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Original Research Article

Body Mass Index and Body Fat Percentage for the Assessment of Obesity-Induced Abnormalities in Dynamic Lung Volumes

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Abstract

The body mass index (BMI) is commonly used in the assessment of obesity and overweight; however, its use in the diagnosis of adverse effects of obesity is questioned. This study aims to explore the agreement between the BMI and the calculated body fat percentage (BF%) in detecting obesity-induced ventilatory abnormalities. We carried out a cross-sectional study on a random sample of 150 healthy male students, aged 17 to 25, with a mean age of 20.8 ± 2.6 years. We measured the BMI, BF%, and pulmonary function of each participant. The students were classified into overweight-obese and normal groups based on the BMI and the BF% results. The Chi-square test was performed to analyze differences between the groups. About one-fifth of all participants had a fat mass ≥ 20%, among which 90% fulfilled the BMI definition of overweight and obesity ($p < 0.05$). The comparison between the two BF% groups showed that 20% of the overweight-obese group had a significant reduction in FEV1 (p= 0.025, Relative Risk= 3.00, 95% Confidence Interval= 1.13-7.99), and 23% of them had a significant reduction in FVC (p= 0.012, Relative Risk= 3.11, 95% Confidence Interval= 1.26-7.68). The changes in FEV1/FVC were statistically insignificant. The effects of the BMI categories on the dynamic lung volumes were statistically insignificant. The direct estimation of BF% is better than the calculation of BMI in the diagnosis of obesity-induced abnormalities in lung function. The use of BMI as an indicator of obesity in population health studies should be avoided.

Keywords: Obesity; BMI; Skinfold thickness; Lung function, FVC; FEV1.

INTRODUCTION

A recent review of body mass index (BMI) trends over the past four decades has shown a universal increase in the prevalence of obesity among both males and females (NCD-RisC, 2016). As reported in the review, the prevalence is plateaued in many high-income countries while increasing in some low and moderate-income countries (NCD-RisC, 2016). To curb the rise of obesity, governments have to raise community awareness about its adverse health consequences and encourage research on this area. Besides, effective health intervention programs are necessary to endorse physical activity and promote the consumption of a healthy diet with a low intake of fat and sugar that increase the risk of many chronic diseases, including obesity. The success of these programs requires appropriate planning that depends on the correct estimation of the problem size.

There are several simple methods for the assessment and classification of obesity. The Body Mass Index (BMI) was adopted by the WHO in the early 1990s as an indicator of the physical status (WHO, 1995). Since then, it becomes widely accepted because of its correlation with the amount of body fat (BF) in the majority of individuals (Misra *et al*, 2019); however, it does not differentiate between lean body mass and fat mass; and therefore, it may give wrong results (Nuttall, 2015). Another simple measurement is the skinfold anthropometry that, when compared to the DXA scan, provides an accurate estimation of the body fat percentage (BF%) (Juan *et al*, 2018). The method gives highly reproducible results for individual persons.

Obesity and overweight have adverse effects on many systems in the body, especially the respiratory system (Anne *et al*, 2018; Yunus *et al*, 2015; Forono, *et* *al*, 2018). Total BF and central adiposity are inversely associated with lung function, whereas increased fat-free mass, reflecting an increase in muscle mass, is associated with improved lung function. Therefore, the obesity parameters should be considered in addition to sex, age and height when selecting reference values for ventilatory parameters.

Many previous studies reported a variable reduction in the static lung volumes that is induced by obesity, with inconstant findings regarding the dynamic lung volumes (Yunus *et al*, 2015; Forono, *et al*, 2018). This study aims to determine the effects of overweight and obesity, as defined by either the BMI or the calculated BF% on the dynamic lung volume indicators and to explore the agreement between the two parameters in detecting obesity-induced ventilatory abnormalities.

Experimental section

We carried out a cross-sectional study on a random sample of medical students from the University of Khartoum, Sudan. The Research Ethics Committee of the University approved the study. All the participants gave their written consent before enrollment in the study. The total number of participants was 150, aged 17 to 25, with a mean age of 20.8 (SD 2.6) years. We included normal male students who reported no current or past history of medical abnormalities that could affect the respiratory system. Female students were excluded to eliminate the gender effect on the results.

