



Original Article

## Association between non-obesity and health state among young Japanese male university students

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**Abstract.** [Purpose] The obesity rate in both males and females has been lower in Japan than in other countries. However, the prevalence of metabolic syndrome-related risk factors is not low when compared with that in Western countries. In this study, we aimed to evaluate the health state of young, non-obese adults in Japan. [Participants and Methods] We recruited 20 young, non-obese Japanese male university students and examined the maximum oxygen consumption, physical activity, and components of metabolic syndrome. We evaluated the physical activity level and dietary habits of the participants through a questionnaire survey. [Results] The questionnaire survey revealed that 70% participants had non-standard dietary habits, 55% did not engage in any regular exercise, and 25% were inactive. On examination, 20% participants had at least one positive risk factor for metabolic syndrome. The homeostatic model assessment of insulin resistance and triglyceride values did not correlate with the body mass index of the participants; however, the values were inversely related to the maximum oxygen consumption levels. [Conclusion] Even participants with normal body mass index had poor dietary habits and a lack of exercise. Our results confirmed that even non-obese Japanese individuals have certain health risks and that having higher maximum oxygen consumption has beneficial effects in preventing the risk factors of severe and life-threatening diseases.

**Key words:** Metabolic syndrome, Oxygen uptake, Non-obese

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### INTRODUCTION

It is common knowledge that obesity is associated with a much greater risk of developing serious health conditions, including heart disease and /or type 2 diabetes<sup>1-5)</sup>. For this reason, most people tend to think that a non-obese condition is healthier than an obese one. However, it cannot be definitively said that a standard body shape expresses a healthy lifestyle as weight loss is simply a matter of eating at a calorie deficit, which can be achieved even through regular consumption of an unhealthy diet devoid of nutrition. According to the Organization for Economic Co-operation and Development survey among the member countries, the obesity rate is the lowest for both males and females in Japan<sup>6)</sup>. However, it has been shown that some young Japanese people tend to manage their weight through dieting alone, without concern for exercise or minding nutrition<sup>7-9)</sup>. There is a trend among young Japanese people to be more concerned with their appearance than overall health. That is because most young adults simply believe that they will be healthy at a current normal weight, as long as they do not feel any ill physical effects of their condition at the present.

Even though the prevalence of overweight and obesity in Japan is much lower than in Western countries, the condition known as metabolic syndrome is not<sup>10-13)</sup>. Therefore, the question arises of whether young Japanese adults at a normal body mass index (BMI) are truly healthy. It should be noted that metabolic syndrome is highly prevalent among middle-aged and

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older populations. The prevention rate of severe diseases such as cardiovascular disease and type 2 diabetes is improved if certain changes in activity and diet are encouraged during the early periods of life.

The purpose of this study is to evaluate the health condition of young, non-obese university students in Japan. Furthermore, the results of this study will demonstrate the importance of preventive care to non-obese Japanese university students.

## PARTICIPANTS AND METHODS

Male university students (n=22) from the Department of Rehabilitation Medicine at the university were recruited for the study. None had taken any medications, had any medical issues, or had any dietary restrictions during the past year. Furthermore, the participants did not make any lifestyle adjustments during the study. All participants provided written informed consent and the University Medical Research Committee has approved the study protocol (NO. 2010C0012).

Weight, height, waist circumference, and blood pressure were measured in all participants. Each participant's BMI was calculated by dividing the weight (kg) by the square of the height (m<sup>2</sup>). We categorized obesity in accordance with the Japan Society for the Study of Obesity as a BMI of 25 and above.

