Middle-East Journal of Scientific Research 7 (5): 634-642, 2011
ISSN 1990-9233

Anthropometric Measurements and Ventilatory Function in Obese and Non-Obese Female College Students

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Abstract: Obesity is global risk factor for many health problems. The aims of this study were to assess the relationship between the anthropometric measurements [Body mass index (BMI), waist circumference (WC), waist-hip ratio (WHR) and abdominal circumference (AC)] and ventilatory function parameters [Vital capacity (VC), forced expiratory volume (FEV_1), maximum ventilatory ventilation (MVV)] and to investigate the impact and association of cut-off values of BMI, WC and WHR with ventilatory function in obese and non-obese young females. This cross-sectional study was conducted on 69 Saudi female students aged between 18-26 years. All participants were subjected to anthropometric and ventilatory function measurements. The results revealed variable relationships between the anthropometric measurements and parameters of ventilatory function. In obese group BMI was negatively associated with FEV/FVC (β = -0.497, P = 0.026), on average one kg/m^2 increase in BMI resulted in 1.80% reduction in FEV_1/FVC ratio. The WC $\geq$ 88 cm was negatively associated with VC (β = -0.538, P=0.031), FVC (β = -0.624, P=0.010) and FEV_1 (β=-0.609, P=0.012). On average, one cm increase in WC was associated with 3.8 mL reduction in VC, 4.41 mL reduction in FVC and 4.3 mL reduction in FEV_1.The WHR $\geq$ 80% was negatively associated with VC (β = -0.710, P=0.021), on average one percent increase was associated with 2.492 mL reduction in VC. In conclusion, that trunk obesity as measured by WC, WHR and AC is more significant predictor to ventilatory function than overall obesity measure, BMI.

Key words: Obesity · Body mass index · Waist circumference · Waist-hip ratio · Abdominal circumference · Ventilatory function

INTRODUCTION

Obesity is defined as an excessive accumulation of fat that causes a generalized increase in body mass. Obesity is one of the most frequently found health risks and its prevalence appears to be increased all over the world [1, 2]. There is no doubt that its percentages are even greater nowadays because of physical inactivity and westernization in diet [3, 4]. Many studies indicated the association between obesity and a wide range of health problems, including respiratory diseases, cardiovascular disease, hypertension, type 2 diabetes, dislipidemia and cancers [5-9]. Obesity is likely a cause of pulmonary functions decline. Respiratory function is determined by the interaction of lungs, chest wall and muscles. Trunk obesity reduces chest wall compliance, respiratory muscle function and peripheral airway size[10].

Several anthropometric measures like body mass index (BMI), waist circumference (WC), waist-hip ratio (WHR) and abdominal circumference (AC) have been used as measures of overall adiposity and as predictor of pulmonary function in many epidemiologic studies [11,12]. Cut-off values of these measures can also be used to describe the strength and effect size of association of determinants on health outcomes [13]. There has been increasing interest in the association between the body fat distribution and lung functions [2, 14]. Many investigators have evaluated the relation of BMI, WC, WHR and AC to ventilatory function testing variables [2-4]. However evidence based practice and decision making raised the need to explore whether the measures of obesity; BMI, WC, WHR and AC have similar correlation with ventilatory function. Furthermore, additional

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analyses are needed to identify the impact and association of BMI, WC and WHR with ventilatory function. The aims of this study were to assess the relationship between the anthropometric measurements and ventilatory function and to investigate the impact and association of cut-off values of BMI, WC and WHR with ventilatory function in obese and non-obese female college students.

MATERIALS AND METHODS

Subjects: This study was conducted on 69 Saudi female students aged between 18-26 years recruited from College of Applied Medical Sciences (CAMS), King Saud University (KSU). They were free from bronchial asthma, use of steroids or bronchodilators, bronchiectasis, clinical neurological deficits, cardiac and chest diseases or spine deformities. Written informed consent was obtained from each participant. The study was approved by the Rehabilitation Health Sciences Department CAMS, KSU.

