Effect of Obesity on Airway Mechanics

Kumar Shanmugasundaram, Geetanjali Bade, Meghashree Sampath, Anjana Talwar
Department of Physiology, All India Institute of Medical Sciences, New Delhi, India

Abstract

Background: Obesity is known to induce lung function impairment. Previous studies of decline in lung function associated with obesity are well established. **Materials and Methods:** In this cross-sectional study, to evaluate the effects of different obesity indices on lung mechanics, healthy subjects (males-23 and females-22) were recruited. Anthropometric parameters like body mass index (BMI), waist circumference (WC), hip circumference (HC) and neck circumference (NC) were measured and waist-hip ratio (WHR) was derived. Spirometry, impulse oscillometry (IOS) and fractional exhaled nitric oxide (FeNO) measurements were performed to assess lung function. Subgroups were divided and analysed. **Results:** In males, increased WHR is associated with increased total airway resistance (R_5). BMI correlates positively with R_5, R_5% predicted, resistance at 20 Hz (R_{20}) and R_{20}% predicted; likewise, WHR shows a positive correlation with R_5. In females, increased WHR has significantly higher R_5, R_5% predicted, R_{20}, R_{20}% predicted, area of reactance (Ax), resonant frequency (Fres) and decreased reactance at 5 Hz (X_5), reactance at 20 Hz (X_{20}), X_{20}% predicted. The female group with higher WC shows significantly increased R_5, R_5% predicted, R_{20}, R_{20}% predicted, Ax, Fres and lower fixed ratio of forced expiratory volume in 1 s (FEV_1)/forced vital capacity (FVC), X_5, X_{20}, X_{20}% predicted. The group with higher NC has a lower FEV_1/FVC ratio. WHR positively correlated with R_5% predicted and Fres while WC correlated positively with R_5, R_5% predicted, Ax and Fres; same way, NC with X_5% predicted. **Conclusion:** Obesity/overweight causes significant changes in lung volumes, capacity and airway mechanics, Higher WC and WHR are associated with significant changes in lung mechanics, which are more prominent in females than in males. NC is not associated with changes in lung mechanics.

Keywords: Gender, impulse oscillometry, lung mechanics, obesity, spirometry

Introduction

Obesity is a complex, multi-factorial and largely preventable disease. If considered overweight, over a third of the world's population is affected by obesity.[1] In India, there is an increased prevalence of generalized and abdominal obesity.[2] Body mass index (BMI) is commonly used to classify overweight and obesity. In Asia, a BMI between 23 and 24.9 is defined as overweight, and a BMI between 25 and 29.9 is considered obese.[3] BMI is a global measure of body mass that includes both fat and lean mass and takes no account of differences in fat distribution. The distribution of fat like abdominal fat can be measured by using other parameters like abdominal or waist circumference (WC), waist-hip ratio (WHR), etc.

Obesity affects the respiratory system directly. It may induce respiratory mechanical impairment, which may be associated with airway narrowing causing the increased prevalence of wheezing and asthma in obese people.[4–6] In obese individuals, fat deposition in the thoracoabdominal region decreases diaphragm mobility and rib movement, which are essential for appropriate ventilatory mechanics. The fat deposition also reduces the compliance of the respiratory system and leads to atypical breathing patterns.[7–9] Usually, the negative pressure gradient facilitates the airflow into the lungs during inspiration by the downward and outward movement of the diaphragm and the chest wall, respectively. But the deposition of fat over the abdominal and thoracic region is likely to have direct effects on the movement of the diaphragm and the chest wall, which imposes a mechanical load on the diaphragm and decreases the expiratory residual volume and functional residual capacity (FRC) and results in reduced respiratory compliance and increased abnormal breathing pattern.[10–14] Abdominal fat measured by WC or WHR is associated with

Access this article online

Quick Response Code:

Website: www.ijem.in

DOI: 10.4103/ijem.ijem_363_22

Address for correspondence: Prof. Anjana Talwar,
Department of Physiology, AIIMS, New Delhi, India.
E-mail: anjantalwar@gmail.com

Submitted: 15-Sep-2022 **Revised:** 15-Jan-2023
Accepted: 27-Jan-2023 **Published:** 14-Apr-2023

How to cite this article: Shanmugasundaram K, Bade G, Sampath M, Talwar A. Effect of obesity on airway mechanics. Indian J Endocr Metab 2023;27:161-6.

