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Original Article

The effects of weekly exercise time on VO_{2max} and resting metabolic rate in normal adults

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Abstract. [Purpose] The present study examined the effect of individual weekly exercise time on resting metabolic rate and VO_{2max} (maximal oxygen uptake), which are important components of individual health indexes. [Subjects and Methods] Thirty healthy adults participated in this study. Questionnaires were used to divide the participants into groups based on average weekly walking. Resting metabolic rate was measured using a respiratory gas analyzer. Graded exercise tests were conducted using a treadmill, and the modified Bruce protocol was used as an exercise test method. [Results] VO_{2max}, anaerobic threshold, and resting metabolic rate were significantly different among the groups. [Conclusion] Average weekly exercise time affected VO_{2max}, resting metabolic rate, and anaerobic threshold, all of which are indicators of individual physical ability and health. These values increased as the individual amount of exercise increased. In addition, VO_{2max}, resting metabolic rate, and anaerobic threshold were found to be closely correlated. These findings were consistent with the results of similar previous studies.

Key words: Exercise, Resting metabolic rate, Maximal oxygen uptake

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INTRODUCTION

In the development of nutritional and physical activity interventions, understanding resting metabolic rate (RMR) is important to identify the absolute daily energy requirement and achieve desirable energy consumption[1)]. RMR provides energy necessary to maintain body functions at rest and accounts for 60–80% of total energy expenditure[2)]. An imbalance of energy intake and expenditure leads to weight gain or loss in the long term[3)].

Physical exercise improves health by improving cardiorespiratory fitness, body composition, and psychosocial well-being. In addition, physical exercise is an important tool in the prevention and treatment of obesity[4–6)]. Physical exercise improves body composition and metabolic activity, thereby reducing excess weight and related comorbidities[7–11)].

VO_{2max} measures the maximal oxygen consumption during exercise to the point of exhaustion of physical strength and is one of the best methods of predicting cardiorespiratory endurance and aerobic preparation. The amount of energy needed by individuals is associated with body mass, and VO_{2max} is associated with body weight. Regular aerobic physical activities increase VO_{2max} and indirectly reduce the effects of many diseases[12)]. The respiratory system plays an important role in providing the energy required by different body systems for metabolism. Therefore, the respiratory system is greatly affected by short- and long-term exercise. Owing to its important role in physical activities, the respiratory system is studied by many researchers[13)]. The level of cardiorespiratory fitness varies with the condition of the respiratory, cardiovascular, and musculoskeletal systems, and its evaluation is important because of its relationship to health and wellness. Poor cardiorespiratory fitness increases the rate of all causes of premature death, and especially that due to cardiovascular diseases. Improvement in cardiorespiratory fitness is associated with reduced premature death rates due to all causes[14, 15)].

Many previous studies examined changes in RMR and VO_{2max} after intervention with defined exercise for a certain period of time[16–19)]. In addition, studies have compared RMR and VO_{2max} for habitual physical activities, regularly performed types

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of exercise, and different fitness levels. Gilliat-Wimbery et al.[20] studied differences in RMR and VO_{2max} between the two groups with different habitual physical activities, and Toth et al.[21] studied differences in RMR and VO_{2max} among three groups with different types of regularly performed exercise. In addition, McCargar et al. compared the levels of VO_{2max} for different fitness levels[22]. However, studies that subdivide individuals by amount of exercise at normal times are lacking.

Therefore, the present study intended to examine the effects of individual weekly exercise time on RMR and VO_{2max}, which are important components of individual health indexes. This study can be helpful in preventing and treating health problems using subdivided exercise programs customized for individuals.

SUBJECTS AND METHODS

Thirty healthy adult male and female subjects between the ages of 20 and 60 who satisfied the following selection criteria were studied: without cardiopulmonary, metabolic, or musculoskeletal disorders; not pregnant; not taking any mood-altering medications or other drugs, including anti-inflammatory drugs, antihistamines, pain medications, antidepressants, or beta-blockers[23]; not athletes; had not participated in similar studies; understood the purpose of the study, and agreed to participate . All participants were informed about the potential risks and experimental design and provided informed consent for participation, with the knowledge that they could withdraw at any time. The Ethics Committee of Namseoul University in Korea also approved the study. The IRB approval number is Research-NSU-1041479-201511-HR-010. The general characteristics of the study subjects are shown in Table 1.

The study subjects were divided into three groups through questionnaire-based surveys. The frequency of walking at moderate or high intensity[24] of exercise awareness (12 or more on the Borg scale) at normal times, and the duration of exercise per session were surveyed. The subjects were divided into Group A, who did not perform any walking exercise at all per week, Group B, who performed walking for less than 200 minutes per week, and Group C, who performed walking for 200 minutes or more per week.