Procedures: The present investigation was designed as cross-sectional study. A digital weight and height scale [ProDoc (DETECTO)] was used to measure body weight (BW) to the nearest 0.1Kg and body height (BH) to the nearest 0.5cm. Subjects were weighed without shoes, in light clothing with the shoulders in relaxed position and arms hanging freely. The BMI was calculated as BW in kilograms (kg) divided by the BH in meter square (m^2). Tape measure was used for the circumference measurements. The WC was measured around the abdomen on the midpoint between the lower border of the rib cage and the iliac crest, while the participant was standing with the abdomen relaxed, both feet touching and arms hanging freely at the end of normal expiration. Where there was no natural waist line, the measurement was taken at the level of the umbilicus. The HC was measured at the maximum circumference between the iliac crest and crotch while the participant was standing and was recorded in the same position. The AC was measured just above the iliac crest [4, 10, 12]. Central obesity was also calculated and defined on the basis of WHR (WC/HC %).

Obesity was assessed using the BMI and fat distribution. According to World Health Organization (WHO) criteria the participants were categorized into normal: BMI 18.5 ≤ 24.9 kg/m^2, overweight: BMI 25 ≤ 29.9kg/m^2 or obese: BMI ≥ 30 kg/m^2 [10]. Based on the National Institute of Diabetes, Digestive and Kidney Diseases (NIDDK) criteria [15, 16] the participants were divided according to fat distribution (WC and WHR) into low and high health risk cut-off values. The WC <88cm is considered as low risk and WC≥ 88cm is high risk. While WHR <80% indicates low risk and ≥ 80% represents high risk [17, 18] (Table 1).

Ventilatory function tests were performed using a Micro Lab 3300 portable spirometer (Micro Medical Ltd; Chorley, Lancashire, England). From standing position, the participant carried out three spirometry tests guided by the following instructions; a) For Forced Vital Capacity (FVC) maneuver: 1- Wear the nose clip 2- Inhale slowly and fully. Place lips around disposable mouthpiece. 3- Exhale full and with as much force as possible, blasting out all the air in the lungs. b) For Vital Capacity (VC) maneuver: 1- Wear the nose clip. 2- Place disposable mouthpiece in mouth. 3- Breath normally. 4- When prompted by "Begin VC or IVC test" (on the screen) inhale fully. 5- Exhale slowly and as fully as possible. 6- Breath normally until test ends. c) For Maximum Voluntary Ventilation (MVV) maneuvers: 1- Wear the nose clip. 2- Place disposable mouthpiece in mouth 3- Inhale and exhale fully and as completely, as fast as possible until test ends. Each participant repeated each test 3 times with 30 seconds rest interval. The average of the three trials was recorded.

Table 1: Cut-off values of BMI and fat distribution (WC and WHR).

Measurements	Cut-off values	
BMI (kg\ m^2)	Normal	18.5 ≤ 24.9
	Overweight	25 ≤ 29.9
	Obese	≥ 30
WC (cm)	Low risk	<88 cm
	High risk	≥ 88 cm
WHR (%)	Low risk	<80%
	High risk	≥ 80%

Data Analysis: The collected data were statistically treated using the Statistical Package for the Social Sciences [SPSS, Version 16 (SPSS Inc. IBM Company Headquarters, Chicago, USA)]. Descriptive statistics means and standard deviations, of anthropometric measurements and ventilatory function were carried out. Pearson correlation coefficient was used to quantify the relationship between anthropometric measurements (BMI, WC, HC, WHR and AC) and ventilatory function (VC, FVC, FEV_1, FEV_1/ FVC and MVV). In addition, linear regression analysis was conducted to study the association of the cut-off values of BMI, WC and WHR with ventilatory function. Chi-square test was carried out to study the relationship between the cut-points cut-off values of MBI, WC and WHR. Confidence interval 95% was assigned so P value < 0.05 was considered.

