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Original Article

The association between total antioxidant capacity and resting metabolic rate (RMR) / respiratory quotient (RQ) in overweight and obese woman

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ABSTRACT

Objective: The effect of total antioxidant capacity on resting metabolic rate (RMR) and respiratory quotient (RQ) of overweight and obese woman has been debated globally. Total Antioxidant Capacity may have an independent effect on resting metabolic rate and respiratory quotient.

Methods and materials: A study population of 263 aged 18–50 years participated in this cross-sectional study from the communities of Tehran based on cluster sampling. Dietary intake assessed by using a semi quantitative food frequency questionnaire (FFQ) Demographic questions. Anthropometrics measurements for each participant were done. Dietary total antioxidant capacity (DTAC) was calculated by the 147-item food frequency questionnaire (FFQ) and FRAP assay. Resting metabolic rate and respiratory quotient was measured by Indirect calorimetry.

Results: The mean DTAC of the study participants was 1251.8 (SD 893.60). There was a statistically significant relationship between dietary total antioxidant capacity (DTAC) and respiratory quotient ($P > 0.013$). People with high dietary total antioxidant capacity have tended to show a lower RQ than those with a lower one. There was a significant correlation between DTAC and RQ for both the adjusted model for age, total energy intake, BMI, physical activity, higher DTAC diet and the crude model which were ($\beta = 0.011$; SE = 0.005; CI = −0.021_0) and ($\beta = -3.143E\text{-}6$; SE = 0; CI = 0), respectively. However, we found no correlation between the DTAC and RMR/FFM-RES ($P < 0.49$). Also, a significantly higher relationship was demonstrated between dietary total antioxidant capacity and intake vegetables ($P \leq 0.006$), fruits ($P \leq 0.009$), white meet ($P \leq 0.03$) and dairy products ($P \leq 0.005$).

Conclusion: RQ is correlated with total antioxidant capacity. Increased intake of high DTAC foods may result in weight loss maintenance. This result may suggest a beneficial role of higher-DTAC diets in the prevention of obesity.

1. Introduction

Obesity as a worldwide phenomenon is a multifactorial condition and may be both a cause and an effect of hypothalamic dysfunction [1]. Endogenous factors including impaired energy regulation, behavioral factors, dietary changes, changes in activity level, and environmental factors each contribute to the rise in obesity [1–3]. The world health organization defines overweight as a body mass index of (BMI)≥25–29.9 kg/m2 and obesity is defined as a BMI of 30 kg/m2 or more [4,5]. Obesity is associated with increased risk for hypertension, dyslipidemia, ischemic heart disease, type 2 diabetes, cardiovascular disease, osteoarthritis, gout, several forms of cancer, reduction in the quality of life, and death [4,5]. The worldwide prevalence of obesity and overweight increased significantly [6] Based on available data from WHO the prevalence of obesity is 21% and overweight is 53% [7]. It is projected that if historical trends continue linearly, by 2030, 51% of U.S. adults will be obese [6]. Studies show that many obese people have

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Abbreviations

BMI	Body Mass Index
DTAC	Dietary Total Antioxidant Capacity
FFQ	Food Frequency Questionnaire
FM	Fat Mass
FFM	Fat- Free Mass
FRAP	Fluorescence recovery after photo bleaching
HDL:	High-density Lipoprotein
Hs-CRP	High-sensitivity C- Reactive Protein
IPAQ	International Physical Activity Questionnaires
RMR	Resting Metabolic Rate
LDL:	Low-density Lipoprotein
RQ	Respiratory Quotient
TC	Total Cholesterol
TG	Triglycerides
USDA:	United States Department of Agriculture
WHO	World Health Organization

lower resting metabolic rates. The main factors that are predictors of RMR are age, gender, fat-free mass and fat mass. According to previous studies there are significant univariate correlation between RMR and body fat and weight. Also, substrate oxidation may be led to gain weight with increased fat mass (FM). Some studies report that obese subjects have a high respiratory quotient (RQ) that is indicative of low-fat oxidation and high carbohydrate oxidation. Antioxidant capacity which have independent effects on resting metabolic rate and respiratory quotient, may have a role. In this study, for the first time, the intermediate effect of total antioxidant capacity on basal metabolic rate and respiratory quotient have been investigated.

