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Relationship between Resting Metabolic rate and Body Composition Factors in Obese and Normal Weight Gymnast Children

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Abstract

Background: Inconsistent results have been reported about the relationship between low RMR and obesity. The purpose of this study was to investigate the relationship between resting metabolic rate and body composition factors in obese and normal weight gymnastics children.

Materials and Methods: 20 obese and 21 normal-weight boys, aged 8-12 years, participated in this study. In the first session, data regarding the participants' anthropometrical (weight, height, waist to hip ratio (WHR)) and body composition (body fat percentage (BF%), body fat weight (BFW), and lean body weight (LBW)) measurements were recorded. In the next session, at first, subjects rested for 15 min and then performed a modified Bulk exhausting test. The subjects were connected to the mouthpiece of gas analyzer throughout the rest and exhausting test and VO2max, RER, and RMR were conducted in both groups.

Results: Significant difference was observed for a mean of VO2max, weight, BF%, BFW, LBW, and WHR between the two groups (P=0/001). The mean of RMR per kg body weight was significantly lower in the obese group than in the normal-weight group (P<0/05). There was no significant difference in the RER variable between the two groups (P>0.05). There was a significant linear relationship between RMR with weight, WHR, BFW, LBW, and VO2max in the obese group (P≤0/05).

Conclusion: Based on the results of the present study it can be concluded that the difference between the weight of obese and normal-weight beginner gymnast children is partly due to low RMR; and the lower RMR in obese children might be due to their low cardiorespiratory fitness.

Key Words: Body composition, Maximal oxygen consumption, Obese children, Resting metabolic Rate.

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1- INTRODUCTION

To have a healthy life and optimal physical condition, people must have sufficient amounts of health-related physical fitness factors (1). Among health-related factors, cardiorespiratory health, and body composition are directly related to chronic and metabolic diseases such as cardiovascular disease, high blood pressure, diabetes, fatty liver, etc. The background of most of the mentioned diseases is obesity and overweight. The remarkable rise in childhood obesity over the past few decades has changed attitudes about childhood obesity; and now it is recognized as one of the 10 major health-related problems in the world (2).

To maintain body weight, the balance between intake and consumption of daily energy is essential; because changes in this balance can be led to obesity even by up to 2% increase or decrease in energy consumption (3). Resting metabolic rate (RMR) accounts for about 60 to 70 percent of energy consumption, therefore its reduction or increase has a significant impact on the total energy consumption, which can reduce or increase the person's weight (4). However, the relationship between lower RMR and obesity has not been determined in studies (5) and there are conflicting results regarding RMR and its role in overweight and obesity. In a study performed on Native Americans during a period of four years, low RMR was significantly associated with an increase in body weight (6). But in another study in a ten-year-period, there was no relationship between RMR and overweight in men (7). It was also found that the RMR (controlled for free fat mass (FFM) and fat mass (FM)) was not significantly different between obese and normal-weight women (8). Many studies suggest that there is a strong genetic factor for RMR. Also, a meta-analysis of RMR in people, who have been obese in the past, shows that the average RMR is 3-5 percentage lower than those who have never been obese (9).

In body composition debates, reduction of body fat percentage is always emphasized as a factor which can be achieved by increasing the percentage of fat used as an energy substrate. The Respiratory Exchange Ratio (RER), which is the ratio between the amount of carbon dioxide (CO_2) in metabolism and oxygen (O_2) used, is an indicator used to determine the type of energy substrate; so that increasing this ratio indicates more carbohydrate oxidation and, therefore, people with a high RER gain a higher percentage of body fat (10), because they have less fat burning.

Many factors affect the resting metabolic rate. One of the most influential factors is physical activity. The best scale and standard for measuring physical activity and cardio-respiratory fitness is maximum oxygen consumption (VO_2max) (11). Investigating the relationship between RMR and body weight, body composition, and VO_2max, as well as comparing these indices in obese and normal-weight children can help to understand the etiology of obesity, to design appropriate strategies for the treatment of obesity and to prevent childhood obesity. Therefore, this study aimed to investigate the relationship between resting metabolism rate with body composition and VO_2max; along with comparing these indices in two groups of 8 to 12 years old obese and normal weight beginner gymnast children.