RESULTS

The main anthropometric measures and ventilatory function testing variables are shown in Table 2. Table 3 shows Pearson correlation coefficient between anthropometric measures of obesity and ventilatory function. Very strong correlations were found between BMI, WC, HC and AC (r = 0.860), (r = 0.898) and (r = 0.8580) respectively. While it had moderate correlation with WHR (r = 0.430).A moderate negative correlation was found between BMI and FEV_1/FVC (r=-0.360). On other hand there was poor negative correlation between HC and FEV_1/FVC (r = -0.253). When correlating the WHR with VC and MVV, poor negative correlation were found (r = -0.299) and (r = -0.290), respectively. Negative correlation was also found between AC and FEV_1/FVC (r = -0.255).

Table 2: Measurements characteristics of the studied subjects

Variables	Mean ± SD	Minimum	Maximum
Age (yr)	20.37±1.69	18.00	26.00
Height (m)	1.59±5.87	1.38	1.71
Weight (Kg)	68.29±15.98	43.40	109.50
BMI (Kg/m^2)	27.18±5.93	18.60	44.50
WC (cm)	76.33±10.85	59.00	112.00
HC (cm)	104.1±10.49	89.00	129.00
WHR (%)	73.13±5.84	60.00	91.00
AC (cm)	88.19±12.56	65.00	125.00
VC (L)	2.55±0.54	0.52	3.80
FVC (L)	1.74±0.46	0.35	2.80
FEV_1 (L)	1.69±0.45	0.35	2.80
FEV_1/FVC %	96.51±5.76	71.00	100.00
MVV (L/min)	63.65±14.89	32.00	96.00

Yr: year, m: meter, Kg: kilogram, cm: centimeter, L: litter, min: minute, Kg/m^2: : kilogram per meter square, L/min litter\ minute,

Table 3: Correlation between anthropometric measurements and ventilatory function

Variables	Age	Height	Weight	BMI	WC	HC	WHR	AC	VC	FVC	FEV_1	FEV_1 /FVC	MVV
Age	1	-0.124	-0.008	0.034	0.218	0.053	0.333^{**}	0.101	-0.056	-0.086	-0.034	0.181	-0.195
Height		1	0.368^{**}	0.099	0.131	0.322^{**}	-0.124	0.307^{*}	0.251^{*}	0.092	0.077	0.026	0.171
Weight			1	0.950^{**}	0.833^{**}	$.941^{**}$	0.344^{**}	0.890^{**}	0.158	0.122	0.012	-0.338^{**}	-0.048
BMI				1	0.860^{**}	0.898^{**}	0.430^{**}	0.858^{**}	0.064	0.081	-0.030	-0.360^{**}	-0.126
WC					1	0.824^{**}	0.744^{**}	0.889^{**}	-0.078	-0.063-	-0.114	-0.153	-0.168
HC						1	0.262^{*}	0.863^{**}	0.148	0.107	0.021	-0.253^{*}	-0.015
WHR							1	0.509^{**}	-0.299^{*}	-0.178	-0.163	0.036	-0.290^{*}
AC								1	0.008	-0.058-	-0.140	-0.255^{*}	-0.143
VC									1	0.397^{**}	0.397^{**}	0.011	0.287^{*}
FVC										1	0.966^{**}	-0.082	0.747^{**}
FEV_1											1	0.162	0.783^{**}
FEV_1/FVC												1	0.191
MVV													1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: Association between BMI, WC, WHR and ventilatory function obtained by linear regression analysis

