J Exerc Nutr Biochem 2014;18(2):197-203
ISSN : 2233-6834 (Print) ISSN : 2233-6842 (Online)
http://dx.doi.org/10.5717/jenb.2014.18.2.197

ORIGINAL PAPER

The effects of landed and aquatic treadmill walking at moderate intensity on heart rate, energy expenditure and catecholamine

Kang Il Lim[1] and Soung Yob Rhi[2]*

[1]Institute of Exercise Physiology, School of Kinesiology, Yeungnam University, Gyeongsan, Korea
[2]Institute of Sports Science, Seoul National University, Seoul, Korea

(Received: 2014/04/17, Revised: 2014/05/12, Published online: 2014/06/02)

Kang Il Lim and Soung Yob Rhi. The effects of landed and aquatic treadmill walking at moderate intensity on heart rate, energy expenditure and catecholamine. *JENB*., Vol. 18, No. 2, pp.197-204, 2014 **[Purpose]** The present study was to examine whether or not the appropriate exercise intensity of water-walking could be accurately prescribed by land-based walking speed. **[Methods]** Using a crossover design, nine healthy male college students completed bouts of walking for thirty minutes at 100m/min, 50m/min, respectively, on land and water treadmills. Heart rate (HR), ratings of perceived exertion (RPE), energy expenditure, blood lactic acid and catecholamine concentration were measured. Two-way repeated measured ANOVA was used with the SPSS program for data analysis. **[Results]** HR ($P < 0.001$), RPE ($P < 0.001$), energy expenditure ($P < 0.001$), blood lactic acid ($P < 0.001$) and epinephrine concentration ($P < 0.05$) were significantly increased during walking both in water and on land. The change of HR was significantly lower at 50min/m in water than 100min/m on land ($P < 0.01$). There were no significant interaction effects for RPE, energy expenditure, blood lactic acid and catecholamine concentration, but these variables were slightly lower in water than on land. These results indicated that the use of land walking speed-based prescriptive norms would underestimate the physiological cost in water walking at the moderate intensity. **[Conclusion]** Therefore, approximately two-half of the speed would be needed to walk in water in order to obtain the same level of physiological load as during treadmill walking at the moderate intensity.
[Keywords] Aquatic walking, Heart rate, Energy expenditure, Catecholamine

INTRODUCTION

Aquatic exercise has excellent exercise effect and stability than any other sports on the ground because of the properties of water, such as water temperature, water pressure, buoyancy, and resistance [1], and especially, the buoyancy reduces the stress of gravity to the people whose musculoskeletal system is weak or the people having uncomfortable body, and improves the aerobic function and flexibility while reducing the impact and stress of musculoskeletal system by minimizing the pressure applied to waist, hip, knee, ankle joint and foot [2]. Thus, the aquatic exercise has been extensively utilized for the purpose of rehabilitation related to various sports injuries, including the disease prevention in terms of health care.

Recently, the previous studies related to most of the aquatic exercise have represented the interest in the effective aspect of exercises as a part of health, rehabilitation, treatment, and general conditioning exercise program of the general public [1,3,4], whereas, they have not presented the correct prescription criterion of aquatic exercises. Since the mid-1990s, the early studies have conducted the research for the respiratory circulation and metabolic response at the time of the exercise walking on the aquatic treadmill by the development of an aquatic treadmill equipment [5-9], but various physiological responses of the exercise intensity for the aquatic walking comparing with the landed treadmill walking exercise is not clearly known.

