., 2000; Takeshima, Nakata, Kobayashi, Tanaka, & Pollock, 1997), while biomechanical analysis has also been conducted on WW (Barela, Stolf, & Duarte, 2006; Kaneda, Wakabayashi, Sato, Uekusa, & Nomura, 2008b; Miyoshi et al., 2005; Nakazawa et al., 1994). According to the metabolic responses during WW, it was reported that WW may be beneficial as a health care program of prevention or improvement for the lifestyle-related diseases such as chronic heart failure (Cider, Schaufelberger, Sunnerhagen, & Andersson, 2003), obesity (Gappmaier et al., 2006), and chronic kidney disease (Pechter et al., 2003). Evans et al. (1978) investigated the metabolic responses during walking and jogging, both in water and on a land treadmill. The research found that one-third to one-half walking speed was needed for the same metabolic intensity during the WW or water jogging compared with the land treadmill equivalent. Gleim and Nicholas (1989) found oxygen consumption ( $VO_2$ ) to be higher during waist deep water treadmill walking than on land treadmill walking at similar walking speeds. Adding to this knowledge base, Shono et al. (2001) and Masumoto et al. (2008) reported that water treadmill walking required higher  $VO_2$  per body weight ( $VO_2/W$ ) rather than the land treadmill walking at the same walking speed. In an earlier study, Takeshima et al. (1997) investigated metabolic response during WW and land walking with the same intensity based on subject's rating of perceived exertion (RPE) of elderly subjects (60+ yr). The investigators reported lower  $VO_2/W$ , heart rate (HR), and walking speed during WW compared with land walking. Walking speeds of WW reported in this study were one-third or less than land walking. Although the physiological characteristics of WW were evident, gender differences of metabolic response during water walking were not reported.

In general,  $VO_2$  during land walking are higher in men than that of women, largely because men possess greater body mass than women, while  $VO_2/W$  was found to be similar between both genders (Bhambhani and Maikala, 2000; Kang, Chaloupka, Mastrangelo, & Hoffman, 2002). The directions of load for human body during WW change from land walking. In WW, water resistance gives horizontal load while buoyancy reduces vertical load to human body. We hypothesized that absolute metabolic responses such as  $VO_2$  were similar between men and women, and relative metabolic responses such as  $VO_2/W$  were higher in men than women during WW. The purpose of this study was to investigate the metabolic responses as well as comparing differences between of young to elderly men and women during WW.

## Method

### Participants

Forty healthy Japanese adults, 26 men (age:  $55.0 \pm 15.2$  yr (ranged 27–73yr), height:  $171.0 \pm 6.4$  cm (ranged 160.2–184.6 cm), weight:  $68.2 \pm 8.4$  kg (ranged 53.3–91.1 kg), body mass index (BMI):  $23.3 \pm 2.4$  kg/m<sup>2</sup> (ranged 19.4–29.7 kg/m<sup>2</sup>), and 14 women (56.0  $\pm$  10.1 yr (ranged 30–70 yr), 158.5  $\pm$  4.2 cm (ranged 149.0–166.1 cm), 55.5  $\pm$  6.1 kg (ranged 48.9–67.6 kg), 22.1  $\pm$  2.9 kg/m<sup>2</sup> (ranged 18.3–27.9 kg/m<sup>2</sup>))

voluntarily participated in this study. Before commencement, participants provided a written informed consent for participation and screened for their medical history and measured blood pressure. All subjects were healthy and free from any diseases as well as any debilitations that may affect energy expenditure. This study was approved by the Ethics Committee of Shonan-Fujisawa Campus at Keio University.

## Experimental Procedures

Participants performed WW at an indoor swimming pool (17.2 m length, 5 m width and 1.1 m depth) at the Medical Fitness Club, Fureai Machida Hospital, Japan. Temperatures were maintained, water (30 °C) and air (25–28 °C), throughout the experiment. The participants walked at stepwise increments at three speeds: 25 m/min, 30 m/min, and 35 m/min, which were equivalent to light, moderate and vigorous intensities. The protocol for walking was five circuits of the pool (light), six circuits (moderate), and seven circuits (vigorous), respectively. This guaranteed the duration of each walking trial to be a minimum of five minutes. To keep intensities constant, a pace-maker walked around the perimeter of the pool as each person participated. Each of the three walking trials was separated by at least a 5-min recovery period.