Blood samples were obtained following an overnight fast. Level of fasting blood glucose, triglyceride, high-density-lipoprotein cholesterol (HDL-cholesterol) and low-density-lipoprotein cholesterol were measured. In addition, HbA1c, and serum fasting insulin levels were also obtained. The homeostasis model assessment of insulin resistance (HOMA) value was calculated using the following formula:

$$[\text{fasting insulin (mIU/ml)} \times \text{fasting blood glucose (mg/dl)}] / 405^{14}.$$

A definition of metabolic syndrome was according to the Japanese national guidelines<sup>15, 16</sup>. Metabolic syndrome is defined as the presence of central adiposity (waist circumference of  $\geq 85$  cm for men and  $\geq 90$  cm for women) plus 2 or more of the following 3 criteria: 1) high triglyceride ( $\geq 150$  mg/dl or on drug treatment) or low HDL-cholesterol ( $< 40$  mg/dl or on drug treatment); 2) high blood pressure ( $\geq 130$  mmHg systolic or  $\geq 85$  mmHg diastolic or on drug treatment); 3) high fasting glucose ( $\geq 110$  mg/dl or on drug treatment).

A self-reported questionnaire was used for data collection and analysis. All participants gave information in said questionnaire on smoking status, dietary habits and physical activity. This questionnaire was compiled under the supervision of the Health Service Bureau, Ministry of Health, Labour and Welfare in Japan. Regarding their physical activity level, participants were asked "over the past year, have you engaged in exercise causing slight sweating for over 30 minutes per day, at least twice a week?" and "have you walked over one hour daily or any equivalent activities?". Response categories included "no" and "yes"; when both answers were "no", a person was categorized as physically inactive.

Daily physical activity was measured using an electronic physical activity monitor (Active Tracer 301, GMS, Tokyo, Japan). The characteristics of the device were as follows:  $9 \times 6 \times 4$ -mm size,  $\pm 3$ -V power supply, 0–500-Hz frequency response, and  $\pm 2$ -g detection range. The acceleration sensors, a band-pass filter (0.3–100 Hz), and a battery were mounted in an electrical circuit and placed in a plastic box of  $7.0 \times 5.0 \times 1.5$  cm in size with a 40-kilobyte memory. The box was equipped with an RS232C port to transport the accelerations in the x-, y-, and z-directions to an external computer. The device, which had a total weight of 65 g, was used to detect acceleration changes and count frequencies that exceeded threshold values. In this study, we assumed acceleration changes of 0.05 G, 0.3 G, and 0.5 G as threshold values and recorded the accumulated data for more than 24 hours. After the measurements were obtained, all data was analyzed using computer software.

A progressive maximum oxygen consumption (VO<sub>2</sub>max) test was performed to determine aerobic capacity in the laboratory (ambient temperature,  $25 \pm 0.5^\circ\text{C}$ ; relative humidity, 60%) using an electronically braked cycle ergometer. Oxygen consumption and carbon dioxide production were measured using a gas analyzer (ARCO-2000, Arco System Inc., Chiba, Japan) with a breath-by-breath analysis of expired gases during the test. Calibration of the gas analysis system was performed before the first test using reference gases and room air and was reconfirmed before each test. After a 3-minute rest on the cycle ergometer, exercise was started at 30 W for a 3-minute warm up, and the workload was subsequently increased by 30 W every one minute. The test was terminated when the participants reached physical exhaustion. The following criteria indicated VO<sub>2</sub>max had been attained: 1) a plateau or slight drop in VO<sub>2</sub> despite an increase in workload; 2) exhaustion; 3) a respiratory exchange ratio above 1.1; and 4) a heart rate above 95% of the predicted maximal heart rate<sup>17, 18</sup>. Heart rate was continuously monitored using telemetry electrocardiogram equipment.

Statistical analyses were performed using SPSS for Windows, version 20 (SPSS Inc., Chicago, IL, USA). All results were expressed as the mean  $\pm$  standard deviation. Spearman's correlation analyses were used to analyze the relationships between blood parameter and anthropometric measure. A p value less than 0.05 was considered statistically significant.