The aquatic treadmill running is just as effective as the landed treadmill running for the aerobic conditioning of healthy individuals [10]. Shono *et al.* [11] have suggested that the relationship between the heart rate obtained in the gradual walk test in the ground and maximal oxygen uptake (VO_2max) can be used to prescribe the exercise intensity of

---

* Corresponding author: Soung Yob Rhi, Tel. 82-32-611-7573, Fax 82-32-611-7573, Email. fltmdduq@naver.com

aquatic walking exercise, and also, the heart rate and Ratings of Perceived Exertion (RPE) have suggested as an effective indicator for the exercise prescription while the aquatic walking in the same way as the land-based walking [12]. On the other hand, recently, Phillips *et al.* [13] have suggested that as the results testing the gradual exercise load using the landed and aquatic treadmill targeting obese women, because the maximal physiological responses of the underwater running is different in comparison with the landed treadmill walking, the criteria of $\dot{V}O_2$max obtained from the landed treadmill is not recommended for the aquatic exercise inspection. Thus, the aquatic treadmill exercise has been typically used for aerobic training for rehabilitation period, but the evaluation for whether it can be brought the cardiorespiratory stress corresponding to the ground exercise is unclear. Migita *et al.* [14] have compared the reaction of circulation respiratory system of a middle-aged man during treadmill walking and flowmill walking. They have reported that the correlations between the heart rate and oxygen uptake at the time of two type of exercise walking are similarly appeared, and they have proposed that approximately twice speed is required in the general treadmill in order to obtain the identical level of the physiological effort. Also, in the study of Shono *et al*. [11, 12], they have set up the intensity of the walking exercises on the general treadmill of 40, 60, 80 m/min, and the aquatic treadmill of 20, 30, 40 m/min, using the same speed application principle. However, it is considered that the intensity of their general treadmill walking is slightly low for the effects of exercise capable obtaining by that actual general public conducts the aerobic exercise as a walking exercise of low intensity. In other words, if considering that the most appropriate walking speed is 50～100 m/min (1.9～3.7 mph) [15], the walking exercise applied by Shono *et al.* [11] belongs to the exercise of low intensity. In addition, according to the report of LeMasurier & Guy [16], ACSM recommends the walking of moderate intensity 80 m/min corresponding to 3.3 METs, and in the case of the U.S. public health and sanitation, the physical activity of moderate intensity of the brisk walking corresponding to 3.0-6.0 METs is recommended. Thus, in general, comparing and evaluating the speed of 50 m/min of the aquatic treadmill walking corresponding to 100 m/min which is the power walking speed of the moderate intensity on the landed treadmill should become an important consideration for the setting of the recommendation exercise intensity for water-walking. In other words, whether the application principle of the landed and aquatic walking speed proposed in previous studies is also applied at the same rate in a moderate-intensity speed as well as a low-intensity, also, whether their physiological reactions is identical in the moderate-intensity when applying the speed difference of 1/2 times, will enable the method approach for the prescription of aquatic walking exercise. In this study, the authors intend to evaluate the difference between the heart rate and RPE indicating the exercise intensity by applying the speed principle of water-walking proposed in previous studies, and to investigate the possibility of the prescription of exercise intensity based on the landed treadmill walking speed for the setting of intensity of the medium intensity-aquatic walking exercise by comparing the momentum through the stress index and the measurement of energy expenditure of blood lactic acid, and catecholamine, etc.

METHODS

Research object

The subjects of this study have not conducted a regular walking exercise for recent six months, but nine healthy male college students who have the basic physical strength were selected. They have not the cardiopulmonary dysfunction, and the medical conditions including special heart disease, and they agreed voluntary to participate in the experiment after hearing the purpose and description for the experiments. Their physical characteristics are the same as in Table 1.

Experimental method

In order to measure the subject's physical characteristics by the prior experiment, the body measurement and the body fat measurement were performed, and the maximum oxygen intake through the exercise test was measured. Unlike the landed treadmill, most of subjects who have not experienced the aquatic treadmill walking exercise have practiced the aquatic treadmill walking by twice, respectively, for adapting the underwater walking through the prior experiments. Each subject wears a swimming suit after arriving at H Institute of Sports Medicine, and carried out the aquatic treadmill walking exercise after taking a rest for 10 minutes to maintain the pulse rate in the stable state. The exercise performance order is determined by the design method for cross over study, and nine subjects are divided into A group (n = 5) and B group (n = 4) in order to exclude the effect of the measure-

Table 1. General characteristics of subjects

n	Age (yrs)	Height (cm)	Weight (kg)	Body fat (%)	$\dot{V}O_2$max (ml/kg/min)
9	23.2 ± 1.2	178.7 ± 4.8	73.8 ± 7.2	14.6 ± 4.6	43.7 ± 3.7

Values are mean ± SD.

ment sequence, and they carry out the Landed treadmill walking (LTW) and the Aquatic treadmill walking (ATW) while changing the measurement sequence at intervals of one week.

