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Original article

Association among basal metabolic rate, body composition and pulmonary function in university students

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Background: Variation in basal metabolic rate (BMR) has been closely related to obesity and pulmonary function.
Objectives: To determine the association between BMR, body composition and pulmonary function among university students aged 19 - 22 years old.
Methods: This cross-sectional study was carried out among the pre-clinical students of the Faculty of Medicine and Health Sciences, Universiti Malaysia Sarawak. Data was collected using questionnaire, anthropometric measurement, and spirometer. Statistical analysis was performed using IBM SPSS version 20.0.
Results: A total of 230 respondents participated in this study. There were 47.7% males and 41.1% females who were overweight and obese, 40.3% of the males and 46.0% of the females had high percentage of body fat, and 22.4% of the male respondents had high and very high visceral fat compared to 7.4% of the female respondents. BMR and force vital capacity (FVC) values were significant higher for males than females. Multivariate analysis showed that after adjusted for gender, percentage of visceral fat (adjust β = 0.620, 95% CI = 24.436 - 32.738), and FVC (adjust β = 0.152, 95% CI = 19.762 - 49.038) were significant associated with BMR.
Conclusions: Visceral fat has a stronger effect on BMR compared to body fat and FVC. Body fat, visceral fat and pulmonary function were found to be significantly associated with BMR, with visceral fat the highest effect on BMR. Understanding the association of these variables help in the intervention of obesity among young adults.

Keywords: Basal metabolic rate, body composition, pulmonary function, overweight and obese.

Basal metabolic rate (BMR) is defined as the rate of energy expenditure by our body during awake to maintain the physiology functions of human body.[1] It is usually measured about 12 hours after the last meal under controlled condition of thermal neutrality.[2] It is the minimum level of energy required to exist and its accounts for about 50.0 – 70.0% of the daily energy expenditure in most sedentary individuals. [3]

Measurement of BMR is one of the essential element in the assessment of nutritional and weight management programme.[4] Previously measured using direct calorimetry, now prediction using equation is widely found in both clinical and non-clinical setting as the later method is more practical, less time consuming and less costly. There are various equations in measuring BMR, ranging from Frankenfield D, *et al*.[5], Mifflin MD, *et al*. [6], Food and Agriculture Organization/World Health Organization/United Nations University [3], and Henry CJ. and Rees DG.[7] In Malaysia, Ismail and his team had developed a BMR predictive equation based on Douglas bag technique for general population of Malaysia adults.[8] These equations based on body-weight reveal that FAO/WHO/UNU [3] and Henry CJ. and Rees DG.[7] predictive equations overestimated BMR of adult Malaysia. As explained by Ismail and his team that the differences could be due to the hot and humid climate experience throughout the year slow down the metabolism of Malaysians.[8]

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Gender, age, body surface area, body composition, genetic composition, pregnancy and hormonal status can influence BMR.[2] The major contributing factor to BMR is fat-free mass, however, literatures had showed that fat-free mass consistently explains only 70.0 – 80.0% of the differences in BMR. The remaining 20.0 – 30.0% of the variations was found to be associated with age, body fatness, body temperature and activity of the sympathetic nervous system.[9] Women have a significantly lower BMR than men of the same body weight and age because women's bodies contain proportionally more adipose tissue. [2] Apart from that, BMR can be varied by ethnicity because there is significance difference between Asian and Western population. One of the possible mechanism is the difference in climate that affect body composition.[10]

Apart from that, BMR has also been associated with pulmonary function. According to a study done by Dixon AE. and Peters U. [11], imbalance between energy input and output leading to obesity and indirectly affect one's BMR will lead to different deleterious effects to respiratory functions. Such effects are alterations in the respiratory mechanism, decrease in respiratory muscle strength and endurance, decrease in pulmonary gas exchange, lower control of breathing, and limitations in pulmonary function test. This is further supported by Koenig SM.[12] where obesity can profoundly change pulmonary function and reduce exercise capacity that affect BMR. Because obesity in young adults can lead to obesity in adults, knowledge on energy metabolism in young people is of clinical importance in the prevention and intervention of obesity-related diseases.

