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Research Article

ASSOCIATION OF OBESITY AND PHYSICAL ACTIVITY WITH LUNG CAPACITY IN ADULT WOMEN

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ABSTRACT

Background: Obesity and poor respiratory function are associated with morbidity and mortality. Obesity affects lung function, however the impact of all degrees of obesity on lung function need to be explored in different populations and genders. **Aims and Objectives:** The authors investigated the relation of BMI, waist circumference, physical activity with lung function in Hail City, Saudi Arabia. **Materials and Methods:** This analysis included 359 females aged 18–44 years with no known preexisting serious illness and who had complete anthropometric (height, weight and waist circumference) and forced vital capacity (FVC) using simple spirometry and chest measurements. Physical activity was measured using "International Physical Activity Questionnaire" (IPAQ). **Results:** Both FVC and predicted FVC along with chest expansion measurements were linearly and inversely related across the entire range of body mass index (BMI) and waist circumference (WC) and positively associated with physical activity in study subjects even after adjusting for age confirming our hypothesis. However, BMI and physical activity explained the greatest proportion of variance for both FVC and chest expansion in regression analysis as compared to WC. **Conclusion:** In the general adult female population, obesity may play a role in the impairment of lung function even from BMI ≥ 35 kg/m^2 while even moderate physical activity can positively affect lung function.

Keywords: body mass index; chest expansion; forced vital capacity; physical activity; waist circumference

INTRODUCTION

Today obesity is the most significant contributor to mortality and morbidity globally, by being able to virtually affect almost any organ or tissue of the human body.[1] Estimations suggest that in 2008, a whooping 1·46 billion adults globally were overweight and 502 million adults among them were suffering from clinical obesity thereby escalating enormously health burden of the world.[2] Kingdom of Saudi Arabia (KSA) ratifies globesity trends after its recent economic and nutrition transition. A review published in 2011 suggests an astounding two thirds to three quarters of Saudi adult population being either overweight or obese.[3] Hail City in KSA is reportedly having highest prevalence of obesity in the entire kingdom.[4]

Available literature confirms the strong inverse association between severe obesity and lung complications including respiratory diseases such as chronic obstructive pulmonary disease and asthma.[5] Although less established than other non communicable diseases, recent research focus on lung capacity connotes multilayered association with the morbidity and mortality.[6] Studies identifying major etiological factors responsible for diminished lung capacity and it's affect on long term health and quality of life are relatively sparse except for association with smoking. It is also being increasingly documented in research that lung function can be positively influenced by other lifestyle factors like habitual physical activity, physical fitness and healthy body weight.[7]

Obesity can influence lung capacity by creating alterations in respiratory mechanics, decrease in respiratory muscle strength and endurance, decrease in pulmonary gas exchange, lower control of breathing, and limitations in pulmonary function tests and exercise capacity.[8] Extra adipose tissue deposition in the chest wall and abdominal cavity can result in a decrease in lung volumes and an overload of inspiratory muscles by decreasing diaphragm displacement, decrease in lung and chest wall compliance, and an increase in elastic recoil.[9] These changes are worsened by an increase in the BMI[10] and the associations vary in different subpopulations.[11] However, impact of lesser degrees of obesity and/or fat distribution on lung capacity is limitedly reported making it difficult to extract any inferences out of these studies. The importance of understanding these phenomena is slowly gaining attention of researchers around the world.

Body mass index (BMI) is the most commonly used measure of obesity in most epidemiological studies. However, BMI is not a dependable index for understanding distribution of fat in the body and/or for differentiating between muscle mass and fat mass both of which can influence pulmonary function.[12] There are few studies which evaluated the relation of central adiposity indices like waist circumference (WC) and waist to hip ratio (WHR) with pulmonary function but reported conflictory results for gender stratification.[13,14] However it's difficult to infer from these studies that whether predicted results are applicable to all degrees of obesity and to both genders in all racial populations. Also, another important confounding variable physical activity influencing lung capacity has not been studied to a large extent in most of these studies.