## Measurements

The expired respiratory gas was collected using Douglas bags during the last two round trips of the each walking trial. The concentration of expired gases (O<sub>2</sub> and CO<sub>2</sub>) were measured using a portable gas analyzer (AR-1 O<sub>2</sub>-ro, Arcosystem Inc., Japan) and the respiratory volume was measured by a dry gas meter (DCDA-2C-M, Shinagawa Corp., Japan). After each walking trial, Borg's RPE scale was used to monitor the walking intensity (Borg, 1973). Subject's HR (bpm) was continuously measured by a heart rate monitor (s810i, Polar Electro, Finland) throughout the experiment. To confirm the participant's walking speed, elapsed time of the person at distances of 1.1 m and 16.1 m of the pool length were measured using a stopwatch. The distance 1.1 m from both sides of the walking course in the swimming pool was used for subject's turning motion at each end. VO<sub>2</sub> (ml/min), VO<sub>2</sub>/W (ml/min/kg), respiratory ventilation (VE, l/min), and actual walking speed (m/min) of the last two rounds were calculated. In addition, the energy expenditure (EE, kcal/min) and EE per body weight (EE/W, kcal/min/kg) for each trial was also calculated by the Weir's formula (Weir, 1949).

For 30 min before commencement of testing, participants rested quietly on a chair at pool side. The measurements began approximately 2 hr after lunch to prohibit the thermic effect of dietary intake. Participants were prohibited any dietary intake except water throughout the experiment. During their rest period, expired respiratory gas was collected as a rest measurement. The metabolic equivalent (MET) was calculated for each walking speed.

## Statistical Analysis

Results are expressed as mean  $\pm$  SD. RPE data were treated as a nonparametric data because of its ordinal scale. The other data were treated as a parametric or nonparametric data depending on whether distribution was normal or not. The parametric

data were evaluated using a two-way (walking speed  $\times$  gender) repeated measures analysis of variance (ANOVA). Tukey's post hoc test was used to determine the differences between each value. The one-way repeated-measures ANOVA with Tukey's post-hoc test was used to evaluate differences in walking speed within each gender group, and the differences between men and women within each walking speed were analyzed using unpaired *t* test if no significant interaction was shown by the two-way ANOVA. The statistical significance was inferred for  $p < .05$ . The differences in walking speed within each gender group were analyzed by Freedman test, with Wilcoxon's sign rank test as a post hoc and evaluated in Bonferroni's inequality for nonparametric data. Statistical significance was inferred for  $p < .016$  because of the comparison of three combinations in the post hoc test for the RPE, actual walking speed, and MET. The significance was inferred for  $p < .008$  at other data which were included the rest data because there were six combinations for the comparison. For comparisons of non-parametric data between men and women within each walking speed, the Mann-Whitney-*U* test was adopted. The significance was inferred for  $p < .05$ . The HR-  $\text{VO}_2$  and HR-  $\text{VO}_2/\text{W}$  relationship for the each gender group was determined by a linear regression analysis. The Pearson product-moment correlation coefficient was calculated in the subject's height-  $\text{VO}_2$ , height-  $\text{VO}_2/\text{W}$ , height- EE, and height- EE/W relationship for all subjects for determine the effect of body load by buoyancy and water resistance. The relationship between the actual walking speed and the  $\text{VO}_2$  or  $\text{VO}_2/\text{W}$  for the each gender group was determined by regression analysis with third-ordered equation. The comparison of two correlation coefficients between men and women were made with the significance was inferred for  $p < .05$ .