2- MATERIALS AND METHODS

2-1. Subjects and groups

Forty-one 8 to 12 years old boys, who had enrolled in the elementary level of gymnastics, participated in this study and were divided into an obese and normal-weight group. The participants were diagnosed based on the American Council Exercise lists (Jackson and Pollock equation for three-point subcutaneous fat measurement, considering fat percentage of 26 and above as obese group and fat percentage of 6 to 13% as normal weight group) (12, 13) without concomitant diseases. Exclusion criteria included evidence of any disease, drug therapy, and structural abnormality.

2-2. Ethical Approval

The study protocol was approved by the Ethics Committee of Ardabil University of Medical Science (IR.ARUMS.REC.1397.290) and Iranian Registry of Clinical Trials (IRCT20190917044807N1). This study was performed under the Declaration of Helsinki (revised 2008). All subjects and their parents were informed about the study procedure and the possible risks involved, and both parents and subjects signed a written consent form. Then subjects came to the Physiology Laboratory of Mohaghegh Ardabili University for collecting data such as height, weight, waist to hip ratio (WHR), body fat percentage (BF %), body fat weight (BFW) and lean body weight (LBW), resting metabolism rate (RMR), maximal oxygen consumption (VO_2max), and heart rate activity.

2-3. Anthropometrical and body composition measurements

Height was measured using a stadiometer with an error coefficient of 1% cm (SECA213; SECA, Hamburg, Germany). The subjects were instructed to remove their footwear and to stand in an upright position with their feet together. Weight was measured using a portable scale with an error coefficient of 1% kg (H20B; Biospace, Seoul, Korea). Subjects were requested to remove heavy clothing and to stand up straight. To measure waist and hip circumference, the subjects were asked to stand up straight and breathe out. The smallest circumference between the umbilicus and the xiphoid process was considered as waist and the largest circumference around the buttocks was considered as hip. These circumferences were measured by measure tape.

Three points skinfold test is a reliable method for estimating body-fat percentage that was used in the present study. Harpenden caliper was applied in tight (quadriceps), chest (pectoral), and belly (abdomen) and Jackson/Pollock 3-Site equation was used to predict BF%.

Body Fat % =495 / (1.10938-(0.0008267*s) + (0.0000016*s*s)-(0.0002574*a)) - 450.

s = sum of 3 skin-fold mm

a = age

To obtain the best and most consistent measurements, all skin-fold measurements were taken on the right and by the same person. Also, a minimum of two measurements was taken at each location. If the two measurements differed by more than 2 millimeters, a third measurement was taken. BF% was calculated by putting the average of the 2-3 measurements in an online body composition calculator. BFW and LBW were calculated by following formulas" (12, 13).

BFW=Body weight× BF%, LBM=Body weight-BFW.

2-4. VO_2max measurement

To measure VO_2max, Participants were instructed not to feed two hours before the test, be abstained from caffeine, and do not perform any strenuous physical exercise 48 hours before the test. Participants were familiarized with the ergometer (automatic ergometer treadmill) a few days before the test. As subjects were children aged 8–12 years old, a modified Balke protocol was used for evaluation of their maximal oxygen consumption (14); because this continuous protocol is well suited for the unfit, the obese, the very young child, or the chronically ill individual (14). After warming up for 5 min at a speed of 1 m/s without slope, each subject performed modified Balke protocol, which progressively increases the slope from 2% to more than 10% at 2% increments per minute until the subject could not maintain a constant speed of 3.5 mph and reaches to exhaustion (14). Subjects continued the test until exhaustion, while they were verbally encouraged throughout the test. The running time and distance were recorded; and VO_2 and respiratory exchange ratio (RER) data were also obtained every 10 seconds by a gas analyzer. VO_2max was considered the maximum value of VO_2 attained during the incremental test (15). The subject's heart rate was measured by installing a polar on the subjects' chest and recorded every 1 second.

