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ORIGINAL PAPER

Accuracy of predicted resting metabolic rate and relationship between resting metabolic rate and cardiorespiratory fitness in obese men

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[Purpose] The purpose of this study is to examine that not only the relationship of the resting metabolic rate (RMR) and cardiorespiratory fitness(VO2peak), but also the comparison between measured and predicted results of RMR in obese men. **[Methods]** 60 obese men (body fat>32%) were recruited for this study. They did not participate in regular exercising programs at least 6 months. The RMR was measured with indirect calorimetry and predicted RMR using Herris-Benedicte equation. The cardiorespiratory fitness was determined by directly measuring the oxygen consumption (VO2peak) during the exercise on the treadmill. **[Results]** The significance for the difference between the measured results and predicted result of RMR were tested by paired t-test. Correlation of measured date was obtained by Pearson correlation coefficient. The value of predicted RMR and measured RMR were significantly different in these obese subjects. ($p < 0.001$). The difference between RMR cardiorespiratory fitness and cardiorespiratory fitness showed significant correlation ($r=0.67$, $p < 0.05$). **[Conclusion]** The current formulas of predicted RMR have limited the evaluation of measured RMR for Korean obese men. Therefore, this study suggests that new formula should be designed for Korean in order to obtain more accurate results in obese. **[Keyword]** Resting metabolic rate, VO_2peak, Obese men

INTRODUCTION

With the rapid increase of obese population, the World Health Organization (WHO) predicted in 1997 that overweight and obesity may soon replace more traditional public health concerns as the most significant cause of poor health [1]. Generally, body mass index (BMI) is a person's weight in kilograms divided by the square of their height in metres. It is one of the most commonly used ways of estimating whether a person is overweight. Based on many studies, WHO (Asia-Pacific Region) and Korean Society for the Study of Obesity defined overweight as a BMI ≥ 23 kg/m^2 and obesity as a BMI ≥ 25 kg/m^2 [2]. Obesity is a health problem that requires attention because it increases the risk for many chronic diseases including insulin resistance, diabetes, hypertension, cardiovascular disease, certain types of malignant tumors, etc. that may eventually lead to death [3,4]

There are many complex genetic, environmental and mental factors that combine to contribute to the causes of obesity. But obesity is most commonly caused by a lack of energy balance between calories consumed and calories expended [5]. Thus, a study on obesity can be seen as a research into an energy balance that focuses on relationship between calories consumed and calories expended. Major factors that determine a person's energy consumption include resting metabolic rate (RMR), thermic effect of activity, thermic effect of meal and temperature. RMR accounts for 60~75% of a person's daily total energy consumption. It represents the minimum amount of energy required to keep a person's body functioning at rest including sleeping. 15~30% of the total energy is consumed by physical activity and the rest 10% is expended by thermic effect of food, an increase in metabolic rate after ingestion of a meal [6]. Since RMR accounts for the biggest share in total energy consumption, it is deemed an important factor in studies on obesity. Potential factors that affect RMR include: age, weight, sex, heredity, race, body composition, thyroid function, the sympathetic system, physical strength, etc [7,8].

In clinical situations, an indirect measurement method such as respiratory gas analysis is widely used to measure RMR. Intake of food, alcohol, caffeine as well as smoking are

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banned before the measurement as they affect a person's metabolism. Certain physical activities are also restricted before the test [9]. The amount of CO_2 produced and O_2 consumed in one breath is measured to investigate the respiratory exchange ratio (RER) for the analysis of respiratory gas. RER is about 0.78~0.8 at rest. Likewise, measurement of actual RMR requires strict restrictions and special devices. That's why simple RMR-predicting equation is used to calculate RMR. Since the formula had been first proposed by Harris & Benedict in 1919 [10], another formulas have been introduced by Mifflin *et al*. [11] and Owen [12].

Exercise is absolutely vital in treatment of obesity. It is intended not only to induce weight loss by increasing energy consumption but also to enhance physical strength. Enhancing physical fitness is important for obese people because weak cardiorespiratory fitness is considered one of causes of cardiovascular death and an independent risk factor for all causes of death [13].

In studies by Berke [14] and Poehlman [15] that investigated the relationship between cardiorespiratory fitness and RMR, a person's aerobic capacity and RMR had a positive relationship and those who enhanced their aerobic capacity through exercise had higher RMR than that of people who did not exercise regularly. Also, a study by Ormsbee and Arciero that investigated swimmers reported that athletes who stopped training showed decreased maximum oxygen consumption and decreased RMR [16]. A study by Carlsohn *et al*. [17] also reported that RMR of elite athletes with high aerobic capacity showed greater RMR in actual measurement than predicted RMR.

If exercise in the treatment of obesity is intended not only to consume energy but also to enhance physical strength, and thus increase patients' RMR in order to effectively control their weight, clear relationship between these needs to be revealed. Studies mentioned above reported different RMR among different races and they are conducted mostly on Westerners [18]. As of now, there are only a few Korean studies on the same subject. Even they are limited to women subjects [19-21] However, the health statistics for 2012 published by National Health Insurance Corporation showed [22] higher proportion of obesity in men (38.1%) than women (29.5%). The proportion went up to 41.1% in men among those in their 30s and 40s. Therefore, this study aims to provide basic data for the effective treatment of obesity by investigating the accuracy of predicted RMR in comparison to measured RMR and a relationship between physical fitness and RMR.