The dimension of  $\text{VO}_2$  and  $\text{VO}_2/\text{W}$  could be equivalent to EE or EE/W. The water resistance (*D*) is expressed in proportion to the square of the traveling speed as follows:

$$D = \frac{1}{2} Cd \rho S v^2 \quad (1)$$

where  $\rho$  is water density, *S* is a frontal projected area of the traveling object, *Cd* is coefficient of drag. Thus, power can be expressed as follows:

$$\begin{aligned} P &= Dv \\ &= \frac{1}{2} Cd \rho S v^3 \end{aligned} \quad (2)$$

For the WW, propelling power is proportional to the cubic of the traveling speed. Thus,  $\text{VO}_2$  and  $\text{VO}_2/\text{W}$  are also proportional to the cubic of walking speed.

## Results

### Physical Characteristics

The height and weight of men were significantly greater than women with unpaired *t* test ( $p < .05$ ). The age and BMI were not significantly different between men and women.

## Metabolic Variables

The mean  $\pm$  *SD* of the metabolic variables during rest and each walking speed were described in Table 1. The significant interaction was evident in  $\text{VO}_2/\text{W}$ , HR, EE/W, and actual walking speed. All measurements within each gender group were significantly increased from the rest period and/or from a speed of 25 m/min to 35 m/min ( $p < .05$ ). Significant differences were found between men and women for their  $\text{VO}_2$ , VE and EE at the rest, with men reporting higher than women ( $p < .05$ ). On the other hand, significantly lower values were obtained in men than women for HR and MET at the speed of 25 m/min ( $p < .05$ ). At the speed of 30 m/min, the  $\text{VO}_2/\text{W}$ , HR, EE/W, and MET were significantly lower in men than women ( $p < .05$ ). Similarly, at the speed of 35 m/min, significantly lower values were reported in men than women for  $\text{VO}_2/\text{W}$ , HR, EE/W, MET, RPE, and actual walking speed ( $p < .05$ ). See Figure 1.

Figure 1 shows the relationships between the HR (bpm) and  $\text{VO}_2$  (ml/min) or  $\text{VO}_2/\text{W}$  (ml/min/kg) in the each gender group. The correlation coefficient between the HR and  $\text{VO}_2$  was 0.64 ( $\text{VO}_2 = -186.32 + 10.94 \text{ HR}$ ,  $p < .05$ ) for men and 0.74 ( $\text{VO}_2 = -225.75 + 9.56 \text{ HR}$ ,  $p < .05$ ) for women, respectively. Similarly, the coefficient between the HR and  $\text{VO}_2/\text{W}$  was 0.71 ( $\text{VO}_2/\text{W} = -4.64 + 0.18 \text{ HR}$ ,  $p < .05$ ) for men and 0.69 ( $\text{VO}_2/\text{W} = -3.74 + 0.17 \text{ HR}$ ,  $p < .05$ ) for women. The values of the Pearson product-moment correlation coefficient were shown in Table 2. The significantly negative correlation coefficients were detected in all speeds of subject's height-  $\text{VO}_2/\text{W}$  and in 35 m/min of subject's height- EE/W ( $p < .05$ ). Figure 2 shows the results of regression analysis with a third-ordered equation between the actual walking speed (m/min) and  $\text{VO}_2$  (ml/min) or  $\text{VO}_2/\text{W}$  (ml/min/kg) in for each gender group. The correlation coefficient between the actual walking speed and  $\text{VO}_2$  was 0.80 ( $\text{VO}_2 = 401.088 + 0.015 v^3$ ,  $p < .05$ ) for men and 0.89 ( $\text{VO}_2 = 236.736 + 0.019 v^3$ ,  $p < .05$ ) for women, respectively. Similarly, the correlation coefficient between the actual walking speed and  $\text{VO}_2/\text{W}$  was 0.81 ( $\text{VO}_2 = 5.719 + 2.227 \times 10^{-4} v^3$ ,  $p < .05$ ) for men and 0.84 ( $\text{VO}_2 = 4.438 + 3.47905 \times 10^{-4} v^3$ ,  $p < .05$ ) for women. There was no significant difference between men and women for each correlation coefficient.