2-5. RMR measurement

All subjects had 8 hours of sleep, did not perform any exercise for 48 hours before each session, and did not eat or consume any liquids, except water for 12 hours before testing. Each subject was transported by motor vehicle to the testing site to ensure minimal activity before RMR determination. All RMR measurements were performed between 09:00 and 11:00 hours. RMR was determined by a gas analyzer system using the open-circuit technique, while the subject was sitting (16). After entering the laboratory, subjects rested in a chair for 15 min in an isolated temperature-controlled room (21-24 C). After the first 15-min rest, the second 15 minutes started and subjects were fitted with a Hans Rudolf face mask, which was connected to the gas analyzer system. The gas analyzer was calibrated before each test according to the specifications of the manufacturer. During the test, the room was darkened, and the noise was kept to a minimum. The subjects were instructed to remain awake, quiet, and motionless before and throughout the entire 15-min period. The average of the last 10 mins of the measurement period was used to obtain resting metabolic rate by the following formula (17-19).

$$\mathrm{RMR} = 3.941\left[\mathrm{VO2}\left(\frac{\mathrm{L}}{\mathrm{min}}\right)\right] + 1.106\left[\mathrm{VCO2}\left(\frac{\mathrm{L}}{\mathrm{min}}\right)\right] = \mathrm{Kcal/min}$$

2-6. Statistical Analysis

Data are expressed as mean and standard deviations (SD). All analyses were performed using SPSS version 23.0. Independent t-test was used to compare dependent variables between groups and Pearson's correlation coefficient was used to assess the relationship between RMR with body composition factors and VO_2max. A value of $p<0.05$ was regarded as statistically significant.

3- RESULTS

The participants in the obese group were 20 boys with mean age and BMI of 10.10 ± 1.25 years and 25.79±1.83 and the normal weight group were 21 boys with mean age and BMI of 9.90±1.51 years and 16.89±1.32, respectively. There was a statistically significant difference between the obese and normal-weight groups in weight and BMI ($P\leq0.05$) and the BMI mean in obese children was higher than in the normal weight group. Body fat percentage (BF %) in the obese group was 27.38 ±1.39% and in the normal-weight group was 7.11±2.00%. the mean of fat percentage in obese children group was significantly higher than that of the normal-weight group ($P=0.001$). There was a significant difference in mean of weight, body fat weight (BFW), lean body weight (LBW), and waist to hip ratio (WHR) ($p<0.05$). These results are shown in Table 1. As it can be seen in **Figure.1**, the mean of absolute RMR in the obese group was 1164.95±278.43 kcal/day, which was higher than the normal weight group with the mean RMR of 1014.47±198.67 kcal/day, but there was no significant difference between the two groups ($p>0.05$). However, when the RMR was adjusted for weight, there was a statistically significant difference between the two groups; and the RMR per kg of body weight in the obese group was 22.34±4.77 kcal, which was significantly lower than in the group of normal-weight children with a mean and standard deviation of 33.33±7.36 kcal (p= 0.001). Furthermore, the VO_2max level in the obese group was 27.56±1.64 $ml.kg^{-1}.min^{-1}$, which was significantly less than that of the normal weight group with the VO_2max equal to 40.09±5.77 $ml.kg^{-1}.min^{-1}$ ($p<0.05$) (**Figure.2**). However, there was no significant difference in RER between obese (0.89±0.04) and normal-weight groups (0.88±0.03) ($p<0.05$) (**Table.1**). In the obese group, RMR had a significant linear relationship ($p<0.05$) with weight, WHR, body fat weight, lean body weight, and VO_2max. However, there was no significant relationship between RMR with any of the variables in the normal-weight group ($p>0.05$). These results are shown in **Table.2**.