a reduction in lung volumes.[15,16] Salome *et al*. have observed that dual-energy X-ray absorptiometry (DXA) and other measurements like WHR which reflect upper body fat show a significant negative correlation with FRC, forced vital capacity (FVC) and total lung capacity.[17] Obstructive sleep apnoea (OSA) is characterized by repetitive upper airway obstruction, resulting in recurrent hypoxaemia and arousal from sleep. Patil *et al*. have demonstrated that both defects in upper airway mechanical properties and impaired neuromuscular responses to upper airway obstruction play critical roles in the development of OSA. The defects in upper airway properties in the form of increased mechanical load play a key role in the pathophysiology of OSA.[18] This increased mechanical load may be because of regional differences in adiposity. Millman *et al*. and Hoffstein and Mateika have shown that increased neck circumference (NC) is associated with an increased incidence of OSA.[19,20] There is increasing evidence that obesity is associated with wheezing, diagnosed asthma and increased risk for hyper-responsiveness of airways which is indicative of decreased airway calibre in obesity.[12,21,22] Obesity is associated with an increased risk of developing asthma and it is also associated with airway inflammation.[23] Adipose tissue can act as the main source of many inflammatory markers including leptin, interleukin-6, adiponectin, etc.[24] Obesity-associated inflammatory changes may induce airway inflammation and thereby impair lung functions.[25] Measuring an exhaled fraction of nitric oxide (FeNO) is a simple, non-invasive method to quantify airway inflammation. It is considered as the surrogate marker for eosinophilic airway inflammation.[26] Studies are available showing the effect of body weight and BMI on airway resistance. Still, very little literature demonstrates the effect of other obesity indices like WC, WHR and NC on airway mechanics and spirometric parameters.[27,28]

This study aimed to characterize the effect of obesity as measured by different obesity indices (including BMI, WC, WHR, NC) and gender on spirometric parameters and lung mechanics, including resistance and reactance properties of the respiratory system in healthy subjects.

Material and Methods

Ethics statement and study design

This study was approved by the institute's ethics committee. Prior informed written consent was obtained from all participating healthy volunteers. Before inclusion in the study, a detailed history was taken to rule out any disease condition. Subjects with a history/presence of any lung disease or history of previous lung volume reduction surgery, lung transplantation, fever, cardiovascular, musculoskeletal, chronic immunological diseases and inflammatory disorders were excluded from the study. The study design included the measurement of obesity indices followed by lung function testing.

Anthropometric measurements

Body weight was measured in kilogram (kg) and height was recorded in metres (m). BMI was calculated by using the formula BMI = weight (kg)/height (m^2), and WC, hip circumference (HC) and NC were measured and WHR was derived. WC and HC were measured as per World Health Organization (WHO) recommendations. WC is measured exactly midpoint between the lower margin of the last palpable rib and the top of the iliac crest and HC should be taken around the widest portion of the buttocks.[21] NC was measured according to the previous studies exactly in the midway of the neck, between the mid-cervical spine and mid-anterior neck.[28] The subgroups were divided depending on standard cut-off values and cut-offs from previous studies. According to the WHO and the Asia-Pacific cut-off points, subjects having BMI ≥25, WC ≥90 cm in males and WC ≥80 cm in females were considered obese.[3] In the same way, as per the US Department of Agriculture and the US Department of Health and Human Services, the WHR threshold for abdominal obesity is ≥0.95 in males and ≥0.80 for females.[29,30] Verma *et al*. have reported NC cut-off values for obesity - NC ≥36.55 cm for males and NC ≥34.05 cm for females.[28]

Impulse oscillometry (IOS)

An IOS system (Eric Jaeger, Hochberg, Germany) is commonly used to measure respiratory impedance. It is an effort-independent technique used to evaluate lung mechanics. Two main components of airway impedance are airway resistance and reactance. The IOS measurements were done according to the European Respiratory Society (ERS)/American Thoracic Society (ATS) guidelines.[31] The test was performed in a sitting position for 90 s. A tight seal between lips and mouthpiece was ensured. The cheeks were held firmly by the subject with their hands. Patients were allowed to breathe normally while the loudspeaker near the mouthpiece delivered sound waves of different frequencies over the range of 5 to 30 Hz, superimposed on spontaneous tidal breathing. Resistance and reactance measured at lower frequency oscillations such as 5 Hz are designated R_5 and X_5, respectively. Similarly, resistance and reactance at a higher frequency of 20 Hz are designated as R_{20} and X_{20}. Sound waves of lower frequency, i.e., 5 Hz are transmitted deep into the lung's alveoli/peripheral airway and reflected back giving total airway resistance. Sound waves of higher frequency, i.e., 20 Hz usually reflected back from proximally or larger airways providing the indices of central airways. The resonant frequency (Fres) is the intermediate frequency at which the total reactance is 0, and the reactance area (Ax) is the integrated low-frequency respiratory reactance (area under the curve) between 5 Hz and Fres. It reflects a composite index for reactance. Coherence is a correlation between airflow and pressure waves. A mismatch between the airflow into the lungs and the amplitude of the pressure wave results in low coherence (ranging from 0 to 1). Acceptable coherence values should be at least 0.8 or higher at 5 Hz and 0.9 or more at 20 Hz, which demonstrates the reliability and quality of the given IOS test performance.[32,33]

Spirometry

The slow vital capacity (SVC) and FVC manoeuvre were performed using the spirometer (Medisoft, Spiro Air, Kent, UK) and the parameters recorded are SVC, FVC, forced expiratory volume at first second (FEV_1), FEV_1/FVC ratio and peak expiratory flow (PEF). The tests were performed as per ATS and ERS guidelines.[34] The FEV_1 and FEV_1/FVC are the most widely used parameters to measure the lung's mechanical properties. In obstructive disorders, FEV_1 and FEV_1/FVC ratio are reduced; in restrictive disorders, FEV_1, FVC and total lung capacity are reduced.