## Discussion

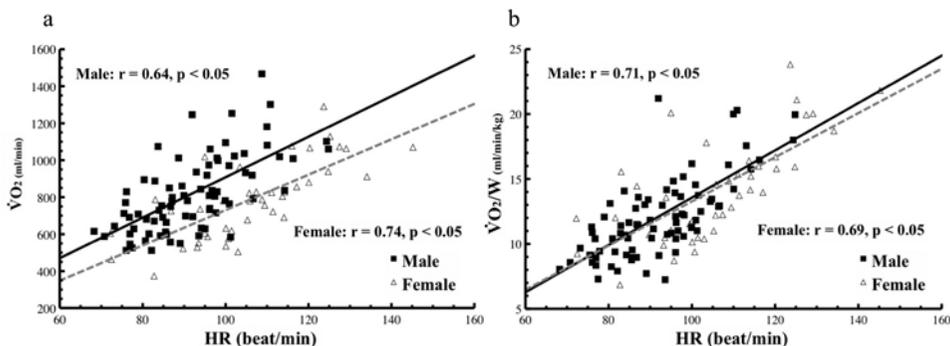
This study aimed to investigate the metabolic responses of young to elderly men and women during WW. All of the metabolic parameters increased with an increase of the walking speed. Previous studies that examined metabolic responses during WW described a similar tendency of those parameters due to an increased water resistance resulting from an increase in walking speed (Evans et al., 1978; Gleim & Nicholas, 1989; Masumoto et al., 2008; Shono et al., 2000, 2001; Takeshima et al., 1997). However, there was no previous study investigating the difference of the metabolic response between men and women during WW.

In this study,  $\text{VO}_2$ , VE and EE were significantly higher in men than women at rest. This outcome is in line with a previous study that found resting metabolic rates correlated with body weight (Carpenter, Poehlman, O'Connell, & Goran, 1995)

**Table 1 The Values of Metabolic Parameters and Actual Walking Speed in Each Walking Speed Condition**

		Rest	25 m/min	30 m/min	35 m/min	Normal distribution (p value)	Gender x speed interaction (p value)
VO <sub>2</sub> (ml/min)	Male	247.9 ± 35.4	639.9 ± 111.7	809.6 ± 132.1	1016.0 ± 165.9	0.014	-
	Female	197.3 ± 24.8	580.0 ± 103.1	768.2 ± 95.9	1002.1 ± 145.5		
VO <sub>2</sub> /W (ml/min/kg)	Male	3.6 ± 0.4	9.4 ± 1.4	11.9 ± 1.7	15.0 ± 2.9	0.144	0.001
	Female	3.6 ± 0.3	10.5 ± 1.6	14.0 ± 2.0	18.2 ± 3.1		
VE l/min, STPD	Male	7.4 ± 1.8	15.5 ± 2.3	18.9 ± 2.9	23.5 ± 4.3	0.033	-
	Female	6.0 ± 0.8	14.5 ± 3.0	18.6 ± 3.6	25.0 ± 6.0		
HR (b/min)	Male	71.0 ± 8.4	84.8 ± 9.8	90.8 ± 10.4	100.6 ± 11.2	0.134	< 0.001
	Female	72.8 ± 9.1	92.7 ± 10.1	104.0 ± 10.4	120.0 ± 14.7		
EE (kcal/min)	Male	1.21 ± 0.18	3.10 ± 0.53	3.93 ± 0.64	4.95 ± 0.80	0.013	-
	Female	0.96 ± 0.12	2.80 ± 0.50	3.72 ± 0.48	4.90 ± 0.74		
EE/W (cal/min/kg)	Male	18.6 ± 4.7	46.6 ± 8.1	58.7 ± 10.0	74.2 ± 16.1	0.065	0.001
	Female	18.9 ± 5.3	52.2 ± 6.1	69.2 ± 9.4	90.6 ± 15.0		
MET	Male	-	2.6 ± 0.4	3.3 ± 0.5	4.2 ± 0.9	0.022	-
	Female	-	3.0 ± 0.4	3.9 ± 0.5	5.2 ± 0.8		
RPE	Male	-	8.8 ± 1.6	10.4 ± 1.7	12.0 ± 1.7	-	-
	Female	-	9.3 ± 1.8	11.5 ± 1.7	13.5 ± 1.9		
Actual walking speed (m/min)	Male	-	25.3 ± 1.0	30.2 ± 0.9	34.8 ± 1.4	0.843	0.003
	Female	-	25.8 ± 1.1	30.3 ± 1.0	33.9 ± 1.2		

Values are Mean ± Standard deviation (SD). VO<sub>2</sub>: oxygen consumption, VE: respiratory ventilation, HR: heart rate, EE: energy expenditure, MET: metabolic equivalent, RPE: ratings of perceived exertion, W: body weight. \*: significant difference between male and female within each walking speed. †: significant difference between each walking speed within each gender group.