In view of the foregoing discussion, we conducted a study to examine the relation between pulmonary function and BMI, waist circumference and physical activity in a given sample of female population. Based on review of literature, we hypothesized that pulmonary function may be positively associated with physical activity and negatively associated with BMI and WC in females.

MATERIALS AND METHODS

The present cross sectional study was carried out at the University of Hail (UOH) female campus with a target population of students and employees with a minimum age of 18 and who were free of any physical deformity. Patients with history of acute or chronic pulmonary disease, neuromuscular disorders, heart failure, severe or poorly controlled hypertension, chronic kidney disease, diabetes mellitus and systemic corticosteroid use were excluded from the study. A total of 359 females fulfilling inclusive criteria participated in the present study after signing informed consent form. We measured height, weight, BMI, WC, physical activity, chest expansion and forced vital capacity of the subjects to examine the study objectives. University of Hail research committee approved the study.

Anthropometric variables considered for the study included body weight, height, BMI and WC. Body weight was measured without shoes and with minimal clothing to the nearest 100 g using a calibrated scale (GIMA Pegaso Electronic Body Scale-Italy). Height was measured to the nearest cm while the subject was in the full standing position without shoes using a calibrated stadiometer attached to the body weight scale. WC was recently reported to be the best simple measure of fat distribution, since it is least affected by sex, race, and overall adiposity.[15] WC was measured horizontally using a non stretchable measuring tape at the level of the umbilicus and at the end of gentle expiration. When measuring WC, the tape was snug, but did not compress the skin. BMI was calculated as a ratio of weight in kg by height squared in meters. We used WHO adults' cut-off points for BMI.[16]

Chest expansion (CE) was measured by the tape measurement at the level of the 4th intercostals space. Subjects were asked to inspire maximally from her nose with closed mouth to fill her lung by air. This is done a minimum of twice and the greater excursion recorded. The participants were asked “please take a deep breath in as far as you can, hold, and then breathe out as far as you can”.

Physical activity is bodily movement produced by the skeletal muscles that results in energy expenditure above the resting value.[17] Because of its complexity, physical activity is difficult to accurately assess under free-living conditions. However, physical activity intensity, duration, and frequency can be measured using either subjective or objective methods.[18] The “International Physical Activity Questionnaire” (IPAQ) is one such tool used to obtain internationally comparable data on health-related physical activity. The IPAQ was previously shown to have a high reliability and an acceptable validity.[19] The questionnaire checked for the frequency and duration of physical activity level (PAL) including vigorous, moderate physical exercise, walking and sitting period for the preceding week. PAL was classified into three levels: High: PAL: ≥3 days/week heavy activities that make one breath much harder than normal or any cumulative PAL; seven days/week of any combination of walking and moderate or vigorous exercise. Moderate: PAL: ≥3 days/week and ≥20 min/day, of moderate exercise or walking: ≥5 days/week and ≥30 min/day; Low, when adequate PAL’s were not achieved to be in categories of moderate or high.

For measuring forced vital capacity (FVC), simple spirometer (12, 1710 Base line Spirometer-China) was used. The participants were seated comfortably. Before measurement the purpose of the test was explained to the participants by well trained students. The participants had some practice attempts before the readings were taken to be familiar with the measuring spirometer. The participants were encouraged to keep blowing out so that maximal exhalation can be achieved. The total number of attempts was limited (practice and for recording) to eight or less at each session. A clean, disposable, one-way mouthpiece was attached to the spirometer. For each participant a fresh mouth piece was used. The participants were asked to breathe in as deeply as possible and hold their breath just long enough to seal their lips. The participants were asked to blow the breath out, forcibly, as hard and as fast as possible, until there is nothing left to expel. The measurement of the FVC was recorded from the spirometer as the maximum reading was reached. The procedure was repeated for three times to take an accurate measurement.

Statistical analysis:

The data set was cleaned and edited for inconsistencies. Missing data were not statistically computed. The Social Package for Social Sciences (SPSS) version 16.0 (SPSS Inc, Chicago, IL, USA) was used to analyze data. Descriptive statistics such as means and standard deviations were calculated for the continuous variables and frequencies for qualitative data. Analysis of variance (ANOVA), student's *t-test* and linear regression analysis were used to examine differentials in variables. Results were expressed as mean ± SD. All reported P values were 2-sided and differences were considered statistically significant at $P<0.05$.