Exercise method

Experimental procedure and setting of exercise intensity

The land-based walking was performed on the general treadmill (Quinton, Sensormedics, USA). In general, the most appropriate walking speed is 50～100 m/min (1.9～3.7 mph), and because the power walking is the speed of 80～107.2 m/min [15,16], the protocol of the landed treadmill walking exercise in this study was performed for total 30 minutes at the speed of 100 m/min which is corresponded to the power walking of moderate intensity, and the gradient of the treadmill was fixed to 0%.

On the other hand, the water-walking was performed on the aquatic treadmill (Aquaciser II, Ferno Ille Co., Ltd., USA) capable of adjusting the belt speed up to 216 m/min (8 mph). Each subject was performed the walking at the speed of 50 m/min corresponded to 1/2 times of the landed treadmill speed for the same time as the landed treadmill. The shaking of the subject's arms was allowed in order to maintain balance during walking in water, and the gradient of the treadmill is 0%, and the depth of water was applied to bottom of each subject's the xiphoid process of the pit of the stomach side. According to previous studies, they have reported that the walking exercise at water temperature of 30℃ lays minimal burden on the heart, and the circulation ability become smooth, and the needed temperature control requirement for the heart regulatory is least. Thus, the water temperature was maintained at 30～31℃, and the temperature of laboratory was also maintained at 23～25℃.

Measurement items

In order to investigate the subject's physical characteristics, the percentage (%) of body fat was measured using a body composition analyzer (Inbody 3.0, Biospace, Korea), and the maximal oxygen uptake ($\dot{V}O_2max$) was measured to investigate their cardiopulmonary through the prior experiment.

$\dot{V}O_2$, $\dot{V}CO_2$, and the amount of ventilation (VE) were measured every 10 seconds by a portable gas analyzer (Vmax ST, Sensormedics, USA), and the heart rate was measured using a portable heart rate monitor (polar system, USA). RPE was measured every 5 minutes [18], and also the energy expenditure from the start time to end time of exercise was calculated using $\dot{V}O_2$ and R (respiratory exchange ratio). The energy expenditure was obtained by substituting the values of $\dot{V}O_2$ and R measured every 10 seconds during exercise into Weir formula [19] [energy expenditure $= \dot{V}O_2 \times (3.9 + 1.1 \times R)$ (kcal/min)].

Blood samples were collected for the concentration analysis of lactate and chatecholamine. The blood lactate concentration was measured by sampling the blood of 0.25ml every 5 minutes by a lactate analyzer (1500, YSI, USA). For the blood collection before and after exercise, the blood of 10ml, respectively, was collected from the forearm vein using a disposable syringe (Becton Dickinson VACUTAINER System) sterilized in vacuum, and the analysis of the plasma epinephrine and norepinephrine was performed by using HPLC-ECD (High-pressure liquid chromatography electochemical detector system).

Data processing

For all statistics processing, SPSS-PC (version 12.0) was used. The average and the standard deviation for the measurement value by each variable were calculated, and the two-way repeated measure analysis of variance (ANOVA) was used for the significance test for the difference by the exercise time (resting, 5 min., 10 min., 15 min., 20 min., 25 min., and 30 min.) between the walking types (landed treadmill vs aquatic treadmill), and the contrast test was performed for the significant difference verification between groups by each time. In particular, 2 × 2 repeated measure ANOVA for the catecholamine was performed in order to investigate the interaction between the walking type and the exercise time (pre vs post). The significance level of all statistical processing was investigated as $p < .05$.