2. Methods and materials

2.1. Study population

In this cross-sectional study 300 healthy overweight and obese women who were referred to community health centers of Tehran university of medical science, volunteers were randomly selected for the study based on the following inclusion criteria: 1) body mass index (BMI) 25–40 kg/m2 - 2) aged 18–50 years old. The primary exclusion criteria included the following:1) menopause 2) pregnancy 3) cardiovascular diseases 4) diabetes 5) Cancer 6) kidney disease 7) thyroid disease 8) acute or chronic diseases 9) use of dietary supplements for weight loss 10) follow up diet during the past year 11) use of lipid lowering drugs 12) use of blood glucose lowering drugs. This study carries out in accordance with the recommendations of the ethics committee of institution with written informed consent from all participants. Based on study protocol, we carried out assessment of demographic characteristics and measurement of anthropometric.

2.2. Demographic questions

Demographic questions collect data about the characteristics such as age, smoking status, education level, life style, marital status, menopause, medical history, taking medication and supplement and etc.

2.3. Anthropometric assessment

For each participant, height, weight, as well as waist, and hip circumferences were measured. Also, BMI was calculated. These measurements were made in compliance with WHO recommendations and the assessments were performed by researchers who have extensive experience. The equipment used was a solar digital scale and a free-standing portable height metre. Participants were weighed without shoes and heavy outdoor clothing and weight recorded to the last 0.1 kg. Standing height was measured with a precision of 0.5 cm without shoes, by trained observers. The body mass index, (BMI) is considered to be the best available population marker for monitoring trends in obesity. BMI was calculated by weight (kg)/height (m) squared. Waist-to-hip ratio (WHR) determines how much fat is stored on your waist, hips, and buttocks. The WHR is the dimensionless ratio of the circumference of the waist to that of the hips. Body mass index (BMI), which is a simple index of weight-for-height, and WHR are commonly used to classify overweight and obesity. According to WHO a waist circumference of 102 cm (40 inches) or more in men, or 88 cm (35 inches) or more in women, is associated with obesity.

2.4. Dietary assessment

The usual dietary intake during the past year were assessed by using a semi quantitative food frequency questionnaire (FFQ). The FFQ includes 147 items with a standard serving size commonly consumed by Iranians. Items are defined by a series of foods or beverages which are categorized into 9 major food groups. Completing a questionnaire aimed at capturing the total dietary intake usually requires 30–60 min. Food frequency categories "daily/weekly/monthly/were used in which participants would be asked to report their consumption frequency of each food item. The reported frequency for each food item was then converted to a daily intake. Energy and nutrient content of foods were computed by the Nutritionist 4 software based on United States Department of Agriculture (USDA) food composition table modified for Iranian foods. Validity and reliability of the FFQ have been confirmed previously [8,9].

2.5. Measurement of resting metabolic rate and respiratory quotient

Indirect calorimetry (IC) is more accurate, sensitive and non-invasive method for energy expenditure estimation in a living human organism. It is based on measures respiratory gas exchange, oxygen consumption (VO2) and carbon dioxide production (VCO2) measurements. The MetaLyzer 3B is a stationary metabolic stress test system for measures volume continuously and simultaneously during treadmill exercise. In this test the participant is wearing a small face mask and has collected the gas sample while the participant exercises on a treadmill. The CO2 output and O2 uptake during each breath is transferred breath-by-breath to a PC for immediate display. Oxygen consumption (VO2) and carbon dioxide (CO2) production occur during the oxidation of carbohydrate, protein, and fat. The respiratory quotient (RQ) is the ratio of CO2 produced to O2 consumed while is helpful in determining what type of fuel is being catabolized and food is being metabolized for energy. Indirect calorimetry (IC) assesses the ratio of carbon dioxide released (VCO2) to the amount of oxygen used (VO2) that is called respiratory exchange ratio (RER) and is measured by the gases exchanged at the mouth and not in the lung. In indirect calorimetry all measurements were done in the morning after a 12-h fast and a minimum of 10 h sleep. The subject should avoid nicotine, caffeine for at least 4 h and exercise for at least 4 h before the calorimetric [8,10].