RESULTS

Table 1: Baseline Characteristics of subjects (N=359)

		F	%
Age (yrs)	18-24	269	74.9
	25 - 44	90	25.1
BMI (kg/m²)	Normal (18.5-24.99)	149	41.5
	Overweight (25-29.99)	45	12.5
	Obesity I (30-34.99)	107	29.8
	Obesity 2 (35 - 39.99)	44	12.3
	Morbid Obesity (≥40)	14	3.9
WC (cm)	≤ 80 cm	207	57.7
	≥ 80.1 cm	152	42.3
Physical Activity Level	Low	244	68.0
	Moderate	115	32.0

Table 1 shows the baseline characteristics of the study population of 359 female subjects. Approximately 75 percent of the study population was in the age group of 18-24 yrs (median 24 yrs). There were no underweight subjects in the study sample. Only around 42 percent of subjects were having normal BMI and approximately 58 percent of the study population was having waist circumference ≤ 80 cm. Majority of the study population reported Low PAL (68 %) during preceding week while high PAL activities were reported in none of the participants.

Table 2 Mean age, anthropometric and Spirometry test variables of the Study Subjects

	Mean±SD	95% CI for mean		Minimum	Maximum
		Lower bound	Upper bound		
Age (yrs)	23.60±5.61	23.02	24.19	18	44
Height (cm)	159.16±5.44	158.32	160.01	145	170
Weight (kg)	71.97±16.78	69.36	74.58	45	133
BMI (kg/m^2)	28.29±6.38	27.63	28.95	19.14	51.95
WC(cm)	80.43±13.57	79.02	81.84	57	127
CE (cm)	2.63±0.83	2.55	2.72	1	5
FVC (L)	2.05±0.59	1.99	2.11	0.5	3.8
% FVC Predicted	61.38±1.76	59.55	63.21	14.97	113.77

Table 2 presents the mean age, anthropometric and spirometry test variables of study subjects. The mean age was 23.60±5.61 years and the mean body height and weight of study subjects was 158.17±5.44 cm and 71.52±16.78 kg respectively. The BMI of the study subjects ranged between 19.14 and 51.95 kg/m^2 with a mean of 28.29±6.38 kg/m^2. WC, CE, FVC and % FVC predicted values ranged from 57 to 127 cm; 1 to 5 cm; 0.5 to 3.8 L and 14.97 to 113.77 respectively.

Table 3 ANOVA for age, WC, CE, FVC and % FVC predicted with stratified BMI groups

BMI Groups#	Frequency	Mean±SD				
		Age	WC	CE	FVC	% FVC
Normal (18.5-24.99)	149	21.86±3.22	71.28±8.22	3.06±0.83	2.17±0.55	65.02±16.56
Overweight (25-29.99)	**45**	22.64±3.41	78.02±12.89	2.72±0.63	2.16±0.49	64.80±14.78
Obesity I (30-34.99)	107	25.11±6.51	85.87±10.50	2.32±0.67	1.99±0.62	59.80±18.54
Obesity II (35 – 39.99)	44	25.30±7.81	93.65±10.92	2.09±0.60	1.81±0.59	54.11±17.85
Obesity III (40 and above)	14	28.36±8.43	102.50±10.33	1.89±0.56	1.56±0.52	46.62±15.48
BMI vs. Variables	**F Value**	10.345**	75.794**	27.666**	6.967**	6.967**

**p significant at 0.0001

WHO adults' cut-off points for BMI were used to create BMI groups [16].

Table 3 shows the ANOVA test for age, WC, CE, FVC and % FVC with stratified BMI groups. All the tested variables were significantly differing in their mean values for BMI groups. Post-hoc Tukey HSD analysis for stratified BMI groups (results not presented) showed that: a) age for normal and overweight groups was significantly lower than all the obesity groups; b) WC measurements and chest expansion varied significantly for normal BMI groups as compared with overweight and obesity groups; c) FVC and % FVC predicted for normal and overweight groups were significantly higher than obesity II and III groups.