	VC		FVC		FEV1		FEV_1/FVC		MVV	
Cut-off values	ß	P	ß	P	ß	P	ß	P	ß	P
BMI (Kg/m^2)										
18.5=24.9 [n=27, (39.1%)] (21.64±2.22)	.420	.029*	.240	.228	.240	.227	.267	.178	.088	.662
25 = 29.9 [n=22, (31.9%)] (27.13±1.44)	.261	.240	.128	.571	.112	.621	-.083	.715	.116	.607
≥ 30 [n=20, (29%)] (34.74±3.63)	-.046	.847	.042	.859	-.117	.624	-.497	.026*	-.065	.786
WC (cm)										
<88 cm [n=53, (76.8%)] (71.49±6.04)	0.144	0.303	0.203	0.145	0.206	.139	.146	.297	.097	.490
≥ 88 cm [n=16, (23.2%)] (92.38±7.06)	-.538	.031*	-.624	.010*	-.609	.012*	.066	.809	-.370	.158
WHR %										
< 80% [n=59, (85.5%)] (71.78±4.1)	-.125	.358	.152	.263	.122	.902	-.113	.406	-.042	.758
≥ 80% (n=10, (14.5 %)) (82.97±3.51)	-.710	.021*	-.490	.150	-.501	.140	-.034	.925	-.266	.457

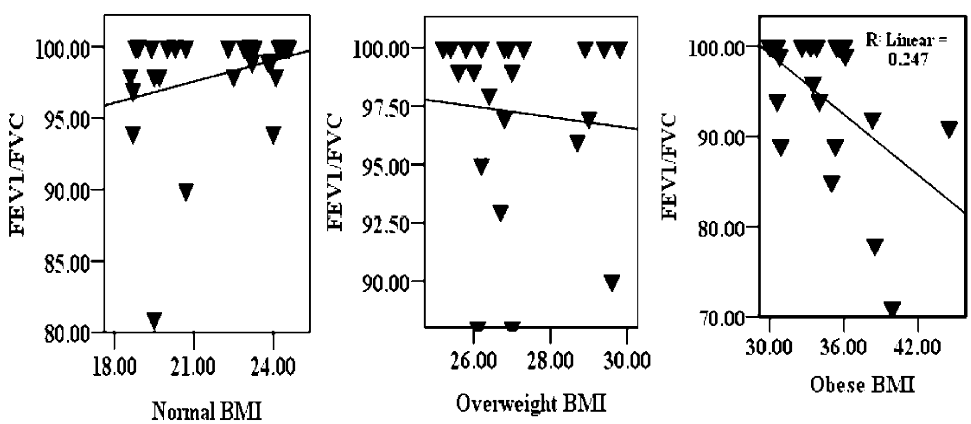

Fig. 1: Linear regressions of FEV1/FVC and BMI subgroups

The VC showed moderate positive correlation with FVC (r = 0.397), FEV_1 (r = 0.397) and poor positive correlation with MVV (r = 0.287). Furthermore, strong positive correlation was observed between FVC and FEV_1, MVV (r = 0.966) and (r = 0.747), respectively. Finally strong positive correlation was observed between FEV_1 and MVV (r = 0.783).

Results of linear regression in Table 4 showed that in normal weight group, BMI was positively associated with VC (β = 0.420,P=0.029), on average one kg/m^2 increase in BMI was associated with 0.93 mL increase in VC. On other hand in obese group BMI was negatively associated with FEV_1/FVC ratio (β = -0.497, P = 0.026). On average one kg/m^2 increase in BMI resulted in 1.80% reduction in FEV_1/FVC ratio (Fig. 1). Furthermore, WC ≥ 88 cm was negatively associated with VC (β = -0.538, P = 0.031), FVC (β = -0.624, P = 0.010) and FEV_1 (β = -0.609, P = 0.012). On average, one cm increase in WC was associated with 3.8 mL reduction in VC, 4.41 mL reduction in FVC and 4.3 mL reduction in FEV_1(Figures 2,3,4). Finally WHR ≥ 80% was