FeNO

FeNO is a surrogate marker for eosinophilic airway inflammation. It is mainly used for diagnosis and treatment decisions for asthma patients. It is a simple, non-invasive technique to assess eosinophilic inflammation. Exhaled NO was measured based on the guidelines of ERS/ATS.[35] FeNO concentrations were assessed with a chemiluminescence analyser (NIOX MINO Analyser, Aerocrine AB, Solna, Sweden). Initially, the subject was asked to exhale the air outside and inhale through the FeNO analyser's mouthpiece followed by steady-state exhalation into the analyser, maintaining the constant flow rate of 50 ml/s for 10 s. Two such tests were performed, and the mean value was taken for analysis.

Statistical analysis

All statistical tests were done using GraphPad Prism version 9.0.1 for Windows (GraphPad Software, Inc., USA). The data were subgrouped as per the cut-off values. Each parameter was tested for data distribution based on standard normality tests (D'Agostino-Pearson omnibus normality test, Anderson-Darling test, Shapiro–Wilk test). The spirometry and IOS parameters were compared between the subgroups using the unpaired *t*-test for parametric distribution and Mann–Whitney *t*-test for non-parametric variables. The results are expressed as mean ± standard deviation or median [interquartile range]. The relationship between the two parameters was evaluated using Pearson's correlation coefficient or Spearman's rank correlation coefficient if they were appropriate. The level of statistical significance was set at $P < 0.05$.

Results

A total of 45 subjects participated in this study, males ($n = 23$) and females ($n = 22$). We divided these gender groups into different subgroups depending on the BMI, WHR, WC and NC cut-off values. The demographic profiles of the subjects are presented in Table 1.

In the male group, when we divided participants based on WHR, we observed a higher R_5 ($P = 0.045$) in the group having WHR ≥0.95 as compared with the group having a WHR ≤0.95 [Table 2]. The correlation of BMI with lung function parameters showed that there is a positive correlation of IOS parameters like R_5% predicted ($P = 0.04$, $r = 0.41$), R_5 ($P = 0.03$, $r = 0.44$), R_{20} ($P = 0.003$, r value-0.58) and R_{20}% predicted ($P = 0.007$, $r = 0.54$) with BMI. Likewise, a positive correlation of R_5 ($P = 0.01$, $r = 0.50$) with WHR and a positive correlation of R_{20} ($P = 0.02$, $r = 0.46$) with WC was observed [Table 3].

Table 1: Demographic profile of the study groups

Parameter	Female (n=22)	Male (n=23)
Age (years)	26.04±5.268	33.78±12.46
Height (cm)	159.72±6.24	169.53±7.28
Weight (Kg)	62.08±10.52	73.53±14.48
BMI (Kg/m²)	24.53±4.21	25.63±5.09
Waist circumference (cm)	86.24±10.54	92.34±11.86
Waist Hip ratio	0.843±1.88	0.94±0.07
Neck circumference (cm)	33.34±1.88	37.30±2.78
Smoking history	Non-smoker-22	Non-smoker-16 Current smoker-4 Ex-smoker-3

Values expressed are mean ± SD

In females, we observed that the group with WHR ≥0.80 shows higher R_5 ($P = 0.001$), R_5% predicted ($P = 0.0003$), R_{20} ($P = 0.007$), R_{20}% predicted ($P = 0.003$), Ax ($P = 0.006$), Fres ($P = 0.002$) and decreased or more negative X_5 ($P = 0.01$), X_{20} ($P = 0.007$), X_{20}% predicted ($P = 0.006$) as compared with the group having WHR ≤ 0.80 [Table 2]. When the groups are divided based on WC, we observed that the group with WC ≥80 cm shows decreased FEV_1/FVC ratio ($P = 0.030$), X_5 ($P = 0.016$), X_{20} ($P = 0.003$) and X_{20}% predicted ($P = 0.004$) and increased R_5 ($P = 0.001$), R_5% predicted ($P = 0.008$), R_{20} ($P = 0.0070$), R_{20}% predicted ($P = 0.007$), Ax ($P = 0.005$), Fres ($P = 0.002$) as compared with the group having WC ≤80 cm [Table 4]. Likewise, the group with NC >34.05cm shows decreased FEV_1/FVC ($P = 0.015$) as compared with another group with NC <34.05cm [Table 5]. The correlation of lung function parameters with anthropometric parameters shows that there is a positive correlation of R_5% predicted ($P = 0.005$, $r = 0.53$), Fres ($P = 0.0009$, $r = 0.62$), and a negative correlation of X_{20}% predicted ($P = 0.006$, $r = -0.51$) with WHR. Same way, WC was positively correlated with R_5 ($P = 0.0235$, $r = 0.45$), R_5% predicted ($P = 0.021$, $r = 0.45$), Ax ($P = 0.017$, $r = 0.47$), Fres ($P = 0.0003$, $r = 0.66$) and negatively correlated with X_{20} ($P = <0.0001$, $r = -0.71$), X_{20}% predicted ($P = 0.001$, $r = -0.58$). We also observed a positive correlation of X_5% predicted ($P = 0.047$, $r = 0.39$) with NC [Table 3]. The rest of the data was given in the Supplementary Material.