T test for WC groups also indicated that all the tested variables varied significantly (Table 4). Both chest expansion and FVC were significantly higher in WC group with ≤ 79 cm which is considered normal cutoff for Asian populations [20].

Table 4 T-Test for age, WC, CE, FVC and % FVC predicted with stratified WC groups

WC Groups	Frequency	Mean±SD				
		Age	BMI	CE	FVC	% FVC
≤ 79 cm	207	22.11±3.50	24.69±4.45	2.89±0.83	2.14±0.58	64.09±17.25
≥ 80 cm	152	25.64±7.12	33.19±5.26	2.29±0.69	1.93±0.59	57.69±17.59
WC vs. Variables	**T Value**	-6.190**	-16.534**	7.228**	3.438**	3.438**

**p significant at 0.0001; *p significant at 0.001

Table 5 T-Test for age, BMI, WC, CE, FVC and % FVC predicted with stratified PAL groups

PAL Groups	Frequency	Mean±SD					
		Age	BMI	WC	CE	FVC	% FVC
Low PAL	244	23.53±5.60	28.02±6.39	80.20±13.72	2.50±0.82	1.94±0.54	58.24±16.29
Moderate PAL	115	23.76±5.65	28.84±6.36	80.91±13.29	2.91±0.77	2.27±0.62	68.05±18.63
PAL vs. Variables	**T Value**	-0.355	-1.128	-0.461	-4.409**	-5.082**	-5.082**

**p significant at 0.0001

For PAL groups however significant mean differences were found only for variables CE, FVC and % FVC predicted (Table 5). In the present study no subjects reported having "high PAL". Results suggest that probably BMI and WC do not necessarily get influenced with the current activity level of the subjects as contrasted with lung capacity indices studied

Table 6 Regression Coefficients for Adiposity Markers and PAL entered into separate models (each model adjusted for age) predicting % FVC predicted and CE.

	% FVC predicted					Chest Expansion				
	B	SE	β	*p*	R^2	B	SE	β	*p*	R^2
PAL	10.205	1.871	0.267	0.000	0.151	0.474	0.078	0.263	0.000	0.336
BMI	-4.493	1.016	-0.291	0.000		-0.355	0.042	-0.486	0.000	
WC	-0.410	2.348	-0.011	0.861		-0.111	0.098	-0.066	0.258	

Table 6 summarizes the regression coefficients for adiposity markers and PAL that were entered individually into % FEV predicted and CE linear regression models adjusted for age. Overall, there were negative associations of each adiposity markers with % FEV predicted and CE however the associations were not statistically significant for WC. PAL was significantly associated positively with both % FEV predicted and CE.

DISCUSSION

Available normative lung function tests data for Kingdom of Saudi Arabia (KSA) population is relatively scarce and is mostly limited to subjects from coastal areas.[21] Lung function can vary inter-individually depending on gender, age, height, ethnicity and geographic factors like altitude, dry and humid climates and hence is important to research lung function test data and factors influencing it from various regions. The present study is conducted in UOH from Hail City, Saudi Arabia. Hail city is in northern part of KSA at an elevation of approximately 1000 meters with typical arid desert climate. Humidity is very low, with average rainfall of less than 125 millimeters per year. To the best of our knowledge there are no studies reporting on lung capacity test values from northern part of KSA. [22]

In the current study, we assessed the correlation of BMI, waist circumference and physical activity with lung capacity in 359 women (age range from 18 to 44 years) who were nonsmokers and had no previous history of pulmonary diseases or serious illnesses. Two well-known simple methods estimating lung capacity have been employed; 1) the measure of chest expansion as an index of lung capacity and 2) FVC spirometer readings as the accurate measure of lung capacity.

Our mean FVC readings were lower as compared to other studies which reported for female subjects from Saudi Arabia [21, 22] and other parts of the world.[23 - 25] To our knowledge we couldn't find any chest expansion reference values from KSA emphasizing for the need for more such studies from the region. We found inverse associations for BMI and WC with lung capacity while physical activity was positively associated even after adjusting for age confirming our hypothesis. However, BMI and physical activity explained the greatest proportion of variance for both FVC and chest expansion in regression analysis as compared to WC.