The prevalence of overweight and obesity in young adults is rapidly increasing in Malaysia. A recent study among the undergraduate students in five universities in Malaysia indicated the prevalence of overweight and obesity has reached 40.6% [13], a figure that is alarming as it is close to the National Health and Morbidity Survey where the prevalence of overweight and obesity among adults was 47.7%.[14] Obesity during young adults is associated with elevated blood pressure and lipid profile in the later life, which increase the risk of obesity related diseases such as cardiovascular diseases, metabolic syndrome and type II diabetes.[15] Therefore, intervention at the younger age group has become an increasing interest in the treatment of obesity among adults. Obesity occurs because of excess of adipose tissue in human body and fat tissue has a lower metabolic activity than fat-free mass.

As the study on the association between BMR, body composition and pulmonary function is limited among young adults, this study aimed to determine the association among BMR, body composition and pulmonary function in university students aged 19 - 22 years old.

Materials and methods

This cross-sectional study was carried out among the pre-clinical students of the Faculty of Medicine and Health Sciences, Universiti Malaysia Sarawak. Sample size was calculated based on sampling frame of 693 (total students), prevalence of 41.0% (BMR >1,500) [16] confidence level of 95.0%, estimated number of subjects needed was 243. All healthy preclinical students with no current acute illness were selected. Subjects with history of asthma, chronic cough, or with spirometry contraindication were excluded from the study. The study was conducted from January 2019 to August 2019. The study was approved by the Medical Ethics Committee of Universiti Malaysia Sarawak [UNIMAS/NC-21.02/03-02 Jld.3]. All subjects were briefed thoroughly regarding the research before gaining consent. They were also informed about the purpose, procedures, protocols and confidentially of their personal information as well as their rights to take part in the procedure.

Instruments

The questionnaire includes questions on socio-demographic characteristics such as race, age and gender of the subject.

Body composition

Prior to the measuring of body composition, respondents were asked to refrain from eating and drinking for at least 4 hours. However, they were allowed to drink water. Height was measured by a stadiometer (model: SECA 213) in which, the respondents were asked to stand upright barefooted on a flat surface with their back of the heels and occiput against the body meter. The body must be in straight line and required to look straight ahead. [17] Measurement of body mass index (BMI) and body composition were measured through bioelectrical impedance analysis (Body composition Monitor HBF-375), a medical device to measure the body composition parameters which includes body fat (%), visceral fat (%), skeletal muscle (%) and BMI.

BMI is classified as follows: underweight (BMI < 18.5 kg/m2), normal (18.5 - 22.9 kg/m2), overweight (BMI ≥ 23 kg/m2), and obese (BMI ≥ 27.5 kg/m2). [18] The percentage of body fat can be can be classified as follows: for male < 9.9 as low, 10 - 19.9 as normal, 20 to 24.9 as high and ≥ 25 as very high and for female, < 19.9 as low, 20 - 29.9 as normal, 30 to 34.9 as high and ≥ 35 as very high body fat %.[19] For the visceral fat percentage, it can be classified as follows: normal (1 - 9), high (10 - 14) and very high (15 - 30) for both genders and for skeletal muscle percentage, it can be classified as follows: for male < 33.3 for low, 33.3 - 39.3 for normal, 39.4 - 44.0 for high and ≥ 44.1 for very high percentage and for female < 24.3 as low, 24.3 - 30.3 as normal, 30.4 - 35.3 as high and ≥ 35.4 as very high. [20]

Pulmonary function

It was measured by a power lab spirometer pod (model: ML 311, AD Instrument). Before starting the procedure, subjects were explained the test. The technician demonstrated the technique and asked the subject to follow the procedure according to American Thoracic Society standards (ATS) and European Respiratory Society (ERS). There are three phases for manoeuvre: maximal inspiration, a 'blast' exhalation and continue complete exhalation to the end of the test. The subject was asked to assume correct posture with the head slightly elevated. It was important to attach nose clip, placed the mouthpiece in mouth and closed lips around the mouthpiece. The subjects were asked to inhale completely and rapidly with a pause of less than one second and then exhaled maximally until no more air can be expelled while maintaining an upright posture.[21] A total of three readings were collected with the best of the three was selected.

