

The effects of strenuous exercises on resting heart rate, blood pressure, and maximal oxygen uptake

Deuk-Ja Oh¹, Hyeon-Ok Hong², Bo-Ae Lee^{1,*}

¹Department of Physical Education, College of Education, Pusan National University, Busan, Korea

²Department of Social Sports, Dong Eui Institute of Technology, Busan, Korea

The purpose of this study is to investigate the effects of strenuous exercises on resting heart rate, blood pressure, and maximal oxygen uptake. To achieve the purpose of the study, a total of 30 subjects were selected, including 15 people who performed continued regular exercises and 15 people as the control group. With regard to data processing, the IBM SPSS Statistics ver. 21.0 was used to calculate the mean and standard deviation. The difference of mean change between groups was verified through an independent *t*-test. As a result, there were signifi-

cant differences in resting heart rate, maximal heart rate, maximal systolic blood pressure, and maximal oxygen uptake. However, the maximal systolic blood pressure was found to be an exercise-induced high blood pressure. Thus, it is thought that a risk diagnosis for it through a regular exercise stress test is necessary.

Keywords: Resting heart rate, Blood pressure, Maximal oxygen uptake, Strenuous exercises


INTRODUCTION

As average life expectancy increases in modern society because of the development of civilization and medical technology, health care in the middle ages is on the rise as the primary countermeasure to be healthy while in old age. During the middle ages, it is easy to be exposed to chronic adult diseases because of a sedentary lifestyle and reduced physical activities. In these adult diseases, regular exercises improve blood lipid, control insulin resistance, reduce cardiovascular risk factors (Gremeaux et al., 2012), and lower the incidence of cardiovascular diseases and mortality (Mora et al., 2007; Scherr et al., 2011).

Among aerobic exercises, marathon is in the limelight as a sport that people can enjoy easily at various places and community. Moreover, this sport enables citizens to have harmony and fraternity. Also, as a means of maintaining and promoting one's health, a number of the middle-aged people participate in marathons.

As such, marathons require a much stronger mentality and fit-

ness than any other endurance and aerobic sports. However, if middle-aged people participate in this strenuous exercise, cardiovascular risks or rupture of coronary artery plaques may be increased, which is a sudden death risk (Burke et al., 1999; Hart, 2013). Looking at the cause of sudden death resulting from exercise, hypertrophic cardiomyopathy or ischemic cardiovascular disease were reported (Marijon et al., 2015; Taylor, 2014). Hypertrophic cardiomyopathy is characterized by electrocardiogram, which shows left ventricular hypertrophy (Maron and Pelliccia, 2006). Acquisition of this disease is very rare, and the cause of sudden death found in middle-aged people is coronary artery disease. The risk of unexpected death due to strenuous exercises is 5 to 7 times higher than moderate-intensity exercise (Noakes, 1987). In the study by Claessens et al. (1999), ventricular arrhythmia was found to be higher in the group of athletes doing maximal exercise than in ordinary people. It is also reported that the expression of electrocardiography and echocardiography would particularly raise the risk of sudden death. Therefore, it is thought that it is important for subjects in their middle ages who participate in high-in-

*Corresponding author: Bo-Ae Lee  <http://orcid.org/0000-0002-2805-3943>
Department of Physical Education, College of Education, Pusan National University, 63 Geumang-ro 321beon-gil, Geumjeong-gu, Busan 46241, Korea
Tel: +82-51-510-2701, Fax: +82-51-515-1991, E-mail: balee2240@naver.com
Received: November 29, 2015 / Accepted: February 2, 2016

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

tensity exercise to receive periodic exercise stress tests in order to identify their risk degree of cardiovascular diseases. However, these factors have been mostly evaluated in young elite athletes in Korea, and studies conducted on middle-aged people are very insufficient. In addition, with regard to the study method, it was not the value divided by body mass index (BMI) but the absolute values presented that led to errors in the result values. Therefore, the purpose of this study is to analyze cardiovascular factors in middle-aged subjects who have been joining marathons for a long time in order to investigate the positive and negative factors of strenuous exercises.

MATERIALS AND METHODS

Subject

Subjects were all healthy volunteers who had marathon exercise experiences for 5 yr or more with a frequency of 3 times a week, 1 hr and 30 min of exercise time, and 13–15 of RPE (ratings of perceived exertion) as the exercise intensity. People who had cardiovascular diseases and other diseases that might affect the heart were excluded from this study. The general characteristics of subjects are described in Table 1.

Measurement items and methods

Measurement items

In this study, body compositions (weight, body fat percentage, and BMI) and echocardiography (cardiac structure and function) were measured and analyzed.