Adequate expansion of lungs and chest is very important for sufficient ventilation. Any interference with free airflow in the respiratory system can result in relative insufficiency in ventilation or fatigued respiratory muscles. Recent literature is increasingly focusing its interest in conceptualizing disease etiology within a life course framework.[26] Saudi Arabia is reportedly having very high prevalence rates for obesity [3] and low physical activity culture among its citizens[27] both of which can influence lung capacity. Poor life style factors like obesity can cause restrictive conditions of the chest wall and can result in decreases in lung volumes such as the FVC or the forced expiratory volume in one second (FEV1) without impeding airflow or the ratio between FVC and FEV1.[28] In contrast regular exercise can promote normal development of lung function and can even limit its decline upon ageing.[29] It is therefore interesting to study how these opposing lifestyle factors contribute for lung function.

In the present study no subjects reported having vigorous physical activity. However our results indicated that even moderate activity can have positive effect on both spirometry and chest expansion tests. Previous studies observed physical activity to be positively correlated to changes in FVC over a long period.[29, 30] The possible beneficial role of physical activity could be in counteracting or slowing down the process of loss of lung elastic recoil and/or stiffening tendency in the chest wall, both of which have been associated with ageing process.[31] Physical activity possibly can also enhance inspiratory muscle endurance.[32] Given that our present study results support beneficial effects of even moderate activity and other studies strongly suggesting that higher physical activity slower decline in pulmonary function [29], there is a definite need for implementing physical activity friendly environments across KSA.

We also studied the relation of obesity as defined by its indices BMI and WC with lung function. There were no underweight subjects and we couldn't analyze its relation with lung function. However, comparisons between normal, overweight and obese I, II and III categories have definitely supported other studies which reported obesity having inverse association with lung function.[33-35] One previous study [34] which studied progressive impact of obesity on lung function by combining normal and overweight BMI groups into one group and comparing it with obese class I, II, III (BMI 40 to 44.9 kg/m^2; BMI 45 to 50.9 kg/m^2 and BMI $\geq$ 51 kg/m^2), concluded that changes in lung function were better demonstrated when BMI is $\geq$ 45 kg/m and even more evident when BMI is > 50.9 kg/m^2. In the present study we compared normal BMI group with overweight and obese I, II and III (BMI $\geq$ 40 kg/m^2). We couldn't further subdivide obese III into further classifications because of less number of subjects in that category (we had only 14 subjects). However our study in contrast to the mentioned study found that FVC and % FVC predicted for normal and overweight groups were significantly better even from BMI $\geq$ 35 kg/m^2. However our study samples were only females while the mentioned study sample included both males and females and both mean absolute and relative values of FVC were higher as compared to the present study.

Our study, however, could not establish very strong negative relationship between WC and lung capacity. Two epidemiological studies including both genders suggested strong negative associations for WC and waist hip ratio even after adjusting for potential confounding factors.[36, 37] However one recent meta-analysis has concluded that the effect of WC on pulmonary function in men as larger than that in women owing to differences in body shape (apple vs pear-shaped).[38] The present study sample included much younger women (18 to 44 yrs) and majorities were below 25 yrs. This probably could be a reason for not finding stronger relation for WC with lung capacity.

The present study had several limitations. Because of the non availability of digital spirometer, we only recorded the forced vital capacity using simple spirometer. Another limitation included usage of questionnaire method for collecting data on physical activity, and sedentary behavior. Including both genders in sample frame could have generated more meaningful understanding of the results. An important limitation of this study is probably clinical application value of these results rather being confined to limited populations and less generalizable to other populations or ethnic groups. However the data definitely adds to global research which tries to understand regional influences on pulmonary function.

CONCLUSIONS

Obesity and physical activity are important determinants of lung function, and it is of greater importance to keep oneself physically active through their life for more than one health reason. It is also important for future research venturing to finding out determinants of pulmonary function to consider inclusion of physical activity as a co-variable along with various obesity indices which can be potential confounding factors.

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