RESULTS

Changes in heart rate

The change of heart rate by the aquatic and landed walking exercise for 30 minutes is equal as shown in Table 2. The statistically significance difference was also found in the interaction effect between time and group, as well as the main effect for time ($P < 0.001$) and the main effect for the group ($P < 0.05$). In other words, the heart rate was increased in both groups as the time is elapsed during 30 minutes walking exercise, but the higher change of heart rate in the landed walking group than the aquatic walking group was shown. Especially, as a result of the contrast test presented in Fig. 1, the difference by a time point for the time showed the

Table 2. The changes of HR, RPE, energy expenditure and blood lactic acid concentration during ATW and LTW

Variables	Group	Rest	5min	10min	15min	20min	25min	30min	*P*
HR (beat/min)	ATW	77.1 ± 4.6	96.0 ± 5.5	103.8 ± 6.2	107.8 ± 7.6	110.0 ± 7.0	113.0 ± 9.7	116.0 ± 11.6	a*** b* c**
	LTW	77.7 ± 4.4	108.7 ± 13.7	115.1 ± 15.2	121.7 ± 15.1	124.7 ± 15.3	128.1 ± 15.3	129.9 ± 15.8	
RPE	ATW	7.7 ± 0.1	8.8 ± 0.4	9.2 ± 0.7	10.1 ± 0.6	10.7 ± 0.5	11.3 ± 0.5	11.8 ± 0.4	a*** b*
	LTW	7.8 ± 0.2	9.2 ± 0.4	10.0 ± 0.7	11.0 ± 1.1	11.7 ± 1.1	12.1 ± 1.2	12.7 ± 0.9	
Energy expenditure (kcal)	ATW	14.5 ± 2.5	22.6 ± 4.6	48.1 ± 7.9	74.6 ± 12.6	101.9 ± 17.0	129.1 ± 21.8	158.6 ± 23.6	a***
	LTW	15.9 ± 1.8	27.0 ± 8.8	55.5 ± 13.8	84.9 ± 19.0	114.3 ± 23.6	144.9 ± 28.9	171.6 ± 32.2	
Blood lactate concentration (mmol)	ATW	1.11 ± 0.14	1.54 ± 0.36	2.02 ± 0.44	1.98 ± 0.34	1.47 ± 0.32	1.13 ± 0.19	0.98 ± 0.09	a*** b**
	LTW	1.29 ± 0.29	2.10 ± 0.63	2.58 ± 0.49	2.55 ± 0.71	1.92 ± 0.71	1.59 ± 0.85	1.36 ± 0.45	

Values are presented as mean ± SD.
*p < 0.05, **p < 0.01, ***p < 0.001, a: time, b: group, c: time × group.
HR: Heart rate, RPE: Rating of Perceived Exertion; ATW: aquatic treadmill walking, LTM: landed treadmill walking.