Discussion

We investigated the effects of obesity indices on the lung functions of males and females.

Subgroups were divided based on obesity parameters like BMI, WHR, WC and NC. The spirometry parameters were comparable in male subgroups and most of the subgroups of females except the group with WC ≥80 cm, where the FEV_1/FVC were significantly lower as compared to the group with WC ≤80 cm and the group with NC ≥34.05cm had decreased FEV_1/FVC. It shows that females are more prone to lung volume changes than males due to abdominal obesity,

Table 2: Data showing effect of waist-hip ratio on spirometry and impulse oscillometry parameters.

Parameters	Males		*P*	Females		*P*
	WHR ≥0.95 (*n*=11)	WHR <0.95 (*n*=12)		WHR ≥0.8 (*n*=15)	WHR <0.8 (*n*=07)	
FEV1/FVC (%)	78.01±1.14	79.34±1.34	0.463	82.17±2.18	79.59±2.14	0.474
R_5 [kPa/(L/S)]	0.423±0.03	0.342±0.018	0.045*	0.490±0.02	0.344±0.01	0.001**
R_5 (%predicted)	156±14.27	128.5±7.87	0.099	149.1±7.34	100.1±3.45	0.0003***
R_{20} [kPa/(L/S)]	0.349±0.03	0.287±0.01	0.089	0.386±0.01	0.309±0.009	0.007**
R_{20} (%predicted)	150.8±15.78	126.3±8.41	0.174	143.9±6.52	111.3±2.83	0.003**
X_5 [kPa/(L/S)]	-0.11±0.007	-0.116±0.01	0.636	-0.175±0.01	-0.125±0.01	0.019*
X_{20} [kPa/(L/S)]	0.042±0.008	0.048±0.007	0.639	0.03(-0.03-20.09)	0.09 (0.045-0.11)	0.007**
X_{20} (%predicted)	57.41±11.60	54.23±7.544	0.817	22.23±11.40	77.93±10.94	0.006**
Ax[kPa/L]	0.536±0.07	0.478±0.08	0.599	0.998±0.13	0.380±0.06	0.006**
Fres [1/S]	16.03±0.79	14.52±0.961	0.241	17.53±0.89	12.52±0.88	0.002**

Values expressed are mean ± SD (Unpaired *t*-test) or median with inter-quartile range (Mann-Whitney test). *P <0.05, ** P <0.01 and *** P <0.001 statistically significant. WHR-waist hip ratio, R_5-resistance at 5Hz, R_{20}-resistance at 20Hz, Fres-resonant frequency, Ax-area of reactance, X_5-reactance at 5Hz, X_{20}-reactance at 20Hz.

Table 3: Correlation of impulse oscillometry parameters with obesity indices in both males and females

	BMI		WHR		WC		NC	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Males								
∏R_5% predicted	0.4136	0.0498*	0.4061	0.0545	0.1493	0.4966	0.1873	0.3920
∏R_5	0.4403	0.0355*	0.5028	0.0145*	0.2424	0.2651	0.1999	0.3606
‡R_{20}% predicted	0.5403	0.0078**	0.3644	0.0874	0.4106	0.0516	0.3087	0.1518
‡R_{20}	0.5858	0.0033**	0.4062	0.0544	0.4610	0.0268*	0.3030	0.1598
∏X_5% predicted	0.03558	0.8720	-0.04545	0.8368	0.2210	0.3110	0.01292	0.7450
‡X_5	-0.08328	0.7056	0.1276	0.5617	0.05285	0.8107	0.1685	0.4422
‡X_{20}% predicted	-0.3095	0.1024	-0.1731	0.4297	-0.2982	0.1670	-0.2554	0.2396
‡X_{20}	-0.3095	0.1507	-0.2411	0.2677	-0.2677	0.2168	-0.09563	0.6642
‡Ax	0.4057	0.0548	0.1468	0.5037	0.2797	0.1961	0.05097	0.8174
‡Fres	0.3815	0.0725	0.3632	0.0885	0.3271	0.1277	0.1332	0.5444
Females								
∏R_5% predicted	0.1703	0.4156	0.5383	0.0055**	0.4570	0.0216*	0.2049	0.3259
∏R_5	0.2537	0.2210	0.3332	0.1036	0.4515	0.0235*	0.1044	0.6195
‡R_{20}% predicted	0.08193	0.6970	0.3537	0.0829	0.2711	0.1900	0.01765	0.9333
‡R_{20}	0.2274	0.2742	0.1504	0.4729	0.2836	0.1695	0.008281	0.9687
∏X_5% predicted	0.2423	0.2432	0.05121	0.8079	-0.03848	0.8551	0.3998	0.0477*
‡X_5	0.1379	0.5111	-0.01779	0.9327	-0.1893	0.3647	0.1249	0.5519
‡X_{20}% predicted	-0.3335	0.1033	-0.5261	0.0069**	-0.5893	0.0019**	-0.3103	0.1312
‡X_{20}	-0.3858	0.0568	-0.04885	0.8166	-0.7161	< 0.0001***	-0.3824	0.0593
‡Ax	0.1249	0.5518	0.3563	0.0804	0.4726	0.0170*	0.1288	0.5395
‡Fres	0.3892	0.0545	0.6241	0.0009***	0.6655	0.0003***	0.3736	0.0658