## RESULTS

The characteristics of the participants and clinical metabolic parameters are presented in Table 1. All participants (n=22) completed the study without complications. During the initial examination, two obese subjects with a BMI greater than 25 were excluded from this study. Their blood test results showed values far more extreme than those of other participants,

**Table 1.** Participant characteristics and metabolic parameters

	Non-obesity (n=20)	Obesity (n=2)
Age (years)	20.8 ± 0.5	20.0 ± 0
Height (cm)	172.4 ± 4.4	172.3 ± 14.6
Weight (kg)	61.6 ± 5.0	100.2 ± 40.7
BMI (kg/m <sup>2</sup> )	20.7 ± 1.4	33.0 ± 8.1
%BF (%)	16.1 ± 2.8	29.1 ± 10.2
WC (cm)	73.8 ± 3.2	104.8 ± 26.5
Systolic blood pressure (mmHg)	111.7 ± 8.9	137.0 ± 2.8
Diastolic blood pressure (mmHg)	69.5 ± 8.3	84.5 ± 3.5
HDL (mg/dl)	53.1 ± 11.0	41.0 ± 4.2
LDL (mg/dl)	93.2 ± 22.2	109 ± 4.2
Triglycerides (mg/dl)	62.5 ± 17.0	81.0 ± 28.3
Fasting glucose (mg/dl)	89.1 ± 6.1	89.0 ± 4.2
Fasting insulin (μU/ml)	4.35 ± 15.3	16.4 ± 14.9
HbA1c	4.6 ± 0.5	4.7 ± 0
HOMA	1.0 ± 0.5	3.7 ± 3.5
VO <sub>2</sub> max (ml/kg/min)	48.0 ± 12.3	30.6 ± 3.9

Values are expressed as mean ± SD. BMI: body mass index; %BF: percentage body fat; WC: waist circumference; HDL: high-density lipoprotein cholesterol; LDL: low-density lipoprotein cholesterol; HOMA: homeostatic model assessment of insulin resistance; VO<sub>2</sub>max: maximum oxygen consumption.

**Table 2.** Relationship between blood parameter and anthropometry

	BMI	%BF	WC	SBP	DBP	HDL	TG	HbA1c	HOMA	HR	VO <sub>2</sub> max
%BF	0.346										
WC	0.513*	0.38									
SBP	0.355	-0.13	0.29								
DBP	0.075	-0.39	0.04	0.39							
HDL	-0.05	-0.10	-0.21	-0.09	0.16						
LDL	-0.28	0.1	0.07	-0.09	-0.15	-0.10					
TG	-0.16	-0.40	-0.34	-0.09	-0.04	-0.40					
FBG	-0.06	0.11	-0.10	-0.33	-0.11	0.66	-0.18				
HbA1c	0.11	0.26	0.07	-0.05	-0.005	-0.17	0.18				
HOMA	0.02	0.27	-0.23	-0.20	-0.48*	-0.20	0.29	0.35			
HR	0.93	-0.32	0.12	0.53*	0.27	0.05	0.29	0.14	-0.01		
VO <sub>2</sub> max	-0.00	0.05	0.37	0.11	-0.01	0.22	-0.57*	-0.22	-0.47*	-0.04	
DPA	0.1	0.41	0.24	-0.32	-0.32	-0.26	-0.25	-0.01	0.11	-0.72*	0.04

BMI: body mass index; %BF: percentage body fat; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; HDL: high-density lipoprotein cholesterol; TG: triglyceride; FBG: fasting blood glucose; HOMA: homeostatic model assessment of insulin resistance; HR: resting heart rate; VO<sub>2</sub>max: maximum oxygen consumption; DPA: daily physical activity.

HOMA and triglyceride values were inversely related to VO<sub>2</sub>max levels. Spearman's correlation analyses were used to analyze the relationships between blood test and anthropometric measure. \* Correlation is significant at the 0.05 level (2-tailed).

especially in terms of the much higher HOMA values. (Table 1). The clinical data from all the other participants were subsequently analyzed (n=20, Table 1).

The results from the questionnaire revealed that 95% of the subjects were non-drinkers and non-smokers. Additionally, 75% had poor dietary habits, such as eating snacks often, going without breakfast, or eating supper within 2 hours of going to bed. 55% did not exercise during the past year. Furthermore, 30% of participants had not walked for more than one hour in a single 24-hour period or participated in any equivalent activities. The prevalence of physical inactivity among participants was 25%, with 35% having a slower-than-normal gait speed. Only one participant (5%) reported insufficient sleep.