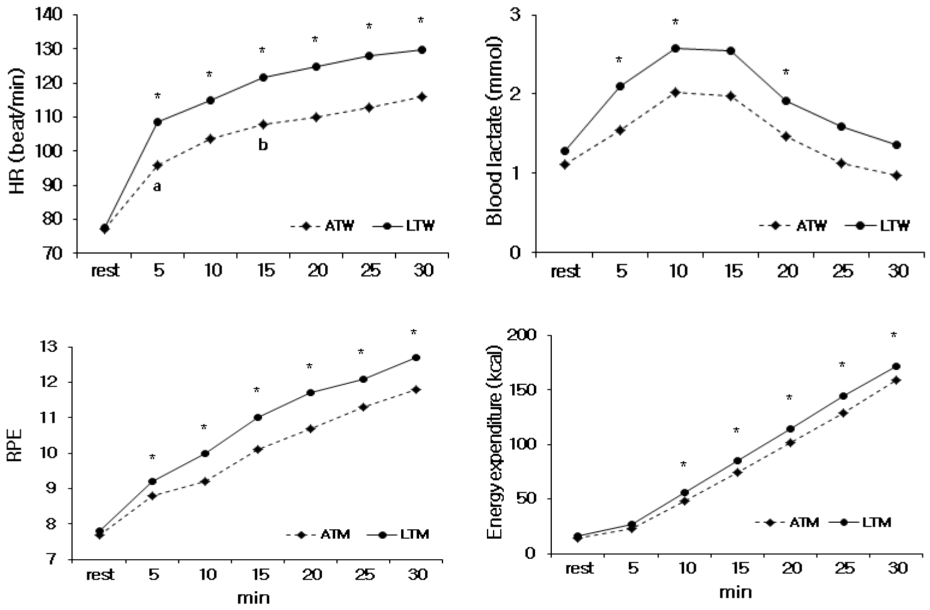

Fig 1. Contrast test on the changes of HR, RPE, energy expenditure and blood lactate concentration during ATW and LTW. $^{*}p < 0.05$ vs pre time (main effect for time); $^{a}p < 0.05$ vs rest (interaction effect for time and group); $^{b}p < 0.05$ vs 10minute (interaction effect for time and group); HR: heart rate; RPE: rating of perceived exertion; ATW: aquatic treadmill walking, LTM: landed treadmill walking

significance increase every 5 minutes, and the change of the heart rate between the resting vs 5 min. (P < 0.05), 10 min. vs 15 min. (P < 0.05) showed more rapid increase in the landed walking group than the aquatic walking group.

Change of RPE

The change of RPE for the aquatic and landed walking exercises showed the main effect (P < 0.001) of time and the main effect (P < 0.05) of group as shown in Table 2, but the interaction effect of time and group did not show statistically significance differences. It showed that the walking exercise for 30 minutes increases RPE irrespective of the type. Especially, it showed that the RPE of the landed walking was significantly higher in comparison with the aquatic walking, but the trend of change for time was not different. In addition, as a result of the contrast test as shown in Fig. 1, the difference by a time point about time showed the significance difference every 5 minutes in comparison with each previous time point (P < 0.001), but the difference of change between the groups considering the time did not show in any time point.

Changes in energy expenditure

As shown in Table 2, the change in the energy expenditure for the aquatic and landed walking exercise for 30 minutes did not show the main effect of group and the interaction effect between group and time, and only the main effect about time showed statistically significance difference ($P < 0.001$). As shown in Fig. 1, as a result of the contrast test by time point, it showed the significant increase every 5 minutes in comparison with each previous time point, respectively ($P < 0.001$), but it is considered that there is no difference of the energy expenditure by both walking exercise because the difference of the change between groups considering time did not also show in any time point.

Change in blood lactic acid concentration

The blood lactic acid concentration for the aquatic and landed walking exercise are the same as Table 2. It showed the main effect for time ($P < 0.001$) and the main effect for the group ($P < 0.001$), but the interaction effect between time and group did not show the significant difference. The blood lactic acid showed higher numerical value in the landed walking than the aquatic walking, but it showed that the trend of the change about time was not different. Especially, as a result of the contrast test by time point showed the significant increase between the resting vs 5 min. ($P < 0.001$), and 5 min. vs 10 min. ($P < 0.01$), but it showed the significant decrease between 15min. vs 20min. However, the significant difference of both walking exercise at these time points did not show.

Changes in blood catecholamine

The results performing the two-way repeated measure ANOVA for the change in the blood catecholamine before and after the aquatic and landed walking exercise for 30 minutes are equal as shown in Table 3. In the case of epinephrine, the main effect and the interaction effect between group and time did not show, and only the main effect about time showed statistically significant difference ($P < 0.05$). On the other hand, in the case of norepinephrine, the main effect of time and group as well as the interaction effect did not show. In the case of epinephrine, it showed the significant increase in post-exercise for 30 minutes regardless of the group, whereas, in the case of norepinephrine, there were the tendency of increase after the walking exercise of both groups, but statistically significant difference did not show.