The spirometric value to be collected includes force vital capacity (FVC) and Forced expiratory volume in one second (FEV_1). FVC is the volume delivered during an expiration made as forcefully and completely as possible starting from full inspiration, and FEV_1 is the volume delivered in the first second of an FVC.[21]

Calculation for basal metabolic rate (BMR)

The equation for predicting BMR was used for calculation of BMR of the respondents. The predictive equation was derived from a study on Malaysian adults for the general Malaysian population. [8]

Males (18 - 30 years):
BMR (MJ/d) = 0.0550 (Body weight) + 2.480
Females (18 - 30 years):
BMR (MJ/d) = 0.0535 (Body weight) + 1.994
Conversion: 1 MJ/day = 239.006 kcal/day

Statistical analysis

Data entry and data analysis were performed by using Statistical Package for Social Science Program (SPSS) version 20.0. Data were presented as mean ± standard deviation (SD). Statistical differences groups were calculated using unpaired Student t - test or Chi square. Descriptive and inferential statistic were carried out based on 95.0% confidence interval with $P < 0.05$ as statistically significant difference. Multiple linear regression equations were derived for groups of subjects according to sex and BMR. For the selection of pulmonary function into the multivariate analysis, FVC has been selected as it is a widely used indirect measure of respiratory muscle strength in most clinical research.[22]

Results

Socio-demographic profile of subjects

A total of 230 subjects participated in this study with 70.9% females, mean age of 20.4 (SD 0.58) year. Majority of the respondents were from age 20 - 21 years old (93.5%). The major ethnic group was Malay (52.6%). Details of the socio-demographic profile are presented in Table 1.

Nutritional status of respondents

Table 2 showed the nutritional parameter of the subjects.

In terms of BMI classification, there was not significant differences between males and females. Similarly, for classification of body fat and skeletal muscle. However, there was significant difference in visceral fat where more males were found to have high and very high percentage of visceral fat compared to females.

The results also showed a high prevalence of overweight and obese (47.7% for males and 41.1% for females) among the subjects. The body fat profile also showed 40.3% of the males and 46.0% of the females had high percentage of body fat. In terms of visceral fat, 22.4% of the male respondents had high and very high visceral fat compared to 7.4% of the female subjects.

Basal metabolic rate and force vital capacity profile of subjects

Table 3 showed the BMR and pulmonary function of the respondents. BMR values were significant higher for male respondents than female respondents. However, when expressed relative to body weight, the differences were not significant. Similarly, for FVC, FEV_1, males had higher readings compared to females and the differences were significant.

Factors associated with BMR

Table 4 showed the Multiple Linear Regression analysis to determine the association between BMR with percentage of body fat, percentage of visceral fat, percentage of skeletal muscle and FVC (L) as independent variables. The results showed percentage of visceral fat and FVC (L) were significant associated with BMR.

Table 1. Socio- demographic profile of respondents (n = 230).

	Mean (SD)	**n (%)**
Age (years)	20.5 (0.6)	
Gender		
Male		67 (29.1)
Female		163 (70.9)
Ethnicity		
Malay		121 (52.6)
Chinese		28 (12.2)
Bidayuh		23 (10.0)
Iban		20 (8.7)
Others (Indian, Melanau, Dusun and other minority indegenious groups)		38 (16.5)

Table 2. Body composition of respondents (n = 230).