At examination, no one was defined as having metabolic syndrome among the non-obese subjects. However, two participants (10%) were indicated as having at least one positive risk factor of metabolic syndrome at low HDL-cholesterol levels, while fasting blood glucose and HbA1c levels were within normal glucose tolerance ranges. The HOMA values of two participants (10%) without a family history of diabetes were greater than or equal to 1.6. HOMA and triglyceride values did not correlate with either BMI or waist circumference, but both values were inversely related to VO<sub>2</sub>max levels (r=-0.57, -0.47, p<0.05, respectively, Table 2). There were no significant correlations between the level of daily physical activity and VO<sub>2</sub>max level, waist circumference, or HOMA values. A significant relationship, however, was found between daily physical activity and resting heart rate (Table 2).

## DISCUSSION

This study investigated the health state among young, non-obese Japanese university students. In said participants, no one was defined as metabolic syndrome. However, our results confirmed that even non-obese Japanese were at risk to health issues, and that having a higher  $VO_2\text{max}$  had more beneficial effects for the prevention of risk factors of severe and life-threatening diseases. This study suggested that poor physical fitness is associated with the development of type 2 diabetes and/or abnormal cholesterol, and that maintaining a high  $VO_2\text{max}$  for young, non-obese Japanese is more effective than having a normal BMI in prevention of risk factors. Obesity in itself was of course shown to be associated with significant problems as well. According to the test results of the two excluded obese participants, their HOMA values indicated that they had already developed insulin resistance despite their young age (Table 1).

It was said that young Japanese adults tend to be fixated on weight issues but do not give sufficient attention to their diet and physical activity<sup>7-9</sup>). The result of the questionnaire in this study made it clear that even among young Japanese who were maintaining proper BMI, they experienced issues of improper dietary habits and poor physical activity. Eating behavior such as a fast eating speed, binge eating, skipping breakfast and frequent snacking are considered to be unhealthy dietary habits linked to obesity and metabolic syndrome<sup>19-22</sup>). Moreover, it is well known that physical inactivity increases the risk of many adverse health conditions<sup>23-25</sup>). It must be noted, however, that our participants were learning about medicine in order to become physical therapists. Thus, there is an inherent bias in the recruitment of medical students as they have significant knowledge of the link between physical inactivity and improper dietary habits and a multitude of negative health outcomes. However, 70% of subjects had non-standard dietary habits, and 55% did not engage in any regular exercise. Furthermore, prevalence of physical inactivity even among medical students was 25%. Thus, it follows that a normal BMI does not necessarily indicate a healthy lifestyle in young Japanese adults. We can therefore conclude that in addition to offering and providing new knowledge about adequate exercise and healthy lifestyles, we should also be encouraging their application.

A group analysis revealed that HOMA values did not correlate with either BMI or waist circumference, which are central factors of obesity. However, HOMA values were inversely related to  $VO_2\text{max}$  levels ( $r=-0.47$ ,  $p<0.05$ ), meaning that increased insulin resistance is associated with decreased  $VO_2\text{max}$ . These results suggest that in young, non-obese Japanese adults, it is better to focus on aerobic capacity to improve insulin resistance rather than on either BMI or waist circumference. In addition, triglyceride values were also inversely related to  $VO_2\text{max}$  levels ( $r=-0.57$   $p<0.05$ ) without correlating with BMI and waist circumference. It is physiologically plausible that HOMA and triglyceride values are inversely related to  $VO_2\text{max}$  levels because  $VO_2\text{max}$  is influenced by the percentage of skeletal muscle mass. The relationship between  $VO_2\text{max}$  and skeletal muscle mass is quite clear; that is,  $VO_2\text{max}$  is positively associated with muscle mass<sup>26-28</sup>). Since skeletal muscle mass influences exercise performance and uses large amounts of glucose and triglyceride<sup>29-32</sup>), those with a greater  $VO_2\text{max}$  level have increased insulin action and fat burning capability. Therefore, it is important to maintain a high-level aerobic capacity to reduce the risk of severe disease. The present result demonstrated that the subjects with a greater  $VO_2\text{max}$  showed a greater insulin action and decreased triglyceride. This finding emphasizes the need for young, non-obese Japanese to perform in sufficient physical activity for maintaining or improving  $VO_2\text{max}$  with regard to health benefits.