METHODS

Subjects

This study was conducted on 60 men whose BMI were greater than 25 kg/m^2 and body fat percentage exceeded 30%. Excluded subjects included: those who participated in regular exercise during the previous six months; those with cardiovascular disease, hypertension, diabetes, asthma, etc.; and those who took medication that may affect their metabolism.

Measurement items and methods

Measurement of body composition

An impedance fat analyzer (Inbody 720, Korea) by Biospace was used to measure height, weight and body fat percentage (%) and fat-free mass of the subjects. This electrical impedance analyzer measures the resistance of body tissues to the flow of an electrical signal sent through both feet and hands. The proportion and amount of body fat and fat-free mass can be calculated as the current flows more easily through certain parts of the body.

Measurement of RMR

A respiratory gas analyzer (Parvo medics trueone 2400, USA) was used to measure RMR via indirect calorimetry. The subjects fasted for more than 14 hours before the blood test. They were told not to do aggressive physical activities for 24 hours before the measurement. They lied down for more than 30 minutes in resting state in the early morning

Fig. 1. Measurement of resting metabolic rate

before their RMR were measured. The subjects lied down and breathed through a large ventilated canopy for more than 30 minutes at resting state. The RMR was measured by calculating the amount of CO_2 produced and O_2 consumed through a one way-valve between the subject and the analyzer (Fig. 1.).

Measurement of predicted RMR

RMR was calculated using the Harris-Benedict Equation, the most widely used equation in the measurement of RMR. Height, weight and age were applied to the below Harris-Benedict Equation.

Harris-Benedict Equation:

Men: RMR(kcal/24h) = 66.473 + 5.003 × height + 13.75 × weight - 6.75 × age.

Women: RMR = 665.09 + 9.56 × height + 1.84 × weight - 4.67 × age

Measurement of maximum oxygen consumption (VO_2peak)

A Bruce protocol, a diagnostic test used in the evaluation of cardiac function, was used to measure VO_2peak of the subjects. The 12-lead ECG, blood pressure and rating perceived exertion (RPE) were measured every 3 minutes. The test lasted until the subject was unable to continue the exercise due to fatigue or difficulty in breathing or until the subject experienced abnormal condition. An exercise stress test system by Quinton (Quintion Q-4500, USA) was used to measure the 12-lead ECG, blood pressure and rating perceived exertion (RPE). The intensity of exercise was gradually increased every 3 minutes until the subjects were unable to continue the exercise: reaching target heart rate; exceeding RPE 17 by Borg scale; feeling difficulty in breathing; feeling dizziness or chest pain; and etc. Blood pressure and heart rate were checked one minute before every exercise and resting stage. A respiratory gas analyzer (Parvo medics trueone 2400, USA) was used to analyze every 20 seconds the amount of CO_2 produced and O_2 consumed and other data in order to measure VO_2peak. A rating of perceived exertion (RPE) > 17 resulted in good VO_2peak test. Other criterion was Respiratory exchange ratio (RER) > 1.15 and the VO2peak that did not increase despite increased intensity of the exercise. All procedures for the exercise stress test followed the American College of Sports Medicine (ACSM)'s guidelines for exercise testing.

Statistics analysis

SPSS Statistics 15.0 was used to analyze the results from this study. Pearson Correlation Coefficient Partial Correlation was used to investigate correlation between RMR and VO_2peak. Significance of the difference between measured RMR and predicted RMR was defined based on Paired t-test. A P-value < 0.05 was considered statistically significant.

RESULTS

Physical characteristics and VO_2peak

Average and standard deviation of each subject's age, height, weight, BMI, % Body fat and VO2peak are summarized in the Table 1.

Comparison of measured RMR and predicted RMR

Comparison of standard deviation and average measured RMR and average predicted RMR of subjects are summarized in the Fig. 2. Measured RMR and predicted RMR of the subjects were 1684.1 ± 204.7 kcal/d and 1853.3 ± 165.6 kcal/d respectively, showing significant difference between them ($p < 0.001$). (Fig. 2).

Relationship between RMR and VO_2peak

Pearson correlation between RMR and VO_2peak showed a statistically significant correlation ($r = 0.67$, $p < 0.05$). (Fig. 3).

Table 1. Characteristics of study subjects

Subject (n = 60)	Mean	SD
Age (y)	37.4	8.2
Weight (kg)	88.7	7.2
Height (cm)	173	5.5
BMI (Kg/m^2)	29.6	2.26
% Body fat (%)	35.5	4.8
VO2peak (ml/kg/min)	27.4	5.6

SD, standard deviation; BMI, body mass index; % BF, % body fat.