The students were invited to participate after random selection from class lists. Each student filled a questionnaire requesting information about his age, current health status and past medical history. A standardized height and weight scales were used for measurement of the height and weight of each participant. The spirometer (All Flow, Clement Clarke International, UK) was used for the measurement of the FVC, FEV1, and FEV1/FVC. The measurements were carried out according to the spirometry guidelines of the American Thoracic Society (Culver *et al*, 2017). Three acceptable and reproducible readings per participant were obtained, and the highest of these was recorded (Culver *et al*, 2017). A Harpenden skinfold caliper (Baty International, UK) was used for measurement of skinfold thickness from four different anatomical sites for each student (biceps, triceps, subscapular, and suprailiac). All measurements were taken from the right side of the body. Each site was measured once until all sites were measured and then the cycle was repeated until a minimum of three times were completed for each site. The average of the scores at each site was taken for the final skinfold result. The BF% was calculated by the Siri formula "$BF = (4.95/\rho - 4.50) \times 100$" (Durnin *et al*, 1967); where, ρ is the body density in kg/L, calculated from the sum of the four skinfolds (triceps, biceps, subscapular and suprailiac) using the Durnin & Womersley formula "Density = 1.1620 - 0.0630 X (for age 17 to19 years old) or Density = 1.1631 - 0.0632 X (for age 20 to 29 years old)"; where X is the log of the sum of all four skinfold thickness in mm.

The obtained data were analyzed using the Statistical Package for the Social Sciences (SPSS Version 20.0, Chicago, IL, USA). The students were classified into two groups, overweight-obese and normal, based on BF% (cutoff point 20%), and BMI (cutoff point 25.0). The chi-square test was used to analyze the distribution of categorical variables. Statistical significance was accepted for p-values less than 0.05.

RESULTS

Table 1 summarizes general characteristics of the participants, their spirometry results and mean skinfold thickness values of four sites (biceps, triceps, subscapular and suprailiac).

Table-1: General Characteristics and Measurement Results of the Participants

Variable	Mean	SD
Age (y)	20.8	2.6
Weight (kg)	69.30	15.58
Height (m)	177.22	6.50
BMI	22.21	4.88
Biceps (mm)	6.31	2.77
Triceps (mm)	10.11	2.90
Subscapular (mm)	8.77	2.78
Supra-iliac (mm)	15.45	9.29
BF%	16.47	4.31
FEV1 (L)	3.55	0.48
FVC (L)	4.03	0.49
FEV1/FVC Ratio	88.87%	7.13%

The calculated percentage of body fat ranged from 7.9% to 30.8%, with a mean of 16.47% (SD 4.31%). About one-fifth of the participants had ≥ 20% fat mass, among which 90% fulfilled the BMI definition of overweight and obesity, whereas 13.3% of those with low BF% (<20%) were classified as overweight-obese as per the BMI definition ($p < 0.05$), (table 2).

Table-2: Distribution of the participants by the body mass index versus the body-fat percentage

	Percentage of body-fat (BF%)		
BMI Categories	Overweight-Obese (BF% ≥20%)	Normal (BF% <20%)	Total n= 150
Normal (< 25.00)	3 (10%)	104 (86.7%)	107 (71.3%)
Overweight/ obese (≥ 25.00)	27 (90%)	16 (13.3%)	43 (28.7%)

P< 0.05

A comparison between the two BF% groups showed that 20% of the overweight-obese participants had significant reduction in FEV1 (Relative Risk= 3.00, 95% Confidence Interval= 1.13-7.99), and 23% of them had significant reduction in FVC (Relative Risk= 3.11, 95% Confidence Interval= 1.26-7.68); compared to only 6.7% and 7.5% of the normal group, respectively; $p < 0.05$ (table 3).