According to this study's findings, daily physical activities, which were measured using an electronic physical activity monitor, are inversely related to resting heart rate (Table 2), suggesting that daily physical activity is likely to benefit health. Generally, the resting stroke volume of an endurance trained athlete is greater than that of an untrained individual because of a strengthened and hypertrophied cardiac muscle in the athlete, which leads to more blood being returned to the heart<sup>33-35</sup>). Since increased stroke volume is nullified by a lower resting heart rate, it results in keeping equal cardiac output<sup>36-39</sup>). Thus, a lower heart rate at rest implies more efficient heart function and better cardiovascular fitness. The result in this study suggested that daily physical activity was important to cardiac function, and may help prevent a decline in cardiac function that occurs over time.

As was expected, the results of the blood tests among young, non-obese Japanese showed a lower risk of developing a life-threatening disease. However, in spite of this, 20% are still indicated as having a positive risk factor. What is significant in this study is that all participants are very young individuals with a normal BMI. It should be noted that the HOMA values for two participants were high ( $\geq 1.6$ ) and they had developed insulin resistance (though there was no family history of diabetes), and that two other participants also indicated one positive risk factor for metabolic syndrome at low HDL cholesterol levels. The Framingham Offspring Study<sup>40</sup>) reported that all metabolic syndrome components were significant predictors of developing metabolic syndrome in the presence of other components. The components of metabolic syndrome do not suddenly emerge, but develop over time, leading to risks of cardiovascular disease and total mortality. In brief, the presence of only one risk factor can be associated with a significant increase in risk of developing diseases. Moreover, the prevalence of overweight and obesity increased among middle aged Japanese<sup>41</sup>). Therefore, we must note that some participants in this present study already have positive risk factors, despite the sample size. It is crucial to understand that preventive measures should be implemented early, including enhancing aerobic activity, dietary education, and increased blood testing and examinations relating to exercise ability.

In conclusions, young, non-obese Japanese tended to have poor dietary habits and a low level of physical fitness, suggesting that young, non-obese Japanese should be encouraged to increase their physical activity and develop healthy dietary

habits to reduce the risk of developing heart disease and /or type 2 diabetes.

Several limitations of this study should be acknowledged. First, the sample size is relatively small. Moreover, all subjects were university students from the Department of Rehabilitation Medicine. For these reasons, the findings in this study cannot necessarily be generalized to the broader Japanese population. Future studies may benefit from a larger sample size as well as a more homogenous study cohort.

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None of the authors have any conflict of interest.