Measurement method

The body compositions (weight, body fat percentage, and BMI) were measured using the body composition analyzer (In Body 370, Biospace, Seoul, Korea). Subjects were measured while wearing simple clothing without metals, such as earrings, rings, etc., and after a controlled food intake on the examination date and a 30-min rest before the measurement.

Table 1. General characteristics of subjects

Characteristic	Marathon (n=15)	Control (n=15)
Age (yr)	49.27 ± 3.41	48.07 ± 4.49
Weight (kg)	69.26 ± 5.32	71.42 ± 9.62
Height (cm)	169.63 ± 4.67	171.8 ± 5.36
Body mass index (kg/m ²)	24.043 ± 1.07	24.13 ± 2.34
Body fat percentage	14.563 ± 1.86	23.13 ± 2.34

Values are presented as mean ± standard deviation.

The treadmill exercise stress test (Q4500, Quinton Instruments Co., Boston, MA, USA) by Bruce Protocol was conducted. The subjects were asked to finish meals 5 hr before the test, and the test was performed after they rested for 30 min after they arrived at the laboratory. The maximum exercise duration (ED) was set as the time heart rate does not increase anymore and by 17 or more in the Borg Scale. The resting heart rate and blood pressure during exercise were measured with a mercury sphygmomanometer. Through the exercise stress test, maximal oxygen uptake (VO₂max), myocardial oxygen uptake, and the maximal exercise time were recorded.

Data processing

The mean and standard deviation of all measured items were calculated using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA), and they were analyzed using an independent sample *t*-test to verify the difference of means between groups. The statistical significance level was set as $\alpha = 0.05$.

RESULTS

Effects of marathon on cardiovascular factors were analyzed (Table 2). When analyzing the difference of resting heart rate and maximal heart rate, it was found that there was a statistically sig-

Table 2. Result of analysis of effects of marathon adaptation on cardiovascular factors

Cardiovascular factor	Group	Mean ± SD	t-test	P-value
RHR	Marathon	58.80 ± 4.38	-5.929	0.001**
	Control	74.47 ± 9.24		
MHR	Marathon	169.67 ± 12.43	-2.472	0.040*
	Control	178.33 ± 5.46		
RSBP	Marathon	124.67 ± 7.83	-0.908	0.570
	Control	126.93 ± 5.66		
RDBP	Marathon	79.53 ± 2.80	-5.669	0.058
	Control	87.20 ± 4.42		
MSBP	Marathon	219.53 ± 29.31	4.112	0.000***
	Control	185.20 ± 13.65		
MDBP	Marathon	78.60 ± 10.64	2.415	0.093
	Control	70.80 ± 6.56		
VO ₂ max	Marathon	53.10 ± 5.08	7.865	0.002***
	Control	39.56 ± 4.30		
ED	Marathon	862.87 ± 66.48	11.981	0.974
	Control	576.93 ± 64.21		

P* < 0.05. *P* < 0.01. ****P* < 0.001.

SD, standard deviation; RHR, resting heart rate; MHR, maximal heart rate; RSBP, resting systolic blood pressure; RDBP, resting diastolic blood pressure; MSBP, maximal systolic blood pressure; MDBP, maximal diastolic blood pressure; VO₂max, maximal oxygen uptake; ED, exercise duration.

nificant difference ($P < 0.01$ and $P < 0.05$) between groups. In terms of differences of resting systolic blood pressure and resting diastolic blood pressure, there was no statistically significant difference.

Then, in the result of verifying the maximal systolic blood pressure differences, there was a statistically significant difference ($P < 0.001$) between groups, whereas there was no statistically significant difference in the result of maximal diastolic blood pressure difference. Finally, when analyzing the difference of VO_2max , it was found that there was a statistically significant difference ($P < 0.001$) between groups. With regard to ED, no statistically significant difference was found.

DISCUSSION

The purpose of this study is to analyze the cardiovascular factors in exercise stress tests, including body compositions of middle-aged people following the adaptation of marathons to investigate the positive and negative factors of strenuous exercises.

A marathon is known as a typical aerobic exercise. If an aerobic exercise is performed for a long time, it will affect the parasympathetic nerve, thus increasing stroke volume and lowering the resting heart rate, which has a positive effect on reducing cardiovascular diseases (Riebe et al., 2015). In the study by Mont et al. (2009), people who did long-term regular training showed bradycardia in frequent stability, while the mechanism of resting bradycardia was reported to be influenced by the acceleration of the parasympathetic nervous system activity of the heart. In this study, bradycardia phenomenon ($< 60/\text{min}$), which occur in athletes, was found in the marathon group. All these results can be seen as the effects of aerobic exercise. Also a positive effect that can be expected in aerobic exercise effects is a resting blood pressure. Although the phenomenon of blood pressure decrease due to exercise has not clearly investigated up to now due to their complex mechanism, the improvement of peripheral vessel resistance is the most important role in mechanism to reduce blood pressure (Guimarães et al., 2010). The mechanism in which exercises have effect on blood pressure is different depending on exercise intensity, time, and exercise types, but it is known that blood pressure is decreased due to decreased activity of sympathetic nervous system and decreased peripheral resistance (Cavalcante et al., 2007). According to Chobanian et al. (2003), it is reported that, as a positive effect of exercises, hypotensive effect due to exercises is about 4–9 mmHg. In this study, the resting blood pressure of all subjects was in relatively normal range, but the resting diastolic