Table-3: Impact of the body fat percentage on the dynamic lung volumes

Dynamic lung volume indicators		**Body fat percentage (BF%) groups**		**P-value**
		Normal n= 120	**Overweight-Obese n= 30**	
FEV1*	Normal (> 80% of predicted)	112 (93.3%)	24 (80%)	0.025*
	Low (< 80% of predicted)	8 (6.7%)	6 (20%)	
FVC*	Normal (> 80% of predicted)	111 (92.5%)	23 (77%)	0.012*
	Low (< 80% of predicted)	9 (7.5%)	7 (23%)	
FEV1/FVC%	Normal 70-100% of predicted)	115 (95.8%)	28 (93%)	0.561
	High (> 100% of predicted)	5 (4.2%)	2 (7%)	

*Statistically significant difference (p< 0.05)

The changes in FEV1/FVC were statistically insignificant. Table 4 shows that the difference between the two BMI categories in the dynamic lung volumes was statistically insignificant.

Table-4: The relation between BMI and dynamic lung volumes

Dynamic lung volume		**Body Mass Index Categories**		**P-value**
		Normal n= 107	**Overweight-Obese n= 43**	
FEV1	Normal (> 80% of predicted)	99 (83%)	37 (93%)	0.218
	Low (< 80% of predicted)	8 (17%)	6 (7%)	
FVC	Normal (> 80% of predicted)	97 (90%)	37 (97%)	0.408
	Low (< 80% of predicted)	10 (10%)	6 (3%)	
FEV1/FVC%	Normal (70-100% of predicted)	102 (90%)	41 (93%)	0.995
	High (> 100% of predicted)	5 (10%)	2 (7%)	

DISCUSSION

Both the body fat percentage and the body mass index are frequently used for the assessment of obesity. Both measurements are simple, cheap and safe; however, certain limitations might curb their usage. For example, the precision of the skinfold thickness measurements could be affected by operational and observational errors (Zemski *et al*, 2018), whereas the BMI gives higher values in the short and muscular individuals (Nuttall, 2015). Besides, the selection of skinfold site, their number, and the use of a suitable equation for BF% estimation are additional sources of error.

In this study, we classified the participants into two groups, normal and overweight-obese, based on a cutoff value of 25.00 for the BMI and a cutoff point of 20% for the BF%. The group with high BF% (overweight-obese) represented 20% of the sample, whereas those with high BMI ≥ 25.00 were 28.7% of all participants. Our findings indicate that the BMI overestimates the percentage of overweight and obese individuals; however, 90% of those who had high BF% (≥ 20%) also had high BMI (≥ 25.00), indicating a high degree of agreement in the diagnosis of obesity.

Obesity exerts a direct mechanical effect on chest compliance. The accumulation of fat in the subcutaneous layer and around the viscera reduces chest expansion and causes a restrictive pattern on spirometry (Singh *et al*, 2017). In addition, recent studies reported increased airway resistance in obese subjects (Barros *et al*, 2016). All these effects could explain the reduction in FEV1 & FVC that is reported by many researchers (Anne *et al*, 2018; Yunus *et al*, 2015; Forono *et al*, 2018, Singh *et al*, 2017). Similarly, in this study, more than 30 participants (20%) who presented with high BF% showed a significant reduction in FEV1 and/or FVC. It is worth noting that, the predominant lung function abnormality is a reduction of the static lung volumes (e.g., functional residual capacity (FRC)), which were not measured in this study; however, both types of abnormality (reduced FVC or reduced FRC) indicate a restrictive pattern of lung disease. Since the FEV1/FVC ratio is usually high in restrictive patterns, the results of lung function tests might be inconclusive in obese patients and the diagnoses of obstructive pulmonary diseases like asthma for them could be delayed (Yunus *et al*, 2015).

Unlike the BF%, the BMI showed insignificant differences in FEV1, FVC and FEV1/FVC between the two BMI groups. This indicates that the direct calculation of the BF% could be better than the BMI when reporting the effects of obesity on respiratory function. Correspondingly, recent studies concluded that BMI is a poor indicator of ill health (Nuttall, 2015). Besides, the BMI may overestimate obesity in short-muscular individuals (Nuttall, 2015). Likewise, a large survey found that a high BMI, in the range of 24 to 28, is associated with better survival and lower risk of mortality (Pischon *et al*, 2008). These findings suggest that BMI is not suitable for population-based studies that investigate the health consequences of obesity.