* P <0.05 and ** P <0.01 statistically significant (‡pearson correlation, ∏ spearman correlation). R_5-resistance at 5Hz, R_{20}-resistance at 20Hz, Fres-resonant frequency, Ax-area of reactance, X_5-reactance at 5Hz, X_{20}-reactance at 20Hz.

and similar results had been reported in the previous study.[36] The increase in the deposition of adipose tissue around the rib cage, abdomen and visceral cavity of overweight and obese females may significantly affect the lung volumes by reducing the resting lung volumes and movement of the chest wall.[9] Chen *et al*. also reported that there would be a reduction of 13 ml FVC and 11 ml FEV_1 on every 1 cm increase in WC.[13,16]

The relationships between asthma and obesity were well documented, although the exact mechanisms remain unclear. Previous studies also show that high BMI increases asthma incidence; it is T helper 2 (Th2)-mediated eosinophilic airway inflammation. Measuring the FeNO levels is recommended to monitor asthmatic eosinophilic inflammation.[35,37] Our study shows no significant change in the FeNO concentration of different groups in both genders. It shows that being overweight or obese is not associated with significant eosinophilic airway inflammation.

IOS reveals that obesity/overweight affects the lung mechanics parameters like R_5, R_5% predicted, Ax, Fres and X_5. Higher total airway resistance (R_5) is observed in males with

Table 4: Data showing effect of waist circumference on spirometry and impulse oscillometry parameters.

Parameters	Males		P	Females		*P*
	WC ≥90 (*n*=14)	WC <90 (*n*=09)		WC ≥80 (*n*=15)	WC <80 (*n*=07)	
FEV1/FVC (%)	78.06±1.17	79.71±1.33	0.372	78.99±1.65	86.40±3.03	0.030*
R_5 [kPa/(L/S)]	0.355 (0.326-0.429)	0.370(0.272-0.44)	0.705	0.489±0.02	0.345±0.01	0.001**
R_5 (%predicted)	127.2 (114.5-170.4)	141.0 (107.3-166.4)	0.974	145.8±8.44	107.3±5.54	0.008**
R_{20} [kPa/(L/S)]	0.321±0.02	0.3101±0.02	0.772	0.386±0.01	0.308±0.02	0.007**
R_{20} (%predicted)	138.7±12.91	136.9±11.70	0.924	143.3±6.57	112.7±4.44	0.007**
X_5 [kPa/(L/S)]	-0.109±0.006	-0.120±0.012	0.439	-0.175±0.01	-0.124±0.01	0.016*
X_{20} [kPa/(L/S)]	0.042±0.006	0.050±0.009	0.462	0.03 (0-0.04)	0.09 (0.05-0.11)	0.003**
X_{20} (%predicted)	51.36±8.87	62.58±10.10	0.422	26.10(-19.40-46.60)	102.2 (46.40-109.2)	0.004**
Ax[kPa/L]	0.524±0.06	0.477±0.102	0.681	1.0±0.134	0.375±0.05	0.005**
Fres [1/S]	15.78±0.75	14.41±1.124	0.304	17.55±0.91	12.48±0.73	0.002**

Values expressed are mean ± SD (Unpaired *t*-test) or median with inter-quartile range (Mann-Whitney test). *P <0.05, ** P <0.01 and *** P < 0.001 statistically significant. WC-waist circumference, R_5-resistance at 5Hz, R_{20}-resistance at 20Hz, Fres-resonant frequency, Ax-area of reactance, X_5-reactance at 5Hz, X_{20}-reactance at 20Hz.

Table 5: Data showing effect of neck circumference on spirometry parameter.

Parameters	Males		*P*	Females		*P*
	NC ≥36.55 (*n*=16)	NC <36.55 (*n*=07)		NC ≥34.05 (*n*=08)	NC <34.05 (*n*=14)	
FEV_1/FVC (%)	78.64±1.16	78.86±1.27	0.911	76.31±1.20	84.22±2.12	0.015*

Values expressed are mean ± SD (Unpaired *t*-test). *P <0.05, ** P <0.01 and *** P <0.001 statistically significant.

higher WHR. Obese/overweight females with higher WHR and WC also show increased total airway resistance and increased (negative) reactance properties. Our correlation analysis between the anthropometric measurements and lung function parameters shows that in males, BMI, WHR and WC are positively correlated with airway mechanics parameters like R_5, R_5% predicted, R_{20} and R_{20}% predicted. Same way in females, an increase in WHR and WC is associated with an increase in airway mechanics parameters like R_5, R_5% predicted, X_{20}, X_{20}% predicted, Ax and Fres. NC was positively correlated with the X_5% predicted, which reflects the total reactance property of the airways.