2.6. Calculation of dietary total antioxidant capacity

Dietary TAC's ability is used to predict dietary antioxidant status and plasma antioxidant status. This study we estimate dietary TAC by collecting dietary data from an FFQ. The FRAP (Ferric Reducing Ability of plasma) assay, is presented as simple method for assessing "antioxidant power". This assay determines the ability of the sample to reduce ferric iron to ferrous iron in a low-pH environment. The results are expressed as μmol Trolox per litter plasma [11].

3. Results

All participants completed the study and all measurements were available for statistical analysis. The anthropometrical and clinical characteristics of 300 women are presented in Table 1.

3.1. Assessment between DTAC and RQ/RMR

Our results demonstrated that there is a significant relationship between dietary total antioxidant capacity (DTAC) and respiratory quotient ($P < 0.013$) Table 1. DTAC and RQ are dependent variables, whereas age, BMI, FFM, plasma glucose levels, TG, LDL, and HDL are independent variables which did not illustrate a significant relationship with DTAC. In general, obese people was divided into two high group and low group based on the dietary total antioxidant capacity (group 1 = 145, group 2 = 144) Table 1. The high respiratory quotient mean was 0.86 (±0.042 SD) and low respiratory quotient mean was 0.84 (±0.039 SD). The association between RQ and remained significantly, even after adjusting for confounders including age, total energy intake, BMI, and physical activity. The effect of dietary total antioxidant capacity on respiratory quotient in both crude and adjusted linear regression models has been shown in Table 3. We observed no correlation indication between the DTAC and RMR/FFM-RES ($P < 0.49$).

Table 1
Participant characteristics.

Variable	High DTAC	Low DTAC	p-value
	N = 145	N = 144	
Demography			
Age (years)	37.40 ± 8.45	35.73 ± 8.44	0.09
Weight (kg)	81.02 ± 12.81	80.41 ± 11.69	0.67
Height (cm)	161.02 ± 5.58	161.52 ± 6.27	0.47
Body composition			
Wc(cm)	94.87 ± 19.78	96.47 ± 9.18	0.51
Hc(cm)	113.34 ± 16.40	113.83 ± 7.76	0.81
Anthropometry			
RQ	0.84 ± 0.039	0.86 ± 0.042	0.01
RMR (kcal/day)	1560.1.4 ± 259.01	1591.4 ± 259.71	0.31
RMR.normal	1714.8 ± 151.51	1721.5 ± 150.60	0.70
RMR.per.kg	19.39.6 ± 2.97	19.88 ± 3.24	0.18
RMR.per.BSA	842.45 ± 110.74	861.14 ± 117.63	0.16
RMR.FFM.RES	1558.0 ± 203.85	1597.3 ± 209.63	0.11
RMR.CHO	188.71 ± 58.57	207.35 ± 65.03	0.01
RMR.FAT	76.65 ± 24.96	71.50 ± 27.32	0.09
RMR.PRO	17.52 ± 3.14	17.85 ± 3.01	0.37
FMI (kg/m2)	13.35 ± 3.56	12.97 ± 3.23	0.33
FFMI (kg/m2)	18.97 ± 10.91	17.82 ± 1.44	0.21
Biochemical characterize			
SBP (mmHg)	111.76 ± 14.82	111.57 ± 12.70	0.90
DBP (mmHg)	77.95 ± 10.62	77.53 ± 8.53	0.72
Pulse	79.41 ± 11.00	80.12 ± 10.21	0.59
hs. CRP	4.21 ± 4.46	4.42 ± 4.85	0.73
GPT	20.11 ± 15.51	18.19 ± 9.76	0.25
GOT	18.00 ± 8.77	17.67 ± 5.61	0.73
GLU	86.50 ± 9.38	88.53 ± 9.84	0.09
LDL (mg/dl)	93.89 ± 22.91	95.89 ± 25.36	0.51
HDL (mg/dl)	46.37 ± 10.84	47.18 ± 10.90	0.56
TG (mg/dl)	116.13 ± 64.37	128.33 ± 75.88	0.17
Chole	182.44 ± 36.00	187.48 ± 36.28	0.27