blood pressure was significantly lower than that in the control group, which indicates that there was a positive factor of the aerobic exercise effect. However, in maximal exercise, systolic blood pressure was shown as an exercise-induced high blood pressure in the marathon group. Looking at the definition of exercise-induced high blood pressure, it shows a normal range, but the systolic blood pressure increased by more than 210 mmHg in maximal exercise (Lauer et al., 1992). This exercise-induced high blood pressure has 5–10 times higher rates to shift to high blood pressure in a future stability (Singh et al., 1999), and it is also an independent risk factor for cardiovascular and cerebrovascular diseases (Kurl et al., 2001; Tzemos et al., 2015). Exercise-induced high blood pressure is related to endothelial dysfunction, because the resistance of peripheral blood vessel is high (Stewart et al., 2004). Vlachopoulos et al. (2010) reported that a significantly high arterial stiffness was found in marathon players who perform chronic strenuous exercises compared to those who have sedentary lifestyles. In other words, in normal blood pressure reaction during exercise, smooth extension of the peripheral blood vessel no longer increases the blood pressure as cardiac output increases, but in subjects with exercise-induced high blood pressure, blood pressure is excessively increased during exercise because of an extension disorder of the peripheral blood vessel (Wilson et al., 1990). Although it was not measured in this study, the relationship between blood pressure and arterial stiffness of subjects who participate in strenuous exercises, such as marathon, needs to be followed up in further studies. Aerobic exercise is the most important in cardiovascular factors, and the factor that has a positive effect on them is maximal oxygen intake. This factor is the criterion that shows cardiopulmonary fitness in athletes, but it is an important index in the evaluation of patients with cardiovascular diseases and other patients (Fletcher et al., 1995). In this study, it was found that the marathon group had higher cardiopulmonary fitness than the control group. In other words, long-term aerobic exercise improves cardiopulmonary fitness, reported among the middle-aged marathon groups, while the cycling and body building groups showed the highest VO_2max , but in this study, triathlon, marathon, and cycle groups showed similar cardiopulmonary fitness. In other words, in the triathlon group that does comprehensive aerobic exercise, higher cardiopulmonary fitness was expected, but it was found that high cardiopulmonary fitness is only maintained with one concentrated aerobic exercise. Among them, as swimming was higher than the control group but lower than the triathlon and marathon groups, it is thought to be more effective to add running exercise in order to maintain higher cardio-

pulmonary fitness. Also, it is very important to increase the VO_2max through aerobic exercise in patients with cardiovascular diseases in clinical situations. The value dividing the VO_2max by 3.5 mL/kg/min is called 1 MET (metabolic equivalents), and the increase of 1 MET reduces fatal cardiac death by 28%–51%, and nonfatal cardiac death by 17%–29% (Laukkanen et al., 2004). Also, it is known that total survival rate increases by 12% with every increase of 1 MET (Myers et al., 2002). In addition to the VO_2max , the ED of the marathon group, which shows exercise adherence, was found to have a numerically higher tendency than the control group, but it was not statistically significant. Therefore, marathon—which increases VO_2max and endurance—would be seen as relatively good, and if it is applied to patients, jogging would seem to be an effective exercise.

In this study, when investigating the effects of strenuous exercise on resting heart rate, blood pressure and VO_2max , there were significant differences in resting heart rate, maximal heart rate, maximal systolic blood pressure, and VO_2max .

However, as exercise-induced high blood pressure occurs in the maximal systolic blood pressure, the risk should be diagnosed through an exercise stress test. To endure continuous and strong pressure, it is thought that reinforced exercise in the form of resistance that may strengthen heart muscle need to be recommended.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

This research was supported by a 2-Year Research Grant for Free Research Project from Pusan National University.