Obesity may be central or peripheral; in central obesity, there is an increase in the deposition of fat over the thorax, abdomen and visceral organs as compared with peripheral obesity, where the fat deposits mainly on the thighs, hip and limb regions.[38,39] Central obesity affects pulmonary function and mechanics more than peripheral obesity.[17] Likewise, participants with higher WHR and WC show abnormal lung mechanics. In the female subgroup with greater NC, there are no significant changes in airway mechanics except the changes in lung volumes. Thus, WHR- and WC-mediated airway mechanics changes are more prominent in obese and overweight individuals. The exact mechanism for a change in airway mechanics due to obesity is still poorly understood. But, the fat deposition over the chest wall and abdominal region causes a decrease in the resting lung volumes and total respiratory compliance and may reduce the airway calibre increasing the resistive and reactance (negatively) properties of an airway, thereby increasing the effort of breathing.[8–10,13,27] Van Noord *et al*. used rib cage strapping to imitate the effect of low lung volumes over airway mechanics and showed that the decrease in the resting lung volumes would increase the resistance and decrease in reactance properties of the airways.[40] Studies also show that increases in body weight cause an increase in the body's mechanical load, thereby reducing the lung volumes/capacities and limiting distal airway closure, respiratory flow and exercise capacity.[4] The changes in parameters like R_5 and R_5% predicted show that overweight/obese individuals have highly resistive airways which may cause difficulties in the normal flow of air through the respiratory system. Reactance is the rebound resistance produced by distensible airways. Decreases in the X_5 mainly relate to the disturbances in the physical properties of the lung parenchyma and its ability to expand and facilitate alveolar filling in overweight/obese subjects. WHR and WC-associated changes in Ax, Fres and X_5 in females act as sensitive parameters to determine the small airway obstruction and restrictive airway flow.[41] It shows that overweight/obesity severely affects airway mechanics and their functions. These changes in the lung mechanics are very difficult to assess using conventional spirometry and these effects are more prominent in obese/overweight females than obese/overweight male participants.

Limitations

The main limitation of our study was less sample size. Body composition analysis and lipid profile were not studied.