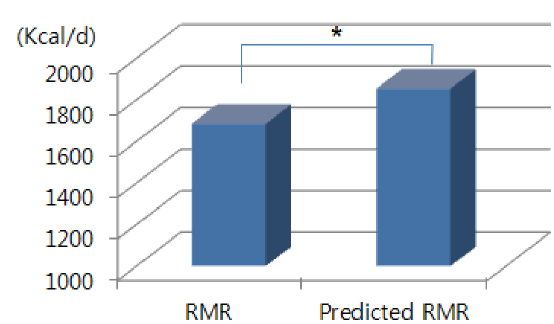

Fig. 2. Comparison of resting metabolic rate and predicted resting metabolic rate

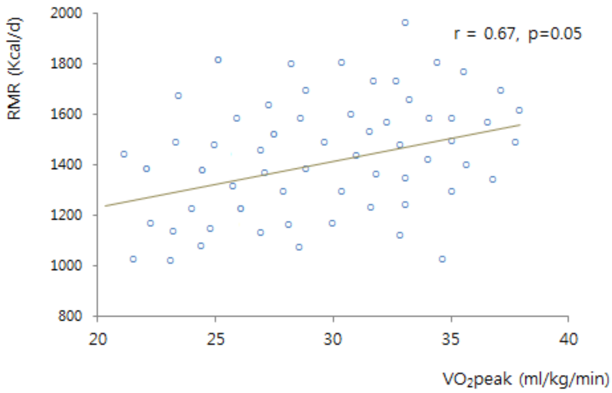

Fig. 3. Correlation of Resting metabolic rate and VO_2peak

DISCUSSION

Obesity is known to be an independent risk factor for coronary artery disease and has close relations with lifestyle diseases such as artherosclerosis [23,24]. Dieting or reducing food intake and increasing physical exercise have been mainstays of treatment for obesity. RMR which accounts for 60~75% of all calorie-burning processes has been considered one of important subjects in the studies for obesity. According to a study by Ravussin *et al*. [25] that focused on RMR in obese people, RMR was higher in obese people than nonobese people by about 500 kcal, but when height and weight of the subjects were taken into consideration, obese people had about 15~20% lower RMR than nonobese people. This is because obese people have higher body fat percentage than those of nonobese people when their weights are adjusted and converted into muscle mass although obese people have higher RMR in absolute values. Those with low RMR are more likely to become obese than those with normal or high RMR. That's why measuring accurate RMR is important in treatment for obesity.

However, since measuring RMR in clinical situation requires expensive respiratory devices and time, predictive equation has been conveniently used to calculate RMR albeit with an accuracy problem. According to a study by Frankenfield *et al*. [26], predicted RMR in nonobese people was 45~81% accurate, while predicted RMR in obese people was 38~64% accurate compared to measured RMRs. Also, in a study that investigated 120 Korean female college students with normal weight, predicted RMR calculated by Harris-Benedict equation in those students was higher than measured RMR (1247.2 ± 147.9 kcal/day) by 112.0 ± 121.13 kcal/day [20]. Likewise, predicted RMR is usually overestimated than the measured RMR and the error range in obese people is expected to get bigger with the increase of weight. In this study, predicted RMR was significantly higher (1853.3 ± 165.6 kcal/d) than the measured RMR (1684.1 ± 204.7 kcal/d) (Fig. 1).

While physical activity is known to directly consume energy, relationship between physical activity or aerobic capacity and RMR has not been clearly explained. In a study by Smith *et al*. [27], no significant relation was found between aerobic capacity and RMR in healthy women aged between 19 and 30. However, in a study by Poehlman *et al*. [15], high correlation was found between aerobic capacity and RMR in men ($r = 0.68$, $p < .0001$). The study also found that RMR was higher in physically stronger men.

On the contrary, in a study by Ormsbee and Arciero [16] that investigated elite swimmers, VO_2peak of the athletes dropped from 46.7 ml/kg/min to 43.1 ml/kg/ min and their RMR also dropped significantly when they stopped training for 5 weeks.

Also in this study, relationship between RMR and aerobic capacity was significant ($r = 0.67$, $p < 0.05$), showing identical results from the previous studies. Therefore, the investigator of this study surveyed researches that monitored the RMR changes produced by exercise programs because continuous aerobic exercise enhances cardiovascular fitness. A study by Allen *et al*. [28] reported an increased RMR in obese women when they participated in the medium intensity weight-loss exercise program. In a study by Potteiqer *et al*. [29] subjects lost about 5 kg and 4% of their body fat after participating in an exercise program three times a week for 16 months. After nine months, the subjects' VO_2max increased significantly, while RMR in women and men increased from 1583 kcal to 1692 kcal and from 995kcal to 2025 kcal respectively. These results suggest that medium intensity aerobic exercise program and a reduced calorie intake resulted in increased RMR and loss of weight and body fat in obese people.

Conclusion and recommendation

Results from this study showed difference in measured RMR and predicted RMR in obese men and also showed a positive relation between their aerobic capacity and RMR.

Therefore, using a formula in predicting RMR in Koreans, especially in obese people, may not be accurate. Thus, a new predictive equation is needed for Koreans to better treat obese Korean people. In order to treat obesity, fat-burning aerobic exercise is recommended to reduce body fat in obese people. Especially, medium intensity exercise is recommended as it enhances cardio fitness and RMR in people.

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