Parameter	**All (n = 230)**	**Male (n = 67)**	**Female (n = 163)**	***P* - value**
Height (cm)[a]	159.7 (8.1)	167.8 (6.7)	156.3 (5.9)	< 0.01
Weight (kg)[a]	59.3 (13.4)	66.3 (14.2)	58.4 (12.0)	0.620
BMI (kg/m^2)[b] **(%)**				
Underweight	23 (10.0)	7 (10.4)	16 (9.8)	0.785
Normal	108 (47.0)	28 (41.8)	80 (49.1)	
Overweight	35 (15.2)	11 (16.4)	24 (14.7)	
Obese	64 (27.8)	21 (31.3)	43 (26.4)	
Body fat (%)[b]				
Low	11 (4.8)	4 (6.0)	7 (4.3)	0.677
Normal	117 (50.9)	36 (53.7)	81 (49.7)	
High	102 (44.3)	27 (40.3)	75 (46.0)	
Visceral fat (%)[b]				
Normal	203 (88.3)	52 (77.6)	151 (92.6)	< 0.01
High	19 (8.3)	10 (14.9)	9 (5.5)	
Very high	8 (3.5)	5 (7.5)	3 (1.9)	
Skeletal muscle (%)[b]				
Low	52 (22.6)	22 (32.8)	30 (18.4)	0.110
Normal	172 (74.8)	44 (65.7)	128 (78.5)	
High	5 (2.2)	1 (1.5)	4 (2.5)	
Very high	1 (0.4)	0 (0.0)	1 (0.6)	

[a] Unpaired Student *t* - test; [b] Chi-Square

Table 3. Basal metabolic rate and pulmonary function of respondents.

	Male (n = 67)	Female (n = 163)	*P* - value
BMR(kcal/day)	1303.6 (163.5)	1074.5 (149.6)	< 0.01
FVC (L)	3.2 (0.8)	2.3 (0.7)	< 0.01
FEV_1 (L)	2.6 (0.7)	1.9 (0.6)	< 0.01
FEV_1/FVC (%)	82.3 (12.7)	82.7 (14.2)	0.535

Table 4. Multiple Linear Regression analysis for association between BMR, body composition and pulmonary function test (n = 230).

	Adjust β	95% CI	*P* - value
BMI	0.002	- 0.003 – 0.003	*NS*
% Visceral fat	0.620	24.436 - 32.738	< 0.001
% Body fat	0.134	0.596 - 0.762	*NS*
Skeletal muscle	0.089	- 0.004 – 0.039	NS
FVC (L)	0.152	19.762 - 49.038	< 0.001

Adjusted for gender; Adjust.R^2 = 0.831; R Square = 0.735. The model fits reasonably well. Model assumptions were met. There was no interaction between independent variables and multi-collinearity problem.
NS = non significant

Discussion

When compared with mean BMI reported by Malaysian Adult Nutrition Survey (MANS)[23] of 24.4 kg/m^2, our samples reported to have slightly lower mean BMI (23.3 kg/m^2). In terms of classification of BMI, the results of our study indicated the same pattern where 47.7% for males and 41.1% for females were found to be overweight and obese, consistent with the study by Wan Mohamed Radzi CWJ, *et al.* [13] where her team found 40.6% of the undergraduate students from five local universities in Malaysia were overweight and obese. University life is an important period where young adults undergo time of transition that involves adapting to a new environment and different lifestyle. It was during this time, poor dietary practices, unhealthy snacking, poor sleeping quality, lack of motivation to exercise causes the weight gain among the students.[24]

Consistent with other studies, males had a significant higher BMR compared to females. This is supported by the results of this study where there were more females with higher percentage of body fat and lower percentage of skeletal muscle. Muhamad N, *et al.* [16] reported men has higher BMR because they are bigger in size, have less body fat compared to women. While body fat may cause decrease in BMR, skeletal muscle on the hand will increase BMR. However, the result only revealed that visceral fat to be significantly associated with BMR ($P < 0.001$), not body fat. Johnstone AM, *et al.* [25] reported that fat free mass exerted more effect on BMR than fat mass, although they further emphasized that their findings were based on a statistical analysis rather than a physiological model of BMR. One possible explanation that they said that the presence of fat mass stimulates the metabolic rate of other tissues as a result of adipokine secretions.