Conclusion

Obesity/overweight causes significant changes in lung volumes, capacity and airway mechanics Higher WC and WHR are associated with significant changes in lung mechanics, which are more prominent in females than in males. NC is not associated with changes in lung mechanics.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. American Medical Association. AMA adopts new policies on second day of voting at Annual Meeting. 2015. Available from: https://www.ama-assn.org/press-center/press-releases/ama-adopts-new-policies-second-day-voting-annual-meeting. [Last accessed on 2022 May 12].
2. Pradeepa R, Anjana RM, Joshi SR, Bhansali A, Deepa M, Joshi PP, *et al*. Prevalence of generalized & abdominal obesity in urban & rural India- the ICMR - INDIAB Study (Phase-I) [ICMR-INDIAB-3]. Indian J Med Res 2015;142:139–50.
3. World Health Organization. Regional Office for the Western Pacific. The Asia-Pacific perspective: Redefining obesity and its treatment. Sydney: Health Communications Australia; 2000. Available from: https://apps.who.int/iris/handle/10665/206936. [Last accessed on 2021 Nov 05].
4. Peters U, Dixon AE. The effect of obesity on lung function. Expert Rev Respir Med 2018;12:755–67.
5. Mohanan S, Tapp H, McWilliams A, Dulin M. Obesity and asthma: Pathophysiology and implications for diagnosis and management in primary care. Exp Biol Med (Maywood) 2014;239:1531–40.
6. Chen Y, Dales R, Tang M, Krewski D. Obesity may increase the incidence of asthma in women but not in men: Longitudinal observations from the Canadian National population health surveys. Am J Epidemiol 2002;155:191–7.
7. Sharp JT, Henry JP, Sweany SK, Meadows WR, Pietras RJ. The total work of breathing in normal and obese men*. J Clin Invest 1964;43:728–39.
8. Naimark A, Cherniack RM. Compliance of the respiratory system and its components in health and obesity. J Appl Physiol 1960;15:377–82.
9. Elliot JG, Donovan GM, Wang KCW, Green FHY, James AL, Noble PB. Fatty airways: Implications for obstructive disease. Eur Respir J 2019;54:1900857. doi: 10.1183/13993003.00857-2019.
10. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, *et al*. The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. Anesth Analg 1998;87:654–60.
11. Hedenstierna G, Santesson J. Breathing mechanics, dead space and gas exchange in the extremely obese, breathing spontaneously and during anaesthesia with intermittent positive pressure ventilation. Acta Anaesthesiol Scand 1976;20:248–54.
12. Schachter LM, Salome CM, Peat JK, Woolcock AJ. Obesity is a risk for asthma and wheeze but not airway hyperresponsiveness. Thorax 2001;56:4–8.
13. Behazin N, Jones SB, Cohen RI, Loring SH. Respiratory restriction and elevated pleural and esophageal pressures in morbid obesity. J Appl Physiol Bethesda Md 1985 2010;108:212–8.
14. Alberti KGMM, Zimmet P, Shaw J. Metabolic syndrome--A new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet Med J Br Diabet Assoc 2006;23:469–80.
15. Canoy D, Luben R, Welch A, Bingham S, Wareham N, Day N, *et al*. Abdominal obesity and respiratory function in men and women in the EPIC-Norfolk Study, United Kingdom. Am J Epidemiol 2004;159:1140–9.
16. Chen Y, Rennie D, Cormier YF, Dosman J. Waist circumference is associated with pulmonary function in normal-weight, overweight, and obese subjects. Am J Clin Nutr 2007;85:35–9.
17. Salome CM, King GG, Berend N. Physiology of obesity and effects on lung function. J Appl Physiol (1985) 2010;108:206–11.
18. Patil SP, Schneider H, Marx JJ, Gladmon E, Schwartz AR, Smith PL. Neuromechanical control of upper airway patency during sleep. J Appl Physiol (1985) 2007;102:547-56.
19. Millman RP, Carlisle CC, McGarvey ST, Eveloff SE, Levinson PD. Body fat distribution and sleep apnea severity in women. Chest 1995;107:362–6.
20. Hoffstein V, Mateika S. Differences in abdominal and neck circumferences in patients with and without obstructive sleep apnoea. Eur Respir J 1992;5:377–81.
21. Litonjua AA, Sparrow D, Celedon JC, DeMolles D, Weiss ST. Association of body mass index with the development of methacholine airway hyperresponsiveness in men: The normative aging study. Thorax 2002;57:581–5.
22. King GG, Brown NJ, Diba C, Thorpe CW, Muñoz P, Marks GB, *et al*. The effects of body weight on airway calibre. Eur Respir J 2005;25:896–901.
23. Mahadev S, Farah CS, King GG, Salome CM. Obesity, expiratory flow limitation and asthma symptoms. Pulm Pharmacol Ther 2013;26:438–43.
24. Mancuso P. Obesity and lung inflammation. J Appl Physiol Bethesda Md 1985 2010;108:722–8.
25. Al Khathlan N, Salem AM. The effect of adiposity markers on fractional exhaled nitric oxide (FeNO) and pulmonary function measurements. Int J Gen Med 2020;13:955–62.
26. Turner SW, Chang AB, Yang IA. Clinical utility of exhaled nitric oxide fraction in the management of asthma and COPD. Breathe 2019;15:306–16.
27. Zerah F, Harf A, Perlemuter L, Lorino H, Lorino AM, Atlan G. Effects of obesity on respiratory resistance. Chest 1993;103:1470–6.
28. Verma M, Rajput M, Sahoo SS, Kaur N. Neck circumference: Independent predictor for overweight and obesity in adult population. Indian J Community Med 2017;42:209-13.
29. Dietary Guidelines for Americans | health.gov [Internet]. Available from: https://health.gov/our-work/nutrition-physical-activity/dietary-guidelines. [Last accessed on 2023 Feb 08].
30. Lear SA, James PT, Ko GT, Kumanyika S. Appropriateness of waist circumference and waist-to-hip ratio cut-offs for different ethnic groups. Eur J Clin Nutr 2010;64:42–61.
31. King GG, Bates J, Berger KI, Calverley P, de Melo PL, Dellacà RL, *et al*. Technical standards for respiratory oscillometry. Eur Respir J 2020;55:1900753. doi: 10.1183/13993003.00753-2019.
32. Brashier B, Salvi S. Measuring lung function using sound waves: Role of the forced oscillation technique and impulse oscillometry system. Breathe Sheff Engl 2015;11:57–65.
33. Bickel S, Popler J, Lesnick B, Eid N. Impulse oscillometry: Interpretation and practical applications. Chest 2014;146:841–7.
34. Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BG, Hall GL, *et al*. Standardization of Spirometry 2019 update. An Official American Thoracic Society and European Respiratory Society Technical Statement. Am J Respir Crit Care Med 2019;200:e70–88.
35. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, *et al*. An official ATS clinical practice guideline: Interpretation of exhaled nitric oxide levels (FENO) for clinical applications. Am J Respir Crit Care Med 2011;184:602–15.
36. Zhou LN, Wang Q, Gu CJ, Li N, Zhou JP, Sun XW, *et al*. Sex Differences in the effects of obesity on lung volume. Am J Med Sci 2017;353:224–9.
37. Shore SA, Johnston RA. Obesity and asthma. Pharmacol Ther 2006;110:83–102.
38. Haslam DW, James WPT. Obesity. Lancet 2005;366:1197–209.
39. James WPT. The epidemiology of obesity: The size of the problem. J Intern Med 2008;263:336–52.
40. van Noord JA, Demedts M, Clément J, Cauberghs M, Van de Woestijne KP. Effect of rib cage and abdominal restriction on total respiratory resistance and reactance. J Appl Physiol Bethesda Md 1985 1986;61:1736–40.
41. Gupta N, Sachdev A, Gupta D, Gupta S. Oscillometry – The future of estimating pulmonary functions. Karnataka Pediatr J 2021;35:79–87.