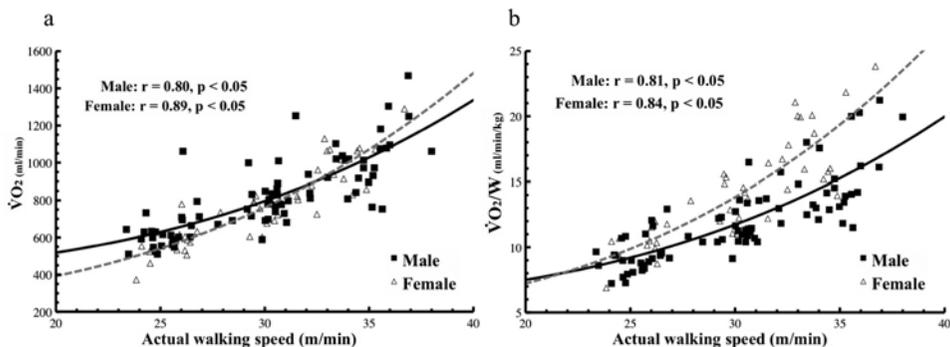


**Figure 1** — The relationships between  $\dot{V}O_2$  and HR (a) and between  $\dot{V}O_2/W$  and HR (b).  $\dot{V}O_2$ : oxygen consumption, HR: heart rate, W: body weight. r: correlation coefficient by single linear regression analysis.

**Table 2 Correlation Coefficient Values Between Height and Each Variable**

$\dot{V}O_2$ (ml/min) vs. height (cm)	25 m/min	30 m/min	35 m/min
Correlation Coefficient	0.300	0.311	0.110
$\dot{V}O_2 / W$ (ml/min/kg) vs. height (cm)	25 m/min	30 m/min	35 m/min
Correlation Coefficient	-0.326 *	-0.398 *	-0.446 *
EE (kcal/min) vs. height (cm)	25 m/min	30 m/min	35 m/min
Correlation Coefficient	0.307	0.316	0.105
EE / W (cal/min/kg) vs. height (cm)	25 m/min	30 m/min	35 m/min
Correlation Coefficient	-0.217	-0.289	-0.369 *

Total samples were 40 because males and females data were combined. \*: significant correlation between two variables.



**Figure 2** — The relationships between actual walking speed and  $\dot{V}O_2$  (a) or  $\dot{V}O_2/W$  (b).  $\dot{V}O_2$ : oxygen consumption, W: body weight. r: correlation coefficient by regression analysis with third-ordered equation.

and that the rate of men was significantly higher than that of women. After normalizing the effect of body weight, there was no difference on the  $VO_2/W$  and  $EE/W$  between gender groups when at rest. During exercise,  $VO_2/W$  and  $EE/W$  were higher in women than that of men with significant differences seen at the 30 and 35 m/min water walking, while there was no significant difference in the  $VO_2$  and  $EE$  at all walking speeds. The reason may be due to the effects of water resistance and buoyancy. In general,  $VO_2$  during land walking is higher in men than that of women. The reason is because men usually possess more body mass than women.  $VO_2/W$  has been shown to be similar between men and women (Bhambhani & Maikala, 2000; Kang et al., 2002). In water, both frontal resistance and turbulent drag give horizontal load, while buoyancy reduces vertical load to human body. The amount of water resistance varies, depending on the immersed area of walking subjects. In this study, the height of men was significantly higher than women participants, resulting in women being immersed to a greater degree than men when taking the constant pool depth (1.1 m) into account. Therefore, women had to generate relatively larger propulsive force than men did. The lower muscle power in women, compared with men, might have also affected the results (Kanehisa, Ikegawa, & Fukunaga, 1994; Komi & Karlsson, 1978). The relatively higher intensity in women than in men would also be expressed in the results of HR, METs and RPE. As an additional analysis, single correlation analysis was made between height and  $VO_2$ ,  $VO_2/W$ ,  $EE$  and  $EE/W$ . Table 2 showed the Pearson product-moment correlation coefficient in each comparison. This result suggests that the absolute intensity was not influenced by subject's height in 1.1 m pool depth though the relative intensity was influenced. Consequently, the results of this current study indicate that the absolute intensity was similar in men and women though the relative intensity was higher in women than men during WW. In addition, it was considered that the absolute intensity such as  $VO_2$  and  $EE$  had a greater influence from walking speed, rather than gender or body size during WW.