## REFERENCES

- 1) Yang F, Wang G, Wang Z, et al.: Visceral adiposity index may be a surrogate marker for the assessment of the effects of obesity on arterial stiffness. *PLoS One*, 2014, 9: e104365. [Medline] [CrossRef]
- 2) Després JP, Lemieux I, Bergeron J, et al.: Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. *Arterioscler Thromb Vasc Biol*, 2008, 28: 1039–1049. [Medline] [CrossRef]
- 3) Whitlock G, Lewington S, Sherliker P, et al. Prospective Studies Collaboration: Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet*, 2009, 373: 1083–1096. [Medline] [CrossRef]
- 4) Bhurosy T, Jeewon R: Overweight and obesity epidemic in developing countries: a problem with diet, physical activity, or socioeconomic status? *Sci World J*, 2014, 2014: 964236. [Medline] [CrossRef]
- 5) WHO Expert Consultation: Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet*, 2004, 363: 157–163. [Medline] [CrossRef]
- 6) Organisation for Economic Co-operation and Development: OECD obesity update 2017. <https://www.oecd.org/els/health-systems/Obesity-Update-2017.pdf>. (Accessed December 1, 2018).
- 7) Wakui S, Shimomitsu T, Odagiri Y, et al.: Relation of the stages of change for exercise behaviors, self-efficacy, decisional-balance, and diet-related psycho-behavioral factors in young Japanese women. *J Sports Med Phys Fitness*, 2002, 42: 224–232. [Medline]
- 8) Sakamaki R, Amamoto R, Mochida Y, et al.: A comparative study of food habits and body shape perception of university students in Japan and Korea. *Nutr J*, 2005, 4: 31. [Medline] [CrossRef]
- 9) Sano A, Le DS, Tran MH, et al.: Study on factors of body image in Japanese and Vietnamese adolescents. *J Nutr Sci Vitaminol (Tokyo)*, 2008, 54: 169–175. [Medline] [CrossRef]
- 10) Yanagisawa N: The future of occupational and general health in Japan. *Ind Health*, 2016, 54: 191–193. [Medline] [CrossRef]
- 11) Arai H, Yamamoto A, Matsuzawa Y, et al.: Prevalence of metabolic syndrome in the general Japanese population in 2000. *J Atheroscler Thromb*, 2006, 13: 202–208. [Medline] [CrossRef]
- 12) Schwingel A, Nakata Y, Ito LS, et al.: A comparison of the prevalence of the metabolic syndrome and its components among native Japanese and Japanese Brazilians residing in Japan and Brazil. *Eur J Cardiovasc Prev Rehabil*, 2007, 14: 508–514. [Medline] [CrossRef]
- 13) Falkner B, Cossrow ND: Prevalence of metabolic syndrome and obesity-associated hypertension in the racial ethnic minorities of the United States. *Curr Hypertens Rep*, 2014, 16: 449. [Medline] [CrossRef]
- 14) Radziuk J: Homeostatic model assessment and insulin sensitivity/resistance. *Diabetes*, 2014, 63: 1850–1854. [Medline] [CrossRef]
- 15) Helgerud J, Høydal K, Wang E, et al.: Aerobic high-intensity intervals improve VO<sub>2</sub>max more than moderate training. *Med Sci Sports Exerc*, 2007, 39: 665–671. [Medline] [CrossRef]
- 16) Doi Y, Ninomiya T, Hata J, et al.: Proposed criteria for metabolic syndrome in Japanese based on prospective evidence: the Hisayama study. *Stroke*, 2009, 40: 1187–1194. [Medline] [CrossRef]
- 17) Mier CM, Alexander RP, Mageean AL: Achievement of VO<sub>2</sub>max criteria during a continuous graded exercise test and a verification stage performed by college athletes. *J Strength Cond Res*, 2012, 26: 2648–2654. [Medline] [CrossRef]
- 18) Lucía A, Rabadán M, Hoyos J, et al.: Frequency of the VO<sub>2</sub>max plateau phenomenon in world-class cyclists. *Int J Sports Med*, 2006, 27: 984–992. [Medline] [CrossRef]
- 19) Horikawa C, Kodama S, Yachi Y, et al.: Skipping breakfast and prevalence of overweight and obesity in Asian and Pacific regions: a meta-analysis. *Prev Med*, 2011, 53: 260–267. [Medline] [CrossRef]
- 20) Odegaard AO, Jacobs DR Jr, Steffen LM, et al.: Breakfast frequency and development of metabolic risk. *Diabetes Care*, 2013, 36: 3100–3106. [Medline] [Cross-Ref]
- 21) Soga Y, Shirai C, Ijichi A: [Association between daily lifestyle and the risk of metabolic syndrome among young adults in Japan. An analysis of Kobe city young adult health examination data]. *Nippon Koshu Eisei Zasshi*, 2013, 60: 98–106 (in Japanese). [Medline]
- 22) Sonoda C, Fukuda H, Kitamura M, et al.: Associations among obesity, eating speed, and oral health. *Obes Facts*, 2018, 11: 165–175. [Medline] [CrossRef]
- 23) U.S. Department of Health & Human Services: Physical Activity Guidelines Advisory Committee report. 2008. <http://www.health.gov/paguidelines/> (Accessed Dec. 1, 2018)
- 24) Warburton DE, Charlesworth S, Ivey A, et al.: A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *Int J Behav Nutr Phys Act*, 2010, 7: 39. [Medline] [CrossRef]
- 25) World Health Organization: Global recommendations on physical activity for health. Geneva, Switzerland: WHO; 2010. <https://www.who.int/dietphysicalactivity/global-PA-recs-2010.pdf>. (Accessed Dec. 20, 2018)
- 26) Kim CH, Wheatley CM, Behnia M, et al.: The effect of aging on relationships between lean body mass and VO<sub>2</sub>max in rowers. *PLoS One*, 2016, 11: e0160275. [Medline] [CrossRef]