Table-1: Subject's characteristics and dependent variables in two groups

Variables	Groups (N=15 for each)		
	Obese	Normal	P-value
Age (year)	10.10±1.25	9.90±1.25	0.65
BMI (kg/m2)	25.79±1.83	16.89±1.32	0.001†
Weight (kg)	52.05±5.95	30.85±4.99	0.001†
BF (%)	27.38±1.39	7.11±2.00	0.001†
BFW (kg)	14.31±2.30	2.19±0.89	0.001†
LBW (kg)	37.73±3.73	28.5±4.33	0.001†
WHR (cm)	0.98±0.03	0.87±0.04	0.001†
VO2max (mL/kg/min)	27.56±1.64	40.09±5.77	0.001†
RMR (kcal/day)	1164.95±278.43	1014.47±198.67	0.53
RMR/kg	22.34±4.77	33.33±7.36	0.001†
RER	0.89±0.04	0.88±0.03	0.23

N = 41 in two groups. Data Shown are mean ±S.D.
†: P values were significant (P<0.05).

Table-2: The correlation coefficient (r) between RMR and age, anthropometric characteristics, body composition, and physiological characteristics

Variables	Obese group (N=20)		Normal weight group (21)	
	correlation coefficient	P-value	correlation coefficient	P-value
Height (cm)	0.270	0.24	0.330	0.14
Weight (kg)	0.541 †	0.01	0.332	0.14
BF (%)	0.365	0.11	0.147	0.52
BFW (kg)	0.505 †	0.02	0.232	0.31
LBW (kg)	0.550 †	0.01	0.354	0.11
WHR (cm)	0.437 †	0.05	0.249	0.27
VO2max (mL/kg/min)	0.469 †	0.05	0.006	0.98
RER	-0.042	0.86	-0.131	0.57

†: Correlations were significant (P<0.05).

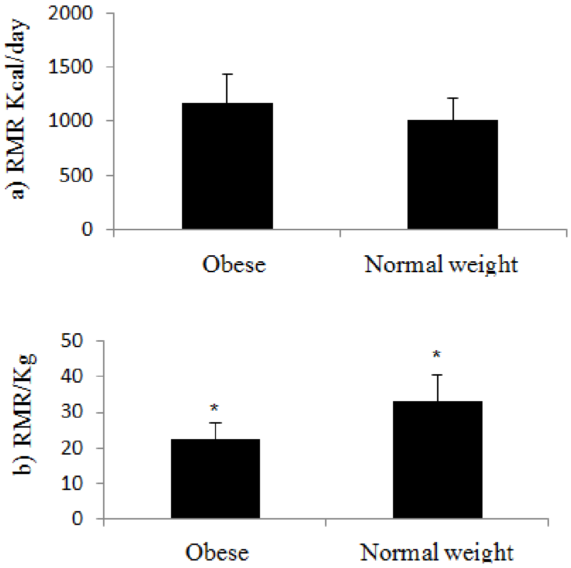

Fig. 1: Comparison of RMR between Obese and normal-weight groups.
a). Absolute RMR Kcal/day b). RMR/Kg of body weight
Data Shown are mean ±S.D. *: P values were significant (P<0.05).

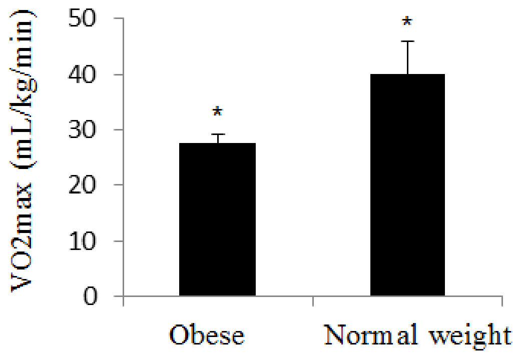

Fig. 2: Comparison of VO2max between Obese and normal weight groups
Data Shown are mean ±S.D. *: P values were significant (P<0.05).