A body composition analyzer (InBody720, Biospace, South Korea) was used, and general characteristics including age, height, weight, body mass index (BMI), fat free mass (FFM), muscle mass, skeletal muscle mass, and obesity indexes such as visceral fat area (VFA) and waist-hip ratio (WHR) were recorded.

RMR was measured using a respiratory gas analyzer (Quark b2, COSMED, Italy). All subjects were prohibited from performing exercise for four hours before measurement of RMR between 10:00 AM and 4:00 PM. RMR was measured in supine subjects for 31 minutes after a five-minute rest[25].

Graded exercise tests were conducted using a 12-channel electrocardiogram scanner (CASE 6.0, GE, USA), respiratory gas analyzer (Quark b2, COSMED, Italy), and automatic blood pressure (BP) and pulse measuring instrument (Tango, SunTech Medical, USA) on a treadmill (T2100, GE, USA) under supervision by a researcher and safety guard. The modified Bruce protocol was used as an exercise test method[26]. Subjects were instructed to stop exercise in one or more of the following situations: heart rate (HR) did not increase with exercise intensity; respiratory exchange ratio was 1.15 or higher; exercise awareness (Borg scale) was 17 or higher; HR was 90% or higher than age-predicted maximum (220 minusage); or O_2 uptake did not increase with exercise intensity[27].

Along with VO_{2max}, exercise ability indexes were measured, including hemodynamic indexes such as BP and HR at the time of maximum exercise, the ventilatory equivalent for O_2 (VE/VO_2), the ventilatory equivalent for carbon dioxide (VE/VCO_2), and the physiological dead space/tidal volume ratio (VD/VT). In addition, respiratory indexes, such as breathing reserve (BR), and metabolic indexes, such as anaerobic threshold (AT) and maximum O_2 pulse, were measured.

To analyze the data in this study, statistics program SPSS 18.0 for windows was used. For general characteristics of this study, frequency analysis, means, and standard deviations were calculated. To compare differences between the groups in headache and stiffness changes, one-way analysis of variance was performed, and Tukey's post-hoc test was conducted. In addition, to examine differences in headache and stiffness before and after each intervention, a paired t-test was conducted. The statistical significance level was set at $\alpha=0.05$.

Table 1. General characteristics of the study subjects

	Group A (n=25) Mean±SD	Group B (n=15) Mean±SD	Group C (n=17) Mean±SD
Gender (male/female)	12/13	6/9	7/10
Age (years)	41.2±13.1	40.2±12.4	42.3±12.7
Height (cm)	164.1±7.2	162.9±8.0	165.7±6.9
Weight (kg)	64.1±12.1	62.7±11.7	63.4±14.2

Values are Mean ±SD. $p<0.05$.

RESULTS

The results of graded exercise tests of the three groups are shown in Table 2. Significant differences in VO_{2max} and AT were found among the three groups ($p<0.05$). However, the remaining indexes did not show any statistically significant differences ($p>0.05$). The results for the RMR and obesity indexes of the three groups are shown in Table 3. RMR was significantly different among the three groups ($p<0.05$).

DISCUSSION

The present study examined the effects of normal weekly exercise time on VO_{2max} and RMR in adults. VO_{2max} and RMR were significantly different among the three groups divided by weekly exercise at normal times.

Similar results were shown in previous studies. Gilliat-Wimberly et al. studied healthy female subjects aged 35–50 years who were divided into groups performing physical activity for at least nine hours per week or for approximately one hour per week[20)]. The RMR of the group performing activity for at least nine hours was significantly higher than that of the group performing physical activity for approximately one hour. In a study by Toth et al., individuals aged 36–59 years were divided into three groups based on types of exercise: a resistance-trained group, an aerobic-trained group, and an untrained group. The RMR and VO_{2max} of the groups were measured[21)]. The aerobic-trained group showed significantly higher RMR than the untrained group and higher RMR values than the resistance-trained group, although the differences were not significant. In addition, the aerobic-trained group showed significantly higher VO_{2max} than the untrained and resistance-trained groups. In a

Table 2. Graded exercise test

Variables	Group A	Group B	Group C
Max. HR (beats/min)	158.6±24.8	159.4±25.4	148.0±24.7
Max. syst. BP (mmHg)	182.0±48.6	182.4±28.2	188.6±24.8
Max. diast. BP (mmHg)	83.0±21.9	87.0±14.1	91.2±16.2
VE/VO_2 (L/min)	46.8±7.5	45.7±7.0	45.6±6.4
VE/VCO_2 (L/min)	37.6±5.1	39.0±5.4	36.1±5.0
VD (ml)	323.5±107.7	376.7±107.7	390.0±118.0
VD/VT	0.214±0.029	0.225±0.043	0.210±0.037
BR (max. VE/MVV, %)	88.0±3.5	87.8±2.6	88.6±3.5
VO_{2max} (ml/min)*	1,735.4±467.5$^{1<2,3}$	2,113.0±443.6	2,445.1±616.6
AT (%)*	61.9±21.0$^{1<3}$	82.6±29.9	92.4±38.6
O_2pulse (ml/beat)	13.0±4.4	15.9±7.3	22.2±20.9