There are not many literatures on the association between visceral fat and BMR except one study on type 2 diabetes mellitus with peripheral neuropathy by Sampath Kumar A, *et al.* [26] They found that BMR increases with increased visceral fat, with the explanation that visceral adipose tissue contains an increased blood flow that is more responsive to norepinephrine and increase sympathetic nervous system activity. As such, we are not able to understand whether organ-specific metabolic rates according to the location of body fat influence the BMR of an individual. However, from the derived multiple linear regression, the coefficient relating to BMR to visceral fat was 0.620.

Unlike other studies, this study has found no significant association between skeletal muscle and BMR. Perhaps this is due to the study sample has low proportion of high and very high skeletal muscle (2.6%) that did not contribute to the analysis. About 22.6% of our study sample showed low percentage of skeletal muscle, a possible indication of physical inactivity among the respondents. BMR depends on the fat-free/muscle mass and metabolic rate of tissues and organs.[27] To further elaborate this, Speakman JR. and Selman C.[28] explained that physical activity may have distinct influence on BMR through: 1) effect of physical activity training that affect the growth of fat-free mass and changes in BMR may be associated with the increase in fat-free mass; and, 2) effect of physical activity on physiological processes that influence residual resting metabolism. Such effects best occur in long term physical training period.

The results revealed in this normal physiological samples, males had better lung function capacity than females, consistent with Merghani TH, *et al*.[4] Males had prominent higher mean values in all pulmonary variable and lower air resistance compared to females due to anatomical difference.[29] However, such findings were contrast with the study by Muhamad N, *et al*.[16] They argued it is difficult to determine as their samples were homogenous in nature, comprised of young adults. We have further explored such difference could have related to obesity based on Liu P, *et al*. [30] where the team believed BMI may not be an appropriate predictor of obstructive lung dysfunction, particularly in sample with low prevalence of obesity. Instead, the presence of restrictive respiratory pattern is associated with obesity.

In studies among elderly, better pulmonary function were observed among those with higher BMR.[31] Such findings were not supported by Muhamad N, *et al*. [16] where they found no correlation between lung function and BMR among their younger respondents. In another study comparing the both athletes and non-athletes on the oxygen consumption and BMR, the researchers reported the same findings where enhanced respiratory functional capacity does not lead to enhancement of BMR.[32] Our sample despite been young and aged 19 - 22 years old, showed there was significant association between FVC (L) with BMR. Perhaps there are other confounding factors to be considered which is beyond the scope of this study. There is more need to be further explored in future studies.

The study, however, had the limitation of generalization and the findings can only be used for any other populations with similar characteristics. We also acknowledged the possible confounding factors related to obesity such as physical activity and fitness level affect pulmonary function, which was not within the scope of this study. In addition, measuring BMR using calorimetry remains as the gold standard in determining BMR. Nevertheless, due to cost and time constraint, current method using predictive formula still remained relevant.

Conclusion

In conclusion, visceral fat and pulmonary function were significantly associated with BMR after adjusted for gender. Among the significant independent variables, visceral fat has a stronger effect on BMR compared to the other indicator. There are many hypotheses on how visceral adipose tissue play a role in influencing BMR physiologically which can be explored further in future research. Further studies regarding hormonal factor, behavioral habits and physical activity are needed to rexplain why BMR is associated with visceral fat and pulmonary function.

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Conflict of interest

We declare, hereby, that we have no conflict of interest.

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