Table 3. Changes in catecholamine before and immediately after each bout of ATW and LTW

Variables	Group	Pre	Post	*P*
Epinephrine (pg/ml)	ATW	48.5 ± 22.4	63.0 ± 28.9	a*
	LTW	53.1 ± 19.4	72.5 ± 28.3	
Norepinephrine (pg/ml)	ATW	466.9 ± 213.0	515.4 ± 335.4	NS
	LTW	434.4 ± 206.5	580.5 ± 245.7	

Values are presented as mean ± SD
$^*p < 0.05$, a: time, NS: not significant.
ATW: aquatic treadmill walking, LTW: landed treadmill walking

DISCUSSION

The present study has evaluated the exercise intensity and stress index at the time of the walking exercise of moderate intensity in the landed and aquatic treadmill by applying the speed principle of the aquatic treadmill walking exercise, and compared the momentum through the measurement of energy expenditure. As the result conducting the walking exercise for 30 minutes applying the speed of 50 m/min corresponded to 1/2 times of 100m/min which is the recommended speed of the landed walking in the aquatic walking speed, all variables showed the significant change according to the exercise time, and the change of the heart rate for the walking speed of two type showed the change of high heart rate during the landed walking in comparison with the aquatic walking by showing the significant interaction effect between groups. On the other hand, it showed that because the change in RPE did not show the significant difference between groups, the walking exercises of two types have the identical RPE. These results are shown that the application principle of 1/2 times speed determining the aquatic walking speed based on the landed walking speed is not matched in the change of the heart rate and RPE that evaluate the exercise intensity.

The heart rate and RPE are an important index that sets the exercise intensity and commonly used for the exercise prescription. It has been reported that the heart rate and VO_2, and the heart rate and RPE show the clear linear relationship according to the increase of speed during the aquatic walking like as the landed walking [5,11,12,14,20]. In addition, many studies have suggested that the heart rate and RPE are the effective criteria to prescribe the aquatic walking exercise [20,21]. In this study, it is considered that during the walking exercises of two types, the change in the heart rate unlike the change in RPE has the tendency somewhat underestimated upon application of 1/2 times speed ratio. Because the exercise intensity conducted in this study showed to correspond to 59%HRmax in the aquatic walking, and to 66%HRmax in the landed walking, it is considered that the exercise intensity corresponded to the same heart rate in the case that applies the speed of 50% or more in comparison with the landed walking will be possible.

In addition, the current result in comparison with the result of Shono *et al.* [20] reported that the aquatic treadmill walking of 50 m/min has corresponded to 75%HRmax, 5.2 MET, and

12~15 RPE represents lower exercise intensity as 59% (range, 51~65%) HRmax, and 11.8RPE. It has been known that this difference is influenced by various factors, such as the type of aquatic walking (treadmill vs. flowmill walking), water temperature, and water level [11], and it is shown that in particular, because both groups were not reached to 13 RPE which is the criteria of moderate intensity during the treadmill walking for 30 minutes, it is the results of the low intensity exercise. The power walking for 30 minutes of the landed treadmill of 100 m/min speed is the recommended speed of moderate intensity for the general adult, but because the young college students who are the subjects in this study have higher physical strength in comparison with the general adults, it is considered that is felt as relatively the exercise intensity of low intensity.