Note: wc = waist circumference, hc = hip circumference, RQ = respiratory quotient, RMR = resting metabolic rate, FMI = fat mass index, FFMI = fat free mass index, SBP = systolic blood pressure, DBP = diastolic blood pressure, hs_CRP = high sensitivity C-reactive protein, TG = triglyceride, LDL = low-density lipoprotein, HDL = high-density lipoprotein.
*P value < 0·05 is significant, DTAC was categorize based on median cut point = 1006.30, High DTAC Mean ± Std. Deviation = 1006.30 ≤ and low DTAC Mean ± Std. Deviation = 1006.30≥.

3.2. Distribution of food among DTAC level

A significantly higher relationship was demonstrated between dietary total antioxidant capacity and intake of vegetables ($P \leq 0.006$), fruits ($P \leq 0.009$), white meet ($P \leq 0.03$), and dairy products ($P \leq 0.005$) Table 2.

4. Discussion

In this study, we found an inverse relationship between DTAC and respiratory quotient (RQ), but no association was observed between RMR and dietary total antioxidant capacity. Several studies have shown that individuals with a high RQ had larger gains in body weight and fat mass [12–14]. Inherent individual variability in substrate oxidation may predispose to obesity. Low fat oxidation and/or elevated carbohydrate oxidation may predispose women to excess adipose tissue and weight gain. Moreover, previous studies have suggested that greater carbohydrate oxidation and lesser fat oxidation may predispose certain individuals to store less glycogen and therefore experience more hunger. This increased hunger may lead to chronic positive energy imbalance and gain fat in body fat [15].

Also, it is well-established that either positive energy balance or high carbohydrate intake can transiently elevate respiratory quotient and lead to increase body weight [15]. Results of this study advance existing evidence about the relationship between DTAC and weight. People with high dietary total antioxidant capacity have tended to show a lower RQ than those with a lower one. Therefore, increased intake of high DTAC foods may result in weight loss maintenance [12–14]. Eating large amounts of food with high TAC value, such as fruits, vegetable, meat, and dairy products increases the antioxidant capacity of human blood plasma significantly. Fruits and vegetables are important components of a healthy diet and rich sources of vitamins, minerals, dietary fiber; and a host of beneficial non-nutrient substances including plant sterols, flavonoids, and other antioxidants. Consuming a variety of fruits and vegetables helps to ensure an adequate intake of many of these essential nutrients [16]. A number of studies have shown that fruits and vegetables, due to high content of antioxidants, such as polyphenol and anthocyanin, reduce free radical processes [16,17]. White-meat diets can increase the total antioxidant capacity levels and improve health. Red meats have a good source of high-quality protein and a variety of micronutrients and may significantly contribute to the total antioxidant capacity [18,19]. Data from the latest UK National Diet and Nutrition Survey indicate that the meat and meat products contain magnesium, iron, potassium, and zinc [18]. Dietary zinc can increase total antioxidant capacity such as increased superoxide dismutase (SOD), glutathione peroxidase (GPX), glutathione reductase (GR), catalase (CAT), the content of glutathione (GSH), as well as decreased the malondialdehyde (MDA) level [20]. These findings highlight that consumption of meat may significantly contribute to the total antioxidant capacity. Previous studies have suggested that an increased dietary protein helps to increase weight loss and limit weight regain in overweight and obese individual [21]. Vegetarian diets can be as effective as

Table 2
Distribution of food groups between high DTAC and low DTAC.