4- DISSUASION

The results of the present study revealed that there is no significant difference between the absolute RMR amounts of obese and normal-weight children and even this amount in obese children (1164.95±.278.43 kcal/day) is slightly higher than in those with normal-weight (1014.47±198.67 kcal/day). However, when the values of RMR were adjusted according to the subjects' body weight, there was a significant difference between the two groups; and the RMR/Kg of body weight in obese children was 22.34±4.77 kcal/day, while in children with normal weight it was 33.33±7.36 kcal/day. The total daily energy expenditure includes the necessary energy for the basal body metabolism, the thermal effect of the activity, and the thermal effect of food (20, 21). The basal body metabolism rate is the highest percentage of the daily energy consumed by a person (approximately 60 to 75%), therefore it can be considered one of the most important factors affecting overweight. However, the results of studies conducted in this area are contradictory. For example, in a study performed on Native Americans over two years, the results showed that there was a significant relationship between metabolism and body weight changes. In this study, the total energy expenditure (controlled for age, sex, and body composition) was measured in the respiratory room. The probability of weight gain more than 7.5 kg was 4 times higher in people with low 24-hours energy expenditure compared to those with more total energy expenditure (200 kcal/day more than estimated value) (6). The results of the present study were consistent with the results of the mentioned research and also several other studies (8, 22, 23). Researchers that reject the effect of RMR on weight gain believe that obese people have more BF and LB than normal people do; and that LB is responsible for 60 to 85 percentage of the RMR. So, the measured RMR in obese people is usually higher (24). However, it should be noted that the components of LB are not homogeneous in metabolic terms. For example, the metabolic rate of bone and skeletal muscles is approximately 2.3 and 13 kcal/kg of tissue per day, which is much less in comparison with other organs including the brain, kidneys, liver, and heart, which is approximately 330 kcal/kg of tissue per day. It was found in the study conducted on African American women and white women that African American women had more skeletal muscle and bone mass than white women, but the weight of other mentioned components was less in them as compared to the white women. And eventually, the African American women had less RMR per kg than the white women did (25).

The results of our study also showed that Vo_2max, which is an index of cardiorespiratory fitness, was significantly lower in obese children than in normal-weight children; and there was a significant correlation between the RMR and Vo_2max in obese children. This result is consistent with those of the study performed by Shock et al., 2014, which showed that 25% of the difference observed between African American and white women were related to the independent role of cardiorespiratory fitness (25). Less VO_2max of obese children may indicate their inactivity compared to children with normal weight, and inactivity is one of the factors contributing to the low RMR (26). Researches have shown that exercise training can increase RMR by increasing absolute mitochondrial density, increasing lipid oxidation, the transition of fast-twitch (type IIB/X) fibers to fast oxidative glycolytic (type IIA) fibers as well as increasing thyroid function, specifically blood thyrotropin, triiodothyronine, and thyroxine (27). Therefore, the obese group in the present study may have a low oxidative capacity due to inactivity. Besides, it has been reported that the sympathetic system plays a key role in controlling daily energy expenditure (28). Visceral autonomic sympathetic hyperactivity has been reported in obese and sedentary people (29). Unlike the liver, pancreas, and skeletal muscle which are controlled by both sympathetic and parasympathetic nerve, adipose tissue is innervated only by the sympathetic nerve (28). Excess activity of the sympathetic nerve causes the desensitization of beta-adrenergic receptors (30), and since the sympathetic flow stimulates lipolysis in the adipocytes by linkage with the beta-adrenergic receptors, therefore, there is a possibility that excessive sympathetic nerve activity due to inactivity induces a reduction in lipolysis.

4-1. Study limitations

Our work had its limitations, such as the lack of girls, as well as the small sample size used. It is then recommended to explore practical usage of the findings in future studies using a large sample size including girls.

5- CONCLUSION

According to the results of this study, it is concluded that part of the difference between the weight of obese children and the normal weight of beginner gymnasts is due to the lower resting metabolic rate in obese children. Also, given the lower cardiorespiratory fitness per kg body weight in obese children, the overweight of children is likely due to their inactivity. Therefore, it is suggested to obese children and their parents to incorporate regular exercise into their daily program to increase resting metabolic rate and consequently to lose weight.

6- **CONFLICT OF INTEREST:** None.

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