Our study has many limitations that need to be considered. The number of obese participants is relatively small, the inclusion of overweight students with the obese students in the same group might mask negative effects of obesity, and the cross-sectional design of the study would not allow follow up of lung function or comparison of the results before and after the development of obesity.

CONCLUSION

The study showed that the direct estimation of BF% could be better than the calculation of BMI in the diagnosis of obesity-induced impairment of lung ventilatory functions. Therefore, use of BMI in health surveys as an indicator of obesity should be discouraged.

REFERENCES

- Anne, E., Dixon, Ubong, P. (2018). The effect of obesity on lung function. Expert Review of Respiratory Medicine, *12*(9):755-767. DOI: 10.1080/17476348.2018.1506331.
- Barros, R., Moreira, P., Padrao, P., Teixeira, V.H., Carvalho, P., Delgado, L. (2016). Obesity increases the prevalence and the incidence of asthma and worsens asthma severity. Clin Nutr., *36*(4); 1068-1074.
- Culver, B. H., Graham, B. L., Coates, A. L. (2017). Recommendations for a Standardized Pulmonary Function Report. An Official American Thoracic Society Technical Statement. Am J Respir Crit Care Med, 196(11):1463-1472.
- Durnin, J. V., Rahaman, M. M. (1967). The assessment of the amount of fat in the human body from measurement of skinfold thickness. Br. J. Nutr., 21: 681-689.
- Forno, E., Han, Y., Mullen, J., Celedon, J.C. (2018). Overweight, Obesity, and Lung Function in Children and Adults—A Meta-analysis. The Journal of Allergy and Clinical Immunology: In Practice, *6*(2):570-581.e10.
- Juan, R.L., Roberto, G. G., Alejandro G. (2018). Accuracy of Anthropometric Equations for Estimating Body Fat in Professional Male Soccer Players Compared with DXA. Journal of Sports Medicine, vol. 2018, Article ID 6843792, 7 pages. https://doi.org/10.1155/2018/6843792.
- Misra, P., Singh, A.K., Archana, S., Lohiya, A., Kant, S. (2019). Relationship between body mass index and percentage of body fat, estimated by bio-electrical impedance among adult females in a rural community of North India: A cross-sectional study. *J Postgrad Med, 65*(3); 134-140.
- NCD Risk Factor Collaboration. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. The Lancet, *390*(10113): 2627-2642.
- Nuttall, F.Q. (2015). Body Mass Index: Obesity, BMI, and Health: A Critical Review. *Nutr Today*, *50*(3); 117-128.
- Pischon, T., Boeing, H., Hoffmann, K. (2008). General and abdominal adiposity and risk of death in Europe. *N Engl J Med*, *359*(20); 2105–2120.
- Singh, J.P., Nagvanshi, S. (2017). Effect of increasing body fat on pattern of pulmonary function: A prospective study. *Int J Med Sci Public Health, 6*(9); 1417-1420.
- World Health Organization. (1995). Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *WHO Tech Rep Ser*, 854: 1–452.
- Yunus, Ç., Jacob, L. M., Jørgen, V., Peter, L. (2015). Overweight and Obesity May Lead to Under-diagnosis of Airflow Limitation: Findings from the Copenhagen City Heart Study, COPD: *Journal of Chronic Obstructive Pulmonary Disease, 12*(1):5-13. DOI: 10.3109/15412555.2014.933955
- Zemski, A. J., Broad, E. M., Slater, G. J. (2018). Skinfold Prediction Equations Fail to Provide an Accurate Estimate of Body Composition in Elite Rugby Union Athletes of Caucasian and Polynesian Ethnicity. International Journal of Sport Nutrition and Exercise Metabolism, *28*(1): 90-99. DOI: https://doi.org/10.1123/ijsnem.2017-0251.