The buoyancy and resistance of water have an effect to make of relatively high energy consumption despite of little movement of the lower joints [1]. For this reason, the walking or jogging in water may be prescribed as the effective exercise to the subjects, such as the middle-aged, elderly person, and to the subjects who feel the burden for the weight bearing. The change in the energy expenditure compared in this study was not represented statistically the significant difference between the groups, but it showed that it is corresponded with the results of previous studies suggested that approximately the aquatic walking speed is corresponded to 1/2 times of the landed walking speed to obtain the same level of energy expenditure [12,14]. It is analyzed that in the case that increases the walking speed in water unlike the land, because the resistance effect of water becomes larger than the buoyancy by the body fat or the depth of water, it shows higher energy expenditure of about twice than the landed walking. Shono *et al.* [11] have described that the buoyancy has an effect that decreases a lot the energy expenditure than the resistance of water for the movement during low-intensity walking of 20m/min unlike the aquatic walking speed of 30m/min and 40m/min. Thus, it is considered that the aquatic walking of the moderate intensity conducting in this study unlike the aquatic walking of low-intensity shows the same energy expenditure if applying 1/2 times of the landed walking speed.

Shono *et al.* [20] have reported that during the aquatic walking of 50 m/min, it showed relatively high blood lactate concentration of 2.4 mmol/L in comparison with the period of rest and other low-intensity walking speed (20, 30, 40 m/min), and most of subjects are reached to the lactate threshold at the speed of 50 m/min. In this study, the blood lactic acid concentration of both groups showed the significant increase till 10 minutes after starting exercise and then showed the significance decrease after 15 minutes, and it represented the similar trend of change without the difference between groups. However, it is considered that because the blood lactate concentration in the aquatic and landed walking showed lower concentration than the previous study [20] showed 2.02 and 2.58 mmol/L, respectively, during the aquatic walking in comparison with the landed walking, it was not reached to the lactate threshold.

It has been known that the epinephrine and norepinephrine called the catecholamine hormones have increased secretion by the need, such as the increase of the heart rate during exercise and the demand increase for energy source. Fujishima and Shimizu [6] have reported that the underwater exercise in the various environment of the water temperature represents high numerical value of epinephrine in comparison with the landed exercise, and Shin [4] has reported that as the results conducting the landed and aquatic treadmill exercises for 60 minutes that are consisted of the walking for 30 minutes of moderate intensity level and jogging for 30 minutes based on the same heart rate, both epinephrine and norepinephrine showed the significant increase after exercising in the aquatic exercise group. It may be explained that in the case of exercise performing in water, it results from the reason that the energy expenditure caused by the loss of body heat by the resistance, conduction and convection of water than the exercise performing on the land is high.

In this study, the epinephrine showed the significant increase after two types of walking exercise, whereas, the norepinephrine showed the trend of increase, but statistically significant difference was not shown. In addition, the interaction effect between the groups according to time did not represent, and the same hormonal change against the speed application principle of 1/2 times was shown. Furthermore, it is considered that generally, the aquatic treadmill exercise shows lower numerical value than the landed treadmill exercise, and when considering that the correlation between the heart rate and these hormones is high, it is corresponded to the results of the aquatic treadmill that show the change in the relatively low heart rate in this study. In other words, it is considered that because the exercise intensity of the aquatic treadmill exercise is somewhat low, the change in these hormones also shows higher numerical value in the landed treadmill exercise.

If synthesizing above results, all variables, except for heart rate did not show the statistically significant difference between groups, but most of physiological indexes show high level in the landed treadmill walking exercise than the aquatic treadmill walking exercise. It is considered that if the speed of aquatic treadmill of moderate intensity is applied to 1/2 times of the landed treadmill speed, the aquatic walking exercise requires lower physiological needs than the landed treadmill walking exercise. However, in this study, because somewhat little subjects to explain the speed application principle of the aquatic treadmill walking exercise of the moderate intensity or more were used as materials, and also there is the limitation that the healthy young college students of the twenties were the subjects, a variety of subjects, that is, the protocol development of the water-walking exercise for the purpose of the health and rehabilitation of the middle-aged or elderly is essential.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2011-35C-G00267)

REFERENCES

[1] Kamioka H, Tsutani K, Mutoh Y, Okuizum H, Ohta M, Handa S, Okada S, Kitayuguchi J, Kamada M, Shiozawa N, Park SJ, Honda T, Moriyama S. A systematic review of nonrandomized controlled trials on the curative effects of aquatic exercise. *Int J Gen Med.* 2011;25(4):239-260.