Values are Mean±SD, *$p<0.05$, [1]Group A did not perform any walking exercise at all per week, [2]Group B performed walking for less than 200 minutes per week, [3]Group C performed walking for 200 minutes or more per week, Max. HR=maximum heart rate, Max. syst. BP: maximum systolic blood pressure, Max. diast. BP: maximum diastolic blood pressure, VE/VO_2: VE for O_2, VE/VCO_2: VE for CO_2, VD: physiological dead space, VD/VT: physiological dead space/tidal volume ratio, BR: breathing reverse (maximum exercise ventilation/maximal voluntary ventilation), VO_{2max}: maximal oxygen uptake, AT: anaerobic threshold (%, O_2 uptake at AT/peak O_2 uptake), O_2 pulse: peak O_2 pulse (VO_2/HR)

Table 3. Results for RMR and obesity indexes

Variables	Group A	Group B	Group C
RMR (l/min)*	1,083.3±267.8$^{1<3}$	1,314±394.0	1,420.2±244.0
BMI (kg/m^2)	22.3±2.1	23.18±2.9	24.6±2.9
FFM (kg)	45.9±9.3	49.8±8.8	53.6±9.7
Muscle mass (kg)	43.3±8.9	47.0±8.5	50.6±9.3
Skeletal muscle mass (kg)	25.3±5.8	27.6±5.4	30.0±6.0
VFA (cm^2)	75.4±36.7	93.0±44.4	89.6±26.8
WHR	0.8±0.0	0.8±0.0	0.9±0.0

Values are Mean±SD, *$p<0.05$, [1]Group A did not perform any walking exercise at all per week, [2]Group B performed walking for less than 200 minutes per week, [3]Group C performed walking for 200 minutes or more per week, RMR: resting metabolic rate, BMI: body mass index, FFM: fat free mass, VFA: visceral fat area, WHR: waist-hip ratio study by McCargar et al., overweight women aged 25–49 years were divided into groups with above or below average fitness levels by using a 1-mile timed walking test[22]. The VO_{2max} of the group with below average fitness levels was statistically significantly lower than the group with above average levels. Therefore, exercise duration and type at normal times and fitness levels have positive effects on VO_{2max} and RMR.

Shim et al. reported that when individuals aged 55 years or older underwent muscle strength training once per week for eight weeks, RMR significantly increased from weeks 4–5[16]. Askarabadi et al. reported that when male subjects aged 35–45 were divided into a fat group and a normal group and performed aerobic exercise three times per week for eight weeks, both groups showed statistically significant increases in VO_{2max}[17]. Moreover, Rezaimanesh et al. reported that when university student athletes were divided into an aerobic swimming group and an anaerobic swimming group and swam intermittently at least three times per week for six weeks, both groups showed statistically significant increases in VO_{2max}[18]. In a study by Osei-Tutu et al., individuals were divided into two groups and walked five times per week for eight weeks; both the group that walked for 30 minutes continuously per day and the group that walked for 10 minutes three times per day showed statistically significant increases in VO_{2max}[19]. The subjects in the present study showed differences in VO_{2max} and RMR for different amounts of exercise at normal times. The above studies show that diverse exercises that are performed consistently will positively affect VO_{2max} and RMR.

In the present study, not only VO_{2max} and RMR but also AT were significantly different among the three groups. AT is a direct indicator of aerobic capacity[28] and is widely used in setting the intensity of aerobic training of healthy subjects[29] and individuals with chronic diseases (e.g., coronary heart disease[30], hypertension[31], or obesity[32]). Aerobic training increases both VO_{2max} and AT. A study by Farrel et al.[33] reported that long-distance running was associated with both VO_{2max} and AT. Previous studies showed that AT is proportional to exercise ability. Group C in the present study is thought to have shown higher AT values compared with the other groups because Group C performed larger amounts of exercise at normal times.

In the present study, weekly exercise at normal times affected VO_{2max}, RMR, and AT, all of which are indicators of individual physical abilities and health, and these three values increased with the amount of exercise. In addition, VO_{2max}, RMR, and AT are considered to be closely related, consistent with the results of previous studies. The results of the present study should be helpful for the development of exercise programs to enhance individual physical abilities.

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