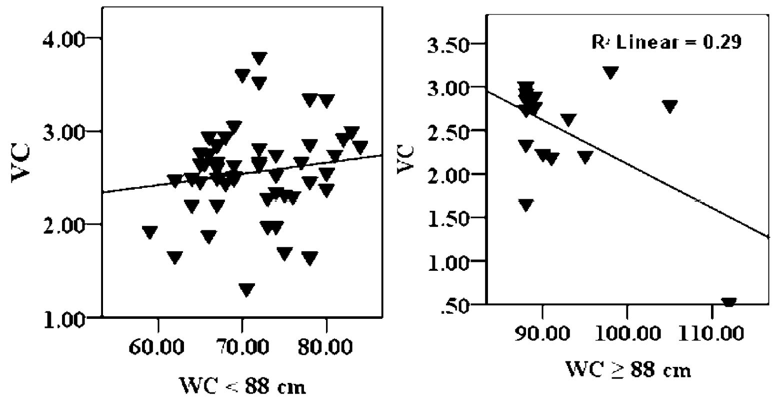

Fig. 2: Linear regressions of VC and WC cut-off values

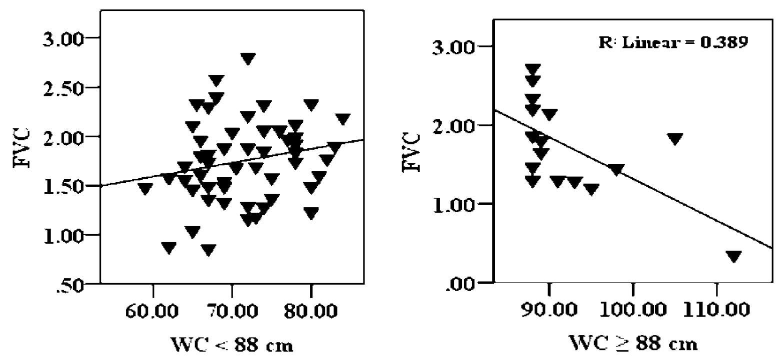

Fig. 3: Linear regressions of FVC and WC cut-off values

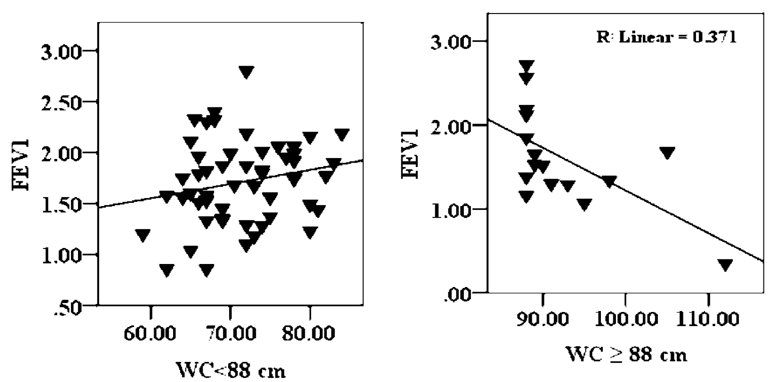

Fig. 4: Linear regressions of FEV1 and WC cut-off values

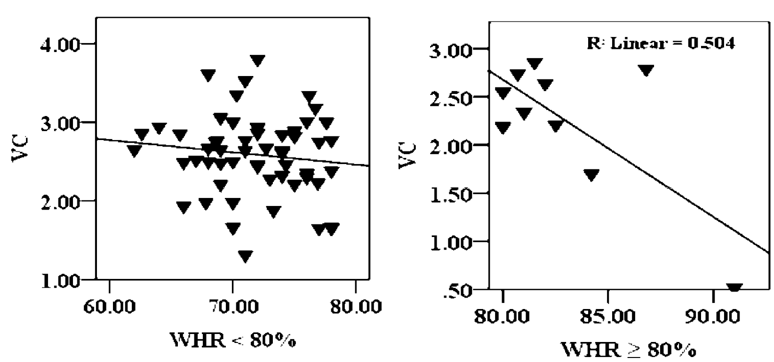

Fig. 5: Linear regressions of VC and WHR cut-off values

Table 5: Cross tabulation between cut-off values of BMI, WC and WHR

	WC		WHR		
BMI Kg/m^2	<88 cm	≥ 80 cm	< 80%	≥ 80%	P- value
18.5 ≤ 24.9	100.0%	.0%	96.3 %	3.7%	0.000
25 ≤ 29.9	100.0%	.0%	100.0 %	.0%	
≥ 30	20%	80%	55.0 %	45.0%	

negatively associated with VC (β = -0.710, P = 0.021). On average one % increase in WHR was associated with 2.492 mL reduction in VC (Fig. 5). The relationships between the cut-off values of BMI, WC and WHR as measured by Chi-square test are presented in Table 5.