The correlation coefficients between the  $VO_2$  or  $VO_2/W$  and HR by the simple linear regression analysis were large ( $r = 0.64-0.74$ ) in this current study (Cohen, 1988). Masumoto et al. (2008) reported  $r = 0.80$  between the  $VO_2/W$  and HR in the water treadmill walking and  $r = 0.67$  on the land treadmill walking. Their simple regression equations were almost the same for both water and land walking. Takeshima et al. (1997) examined the relationship between the  $VO_2/W$  and HR in the WW with elderly people and showed the similar regression equation in the water ( $r = 0.76$ ) and land walking ( $r = 0.83$ ). In this study, the regression coefficients between men and women were similar. Therefore, the estimation for the  $VO_2$  and  $VO_2/W$  by HR during WW was reliable regardless of gender. The relationship between the  $VO_2$  or  $VO_2/W$  and actual walking speed with the third-ordered equation showed very high correlation values, which indicate that  $VO_2$  or  $VO_2/W$  estimation with the third-ordered equation by walking speed may be suitable for WW assessment. In addition, the regression coefficients between men and women were similar as well as  $VO_2$  or  $VO_2/W$  and HR relationships, the estimation for  $VO_2$  or  $VO_2/W$  by third-ordered actual walking speed were also reliable regardless of gender. Previous studies conducted regression analysis for estimating  $VO_2$  or  $VO_2/W$  by speed of WW using a second-ordered polynomial or exponential equation (Masumoto et al., 2008; Shono et al., 2000). However, the dimension of  $VO_2$  or  $VO_2/W$  is equivalent to  $EE$  and it should be expressed as the mechanical power.

Namely, the required power for the WW must be estimated by the third-ordered equation of walking speed. Future consecutive investigations are necessary for further developments of the estimation of energy consumption during WW. This may lead to greater beneficial effects from exercise prescriptions for rehabilitation and health-care program.

Ainsworth et al. (2000) reported the MET intensities for various activities. The authors indicated 4.0 METs for water aerobics and water calisthenics. There was no critical indication of MET intensities for WW. In this current study in the swimming pool, WW at 25 m/min (RPE = 9.1) created 2.8 METs, 3.6 METs at 30 m/min (RPE = 10.9), and 4.7 METs at 35 m/min (RPE = 12.8) on average. Caution should be paid to the differences between men and women during WW intensity. This study suggests MET references with RPE at some speeds of WW. The current study did not maintain uniform pool depth by each subject's height, which means the buoyancy and water resistance loadings are different between each subject. For the purpose of applying our results to those found in contemporary practices, our current study adopted common pool settings especially for typical pool depth. If the effect of the buoyancy and water resistance loadings is the same in each subject, a different result might be expected.

## Conclusion

This study investigated the metabolic responses during WW in young to elderly Japanese men and women. Results indicate exercise intensity is relatively higher ( $VO_2/W$ ,  $EE/W$ , HR METs and RPE) in women than men. The absolute intensity ( $VO_2$  and  $EE$ ) was similar between men and women. HR-  $VO_2$  or  $VO_2/W$  relationships were similar between men and women. The absolute intensity was influenced considerably by walking speed during WW. Therefore  $VO_2$  and  $VO_2/W$  may be used to estimate with third-order equation by actual walking speed. These relationships were similar between men and women.

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