- 27) Bassett DR Jr, Howley ET: Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Sports Exerc*, 2000, 32: 70–84. [[Medline](#)] [[CrossRef](#)]
- 28) Coyle EF: Integration of the physiological factors determining endurance performance ability. *Exerc Sport Sci Rev*, 1995, 23: 25–63. [[Medline](#)] [[CrossRef](#)]
- 29) Abdul-Ghani MA, DeFronzo RA: Pathogenesis of insulin resistance in skeletal muscle. *J Biomed Biotechnol*, 2010, 2010: 476279. [[Medline](#)] [[CrossRef](#)]
- 30) Jordy AB, Kiens B: Regulation of exercise-induced lipid metabolism in skeletal muscle. *Exp Physiol*, 2014, 99: 1586–1592. [[Medline](#)] [[CrossRef](#)]
- 31) Hargreaves M: Skeletal muscle metabolism during exercise in humans. *Clin Exp Pharmacol Physiol*, 2000, 27: 225–228. [[Medline](#)] [[CrossRef](#)]
- 32) Holloszy JO, Kohrt WM, Hansen PA: The regulation of carbohydrate and fat metabolism during and after exercise. *Front Biosci*, 1998, 3: D1011–D1027. [[Medline](#)] [[CrossRef](#)]
- 33) Vella CA, Robergs RA: A review of the stroke volume response to upright exercise in healthy subjects. *Br J Sports Med*, 2005, 39: 190–195. [[Medline](#)] [[CrossRef](#)]
- 34) Fagard R: Athlete's heart. *Heart*, 2003, 89: 1455–1461. [[Medline](#)] [[CrossRef](#)]
- 35) Fletcher GF, Ades PA, Kligfield P, et al. American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology, Council on Nutrition, Physical Activity and Metabolism, Council on Cardiovascular and Stroke Nursing, and Council on Epidemiology and Prevention: Exercise standards for testing and training: a scientific statement from the American Heart Association. *Circulation*, 2013, 128: 873–934. [[Medline](#)] [[CrossRef](#)]
- 36) Hwang SK, Kim DW, Ko SK, et al.: Changes of cardiac output during treadmill exercise by impedance cardiography. *Yonsei Med J*, 1991, 32: 58–63. [[Medline](#)] [[CrossRef](#)]
- 37) Maron BJ, Pelliccia A: The heart of trained athletes: cardiac remodeling and the risks of sports, including sudden death. *Circulation*, 2006, 114: 1633–1644. [[Medline](#)] [[CrossRef](#)]
- 38) Fox K, Borer JS, Camm AJ, et al. Heart Rate Working Group: Resting heart rate in cardiovascular disease. *J Am Coll Cardiol*, 2007, 50: 823–830. [[Medline](#)] [[CrossRef](#)]
- 39) Whelton SP, Blankstein R, Al-Mallah MH, et al.: Association of resting heart rate with carotid and aortic arterial stiffness: multi-ethnic study of atherosclerosis. *Hypertension*, 2013, 62: 477–484. [[Medline](#)] [[CrossRef](#)]
- 40) Franco OH, Massaro JM, Civil J, et al.: Trajectories of entering the metabolic syndrome: the framingham heart study. *Circulation*, 2009, 120: 1943–1950. [[Medline](#)] [[CrossRef](#)]
- 41) Matsushita Y, Takahashi Y, Mizoue T, et al. JPHC Study Group: Overweight and obesity trends among Japanese adults: a 10-year follow-up of the JPHC Study. *Int J Obes*, 2008, 32: 1861–1867. [[Medline](#)] [[CrossRef](#)]