DISCUSSION

The aims of this study were to assess the relationship between the anthropometric measurements and ventilatory function and to investigate the impact and association of cut- off values of BMI, WC and WHR with ventilatory function in obese and non-obese female college students. The results of the present study showed that the relationships between the anthropometric measurements and parameters of ventilatory function were variable. The BMI had modest relationship with the ventialtory function. There were negative correlations between BMI and FEV_1, FEV_1/FVC and MVV. Increase in BMI resulted in decrease in those parameters but the only parameter that showed significant decrease with BMI increase was FEV_1/FVC (r = -0.360).

Although there were positive correlations between BMI and both VC and FVC, these two correlations were not statistically significant. These results were explained by Al-Bader *et al.* [14] and Chen *et al.* [19] who stated that BMI can influence the pulmonary function positively through differences in lean body or muscle mass, particularly in non-obese subjects. In consistent with this explanation the results of regression analysis test showed positive association of normal BMI group with VC (β=0.420, P=0.029) and FVC (β=0.240, P=0.228). When the association of BMI with ventilatory function of the 20 obese subjects' was studied, results showed clearer picture to the negative impact of the obesity on the ventilatory function as there were negative association of BMI with all parameters of the ventilatory function with significance to FEV_1/FVC (β = -0.497, P = 0.026). It can be said that higher BMI, obesity, is required to show up the reverse relation between obesity and ventilatory function. This result could be considered as another explanation of positive correlation between BMI and VC and FVC as the majority of the studied 69 subjects were either of normal weight (n = 27) or of overweight subjects (n = 22). Those 49 subjects (27+22) hid the effect of BMI on the 20 obese subjects VC and FVC.

Studying the two components of BMI (height and weight) showed that height is positively correlated to all parameters of the ventilatory function. Increase the subjects' height resulted in increase in their ventilatory function with significance increase in the VC (P < 0.05). The fact that the taller the subjects, the more increase in their ventialtory function is explained by the mechanics of breathing. Increased vertical diameter of the thorax gives more chance for more diaphragmatic excretion. This finding was supported by Al-Bader *et al.* [14], they stated that many studies have shown that sex, age and height, but not body weight, are significantly correlated to pulmonary ventilation. In addition most of the previous studies have shown that the association between ventilatory pulmonary function and body weight is week or non-significant [20-22].

On the other hand, the second component "weight" showed less consistent pattern with the ventilatory function. This emphasis the fact that, it is not the matter of the body weight or overall adipose tissue,BMI, which interfere with the ventilatory function but more important is the trunk adipose tissue, WC. Chen *et al.* [19] stated that although body weight and BMI can be easily measured and therefore are frequently used in large-scale epidemiologic studies, a major limitation of these measures is that they do not distinguish between fat mass and muscle (lean) mass, which have opposite effects on pulmonary function. In addition, body weight and BMI provide no information on the nature of body fat distribution. Lazarus *et al.* [21] also supported this theory as they stated that although BMI now widely used as a measure of obesity, the numerator in the calculation of BMI, body weight, does not distinguish between fat mass and lean tissue mass. Waist circumference showed more straightforward results. It had negative correlation with all of the ventilatory function's parameters but with no significance with any. The subjects with WC ≥ 88 cm showed significant association with VC, FVC and FEV_1

The cross tabulation and chi square analysis indicated that 16 (80%) of the 20 obese subjects were with WC $\geq$ 88 cm while only 4 (20%) of them were of WC $\leq$ 88 cm (P = 0.0001). It could be said that the negative impact on the ventilatory function shown in the obese subjects was dependant on their wide WC rather than their high BMI. Ochs-Balcom *et al.* [23] had similar results at their study and they documented inverse association of waist circumference with pulmonary function in men and women with $\geq$ 25% of BMI. In addition Al-Bader *et al.* [14] said that the restrictive respiratory impairment with obese subjects is due to increase in body fat which perhaps decreases the chest wall compliance due to associated deposition of adipose tissue around the chest and in the abdomen. They added that this effect seems to be stronger than any increase in lean or muscle mass which may occur in these obese subjects.