	High DTAC Mean ± Std. Deviation N = 145	Low DTAC Mean ± Std. Deviation N = 145	p-value
Cereals	472.62 ± 268.02	427.06 ± 171.82	0.086
Carbohydrates	5.84 ± 6.46	5.20 ± 11.99	0.57
Beans	54.42 ± 43.33	59.03 ± 47.76	0.39
Meat and meat product	105.13 ± 67.31	90.03 ± 48.65	0.030
Dairy	434.56 ± 275.03	353.32 ± 210.63	0.005
Vegetables	452.42 ± 265.35	370.06 ± 235.43	0.006
Fruit	627.50 ± 379.51	514.06 ± 355.70	0.009
Oil	28.40 ± 20.44	28.33 ± 26.16	0.98
Nuts	15.39 ± 17.05	13.36 ± 15.31	0.28
Beverages caffeine	1170.3 ± 896.14	3641.40 ± 199.14	<0.001

Note: Distribution food groups between high DTAC and low DTAC.

Table 3
Association between DTAC and RQ in the crude and adjusted model.

RQ	B±SE	T-value	p	95% CI
Crude	3.143E-6±0.004	−1.12	0.26	0.002 ± 0.003
Model 1	-.012 ± 0.005	−2.534	0.012	−0.022_-0.003
Model 2	-.012 ± 0.005	−2.507	0.013	−0.022_-0.003
Model 3	−0.009 ± 0.005	−1.830	0.069	-.020_-.001
Model 4	-.011 ± 0.005	−2.049	.042	−0.021_0.001

Note: Adjusted model to age, BMI, physical activity, kcal for relationship between RQ and DTAC. Note.CI = confidence interval. 95% Cis were calculated with the use of logistic regression model for RQ in 2 groups of DTAC. BMI entered in the model based on cutoffs (<24.9 kg/m2 and 25 kg/m2). Model 1: Adjusted for age with ANOVA model. Model 2: Adjusted for BMI with ANOVA model. Model 3: Adjusted for physical activity with ANOVA model. Model 4: Adjusted for kcal energy with ANOVA model. Dependent Variable: RQ. *P value < 0·05 is significant.

meat-based diets for appetite control during weight loss [22]. In addition, dairy food has a plant-based antioxidant. Consumption of low-fat milk has a beneficial effect on weight loss maintenance [22].

However, the exact mechanism is unknown. A possible mechanism that may lead to lose weight maintenance associated to increase dietary total antioxidant capacity and low respiratory quotient. The strengths of this research are that no studies that have been conducted regarding DTAC and obesity in this population; therefore, it will be a good contribution to the literature. Also, RQ as a measure of obesity, to the best of our knowledge, is the first method. To be used as an obesity parameter find its association with DTAC, and has provided evidence that it may be one of the better predictors of obesity. Some of the possible limitations of this study are as following: it was cross-sectional, hence limiting inference on the time sequence of the associations. Also, the small sample size from the population limited the statistical power, since a greater power requires a larger sample size considering the overall population of Tehran. Another limitation was the use of questionnaire to collect data on physical activity, which shows a limited reliability and validity. Further, besides the measurement errors, the FFQ may introduce as a result of omission or isolation of part of the meal eaten, so there may be possible error in the calculated DTAC.

5. Conclusion

In conclusion, our findings indicate that an inverse association between RQ and total antioxidant capacity. This may imply a beneficial role of higher DTAC diets in the prevention of obesity. Further studies are required to establish these findings through replication in more diverse populations and ultimately to confirm this correlation.

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Disclosure statement

All authors declare that they have no conflicts of interest.

Conflicts of interest

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