[2] Long KA, Lee EJ, Swank SA. Effects of deep water exercise on aerobic capacity in older women. *MSSE.* 1996;28:S210.

[3] Koh JO. Analysis of Training effects on aqua exercise: A systematic review of evidence. *Journal of Korean Physical Education Association for Girls and Woman.* 2011;25(1):101-120 (in Korean with English abstract).

[4] Shin CH. The effects of aquatic and ground treadmill exercise on metabolism regulatory hormone in obese women. *Exercise Science.* 2005;14(3):439-446 (in Korean with English abstract).

[5] Evans BW, Cureton KJ, Purvis JW. Metabolic and circulatory responses to walking and jogging in water. *Res Q.* 1978;49(4):442-449.

[6] Fujishima K, Shimuzu T. Body temperature, oxygen uptake and heart rate during walking in water and on land at an exercise intensity based on RPE in elderly men. *J Physiol Anthropol Appl Human Sci.* 2003;22(2): 83-88.

[7] Kato T, Onsihi S, Kitagawa K. Physiological responses during underwater walking and running using underwater treadmill. *Research J Phys Educ Chukyo Univ.* 2002; 43:1-8 (in Japanese with English abstract).

[8] Migita T, Hotta N, Ogaki T, Kanaya S, Fujishima K, Masuda T. Comparison of the physiological responses to treadmill prolonged walking in water and on land. *Japan J Phys Educ.* 1996;40:316-323 (in Japanese with English abstract).

[9] Shimizu T, Kosaka M, Fujishima K. Human thermoregulatory responses during prolonged walking in water at 25, 30, and 35℃. *Eur J Appl Physiol.* 1998;78:473-478.

[10] Silvers WM, Rutledge ER, Dolny DG. Peak cardiorespiratory responses during aquatic and land treadmill exercise. *Med Sci Sports Exerc.* 2007;39(6):969-75.

[11] Shono T, Fujishima K, Hotta N, Ogaki T, Masumoto K. Cardiorespiratory response to low-intensity walking in water and on land in elderly women. *J Physiol Anthropol.* 2001;20:269-274.

[12] Shono T, Fujishima K, Hotta N, Ogaki T, Masumoto K. Physiological responses to water-walking in middle aged women. *J Physiol Anthropol.* 2001;20:(2):119-123.

[13] Phillips VK, Legge M, Jones LM. Maximal physiological responses between aquatic and land exercise in overweight women. *Med Sci Sports Exerc.* 2008;40(5):959-64.

[14] Migita T, Muraoka Y, Hotta N, Ogaki T, Kanaya S, Fujishima K, Masuda T. Cardiorespiratory responses during water and land walking. *Kurume Journal of Health & Physical Education.* 1994;2:25-30 (in Japanese with English abstract).

[15] American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and prescription(7th Ed).* 2006; Baltimore: Williams & Wilins.

[16] LeMasurier, Guy C. Walk which way? *ACSM's Health & Fitness Journal.* 2004;8:7-10.

[17] Tomihiro S, Mitsuo K, Kazutaka F. Human thermoregulatory response during prolonged walking in water at 25, 30, 35℃. *Eur J Appl Physio.* 1998;78:473-478.

[18] Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med.* 1970;2:92-98.

[19] Weir, JB. New methods for calculating metabolic rate with special reference to protein metabolism. *J Physiol.* 1949;109:1-9.

[20] Shono T, Fujishima K, Hotta N, Ogaki T, Ueda T, Otoki K, Teramoto K, Shimizu T. Physiological responses and RPE during underwater treadmill walking in women of middle and advanced age. *J Physiol Anthropol.* 2000;19: 195-200.

[21] Kruel LF, Beilke DD, Kanitz AC, Alberton CL, Antunes AH, Pantoja PD, da Silva EM, Pinto SS. Cardiorespiratory responses to stationary running in water and on land. *J Sports Sci Med.* 2013;12(3):594-600.