From clinical point of view, it could be proved that when studying the effect of obesity on the ventilatory function, the trunk obesity or trunk adipose tissue is more important factor than the over all adipose tissue represented by BMI. This is in line with the breathing mechanics in which contraction of the diaphragm during inspiration results in it's descend to increase the vertical diameter of the thorax and increase the intrathoracic negativity. Ochs-Balcom *et al.* [23] found that the trunk obesity or the trunk adipose tissue is the main factor which restricts the movement of the diaphragm. The WHR showed negative correlation with all ventialtory function's parameters except FEV_1/FVC with significant correlation with VC and MVV. These results were supported by Harik-Khan *et al.* [24].They examined the relationship of WHR to FEV_1 and FVC in a large group of subjects and found a strong inverse association between WHR and FEV_1, FVC in men but not in women. In addition Cylan *et al.* [2] found that both FEV_1 and FVC were linearly and inversely related across the entire range of WHR in both men and women.

The results indicated obvious negative impact on the ventialtory function in subjects with WHR$\geq$80% than those with WHR < 80%. In the obese, strong correlation was found between the WHR and WC (r = 0.744). The WC was negatively associated with FVC and $FEV_{1,}$ one cm increase in WC was associated with 4.4 mL reduction in FVC and 4.3 mL reduction in FEV_1. Chen *et al.* [19] reported similar results but with greater value as one cm increase in WC was associated with 13-mL reduction in FVC and 11 mL reduction in FEV_1. The differences between the two studies' results were due to different characteristics of the participated subjects age and gender, the present study's subjects were young females. The AC is another anthropometric measurement that could play an important role when studying the relation between the anthropometric measurements and ventilatory function. The AC showed negative correlation with all ventilatory function's parameters except the VC with significance value with FEV_1/FVC ($P < 0.05$). This could be explained with the fact that trunk obesity reduces chest wall compliance, respiratory muscle function and peripheral airway size [10]. In addition, the mechanical effects of the intra-abdominal pressure on the diaphragm are likely the main reason for the association of central obesity with compromised lung function [19, 25].

A very important practical point was emphasized by Sebo *et al.* [26] as they said that the abdominal obesity can indicate the need for interventions in overweight patients who would otherwise not be considered at risk on the basis of body mass index.

Compile all the above factors indicate that WC is brilliant anthropometric measurement that can clinically be used to measure the impact of obesity on the ventialtory function and that re-appraisal of the BMI for this purpose is necessary. This was in agreement with previous study done by Chen *et al.* [19] who mentioned that WC as a measure of abdominal fat deposition has a somewhat more consistent predictability for pulmonary function than BMI. Furthermore, WHR compared with WC is a more convenient measure and is less likely to be influenced by sex or degree of obesity. Lazarus *et al.* [21] and Ochs-Balcom *et al.* [23] supported this view. They stated that the effects of excess adipose tissue on pulmonary function may be influenced by the location of excess fat deposits as well as by their extent.

CONCLUSION

The findings of the present study suggested that investigators may consider the inclusion of markers of abdominal adiposity (WC, WHR and AC) as a more potential confounding factor than general adiposity markers such as weight and BMI when investigating the parameters of ventilatory function. Anthropometric measurements had different relation patterns with ventilatory function in obese and non-obese young females. Trunk obesity as measured by WC, WHR and AC is more significant predictor of these relations than overall obesity measure, BMI.

RECOMMENDATIONS

Hence, this cross sectional study was conducted on small sample size of young Saudi females, a large sample size of both males and females and longitudinal studies will be of great value in predicting the association between body fat distribution and ventilatory function.

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