REFERENCES

- Burke AP, Farb A, Malcom GT, Liang Y, Smialek JE, Virmani R. Plaque rupture and sudden death related to exertion in men with coronary artery disease. *JAMA* 1999;281:921-926.
- Cavalcante MA, Bombig MT, Luna Filho B, Carvalho AC, Paola AA, Póvoa R. Quality of life of hypertensive patients treated at an outpatient clinic. *Arq Bras Cardiol* 2007;89:245-250.
- Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, Jones DW, Materson BJ, Oparil S, Wright JT Jr, Roccella EJ; National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA* 2003;289:2560-2572.
- Claessens P, Claessens C, Claessens M, Bloemen H, Verbanck M, Fagard R. Ventricular premature beats in triathletes: still a physiological phenomenon? *Cardiology* 1999;92:28-38.
- Fletcher GF, Balady G, Froelicher VF, Hartley LH, Haskell WL, Pollock ML. Exercise standards. A statement for healthcare professionals from the American Heart Association. Writing Group. *Circulation* 1995;91:580-615.
- Guimarães GV, Ciolac EG, Carvalho VO, D'Avila VM, Bortolotto LA, Bocchi EA. Effects of continuous vs. interval exercise training on blood pressure and arterial stiffness in treated hypertension. *Hypertens Res* 2010;33:627-632.
- Gremeaux V, Gayda M, Lepers R, Sosner P, Juneau M, Nigam A. Exercise and longevity. *Maturitas* 2012;73:312-317.
- Hart L. Marathon-related cardiac arrest. *Clin J Sport Med* 2013;23:409-410.
- Kurl S, Laukkanen JA, Rauramaa R, Lakka TA, Sivenius J, Salonen JT. Systolic blood pressure response to exercise stress test and risk of stroke. *Stroke* 2001;32:2036-2041.
- Lauer MS, Levy D, Anderson KM, Plehn JF. Is there a relationship between exercise systolic blood pressure response and left ventricular mass? The Framingham Heart Study. *Ann Intern Med* 1992;116:203-210.
- Laukkanen JA, Kurl S, Salonen R, Rauramaa R, Salonen JT. The predictive value of cardiorespiratory fitness for cardiovascular events in men with various risk profiles: a prospective population-based cohort study. *Eur Heart J* 2004;25:1428-1437.
- Marijon E, Uy-Evanado A, Reinier K, Teodorescu C, Narayanan K, Jouven X, Gunson K, Jui J, Chugh SS. Sudden cardiac arrest during sports activity in middle age. *Circulation* 2015;131:1384-1391.
- Maron BJ, Pelliccia A. The heart of trained athletes: cardiac remodeling and the risks of sports, including sudden death. *Circulation* 2006;114:1633-1644.
- Mont L, Elosua R, Brugada J. Endurance sport practice as a risk factor for atrial fibrillation and atrial flutter. *Europace* 2009;11:11-17.
- Mora S, Cook N, Buring JE, Ridker PM, Lee IM. Physical activity and reduced risk of cardiovascular events: potential mediating mechanisms. *Circulation* 2007;116:2110-2118.
- Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. *N Engl J Med* 2002;346:793-801.
- Noakes TD. Heart disease in marathon runners: a review. *Med Sci Sports*

- Exerc 1987;19:187-194.
- Riebe D, Franklin BA, Thompson PD, Garber CE, Whitfield GP, Magal M, Pescatello LS. Updating ACSM's recommendations for exercise preparticipation health screening. *Med Sci Sports Exerc* 2015;47:2473-2479.
- Scherr J, Braun S, Schuster T, Hartmann C, Moehlenkamp S, Wolfarth B, Pressler A, Halle M. 72-h kinetics of high-sensitive troponin T and inflammatory markers after marathon. *Med Sci Sports Exerc* 2011;43:1819-1827.
- Singh JP, Larson MG, Manolio TA, O'Donnell CJ, Lauer M, Evans JC, Levy D. Blood pressure response during treadmill testing as a risk factor for new-onset hypertension. The Framingham heart study. *Circulation* 1999;99:1831-1836.
- Stewart KJ, Sung J, Silber HA, Fleg JL, Kelemen MD, Turner KL, Bacher AC, Dobrosielski DA, DeRegis JR, Shapiro EP, Ouyang P. Exaggerated exercise blood pressure is related to impaired endothelial vasodilator function. *Am J Hypertens* 2004;17:314-320.
- Taylor J. Sudden cardiac death in young competitive athletes. *Eur Heart J* 2014;35:3081.
- Tzemos N, Lim PO, Mackenzie IS, MacDonald TM. Exaggerated exercise blood pressure response and future cardiovascular disease. *J Clin Hypertens (Greenwich)* 2015;17:837-844.
- Vlachopoulos C, Kardara D, Anastasakis A, Baou K, Terentes-Printzios D, Tousoulis D, Stefanadis C. Arterial stiffness and wave reflections in marathon runners. *Am J Hypertens* 2010;23:974-979.
- Wilson MF, Sung BH, Pincomb GA, Lovallo WR. Exaggerated pressure response to exercise in men at risk for systemic hypertension. *Am J Cardiol* 1990;66:731-736.