Supplementary Material

Table 6: Effect of body mass index (BMI) on spirometry and impulse oscillometry parameters

Parameters	Males		*P*	Females		*P*
	BMI ≥25 (*n*=11)	BMI <25 (*n*=12)		BMI ≥25 (*n*=10)	BMI <25 (*n*=12)	
SVC (%predicted)	84.25±2.65	83.73±4.49	0.924	90.86±2.22	86.28±2.75	0.222
FVC (%predicted)	88.94±3.71	87.52±3.98	0.797	92.50±2.41	91.52±1.83	0.745
FEV_1 (%predicted)	83.10±3.86	83.25±4.90	0.981	85.07±3.03	85.29±2.34	0.953
FEV_1/FVC (%)	78.51±0.94	78.89±1.48	0.832	81.44±3.01	81.27±1.75	0.958
PEF (% predicted)	83.96±7.08	77.66±6.50	0.518	78.39±7.56	78.00±6.01	0.967
FeNO (ppb)	18.50 (7-40)	12 (9-26)	0.458	14.5 (11-28)	18 (9-69)	0.337
R_5 [kPa/(L/S)]	0.405±0.03	0.3586±0.02	0.262	0.450±0.03	0.438±0.03	0.803
R_5 (%predicted)	152.2±14.24	132.0±8.814	0.231	133.3±10.12	133.7±10.33	0.976
R_{20} [kPa/(L/S)]	0.334±0.03	0.300±0.02	0.362	0.365±0.01	0.358±0.02	0.808
R_{20} (%predicted)	147.8±14.21	129.0±10.99	0.301	131.2±6.26	135.5±9.02	0.715
X_5 [kPa/(L/S)]	-0.105±0.007	-0.121±0.01	0.233	-0.147±0.01	-0.169±0.01	0.287
X_5 (%predicted)	-514.0(-875.5– 5611)	-571.5 (-8353 – 211412)	0.877	-729.3(-3294 – 31646)	-1450 (-7448-3052)	0.488
X_{20} [kPa/(L/S)]	0.042±0.007	0.048±0.008	0.650	0.042(-0.020-0.110)	0.045 (-0.030-20.09)	0.740
X_{20} (%predicted)	47.07±8.15	63.70±10.10	0.219	38.14±14.14	41.46±14.84	0.874
Ax[kPa/L]	0.513±0.07	0.499±0.080	0.904	0.764±0.16	0.832±0.15	0.771
Fres [1/S]	15.64±0.88	14.88±0.92	0.563	16.18±1.12	15.73±1.24	0.794

Values expressed are mean ± SD (Unpaired *t*-test) or median with inter-quartile range (IQR) (Mann whitney test). **P* <0.05, ***P* <0.01 and ****P* <0.001 statistically significant. SVC-slow vital capacity, FVC-forced vital capacity, FEV_1-forced expiratory volume at 1st second, PEF-peak expiratory flow, R_5-resistance at 5Hz, R_{20}-resistance at 20Hz, Fres-resonant frequency, Ax-area of reactance, X_5-reactance at 5Hz, X_{20}-reactance at 20Hz

Table 7: Effect of waist circumference (WC) on spirometry and impulse oscillometry parameters

Parameters	Males		*P*	Females		*P*
	WC ≥90 (*n*=14)	WC <90 (*n*=09)		WC ≥80 (*n*=15)	WC <80 (*n*=07)	
SVC (%predicted)	85.28±3.33	81.96±4.341	0.546	87.98±2.20	89.17±3.57	0.770
FVC (%predicted)	89.81±3.70	85.69±3.785	0.465	91.83±1.96	92.26±1.96	0.894
FEV_1 (%predicted)	84.30±4.19	81.43±4.66	0.660	83.33±2.24	89.17±2.84	0.142
PEF (% predicted)	86.65±6.24	71.38±6.41	0.117	73.48±5.36	88.24±8.24	0.141
FeNO (ppb)	18.67±2.55	15.89±2.16	0.436	15 (11.50-24.75)	27 (18.50-55)	0.071
X_5 (%predicted)	-521.7(-780.1-578)	-568.2(-708.1-445.2)	0.592	-1472(-3009-255.1)	-644.2(-1428-136.6)	0.572

Values expressed are mean ± SD (Unpaired *t*-test) or median with inter-quartile range (Mann-whitney test). **P* <0.05 and ***P* <0.01 statistically significant. SVC-slow vital capacity, FVC-forced vital capacity, FEV_1-forced expiratory volume at 1st second, PEF-peak expiratory flow, X_5-reactance at 5Hz

Table 8: Effect of Waist Hip Ratio (WHR) on spirometry and impulse oscillometry parameters

Parameters	Males		*P*	Females		*P*
	WHR ≥0.95 (*n*=11)	WHR <0.95 (*n*=12)		WHR ≥0.8 (*n*=15)	WHR <0.8 (*n*=07)	
SVC (%predicted)	84.66±2.58	83.35±4.52	0.808	87.07±2.26	91.13±3.10	0.315
FVC (%predicted)	85.95±2.38	90.25±4.67	0.435	91.27±1.99	93.46±1.70	0.496
FEV_1 (%predicted)	81.73±2.97	84.51±5.36	0.663	85.21±2.47	85.16±2.55	0.990
PEF (% predicted)	80.91±6.79	80.46±6.88	0.963	78.79±5.73	76.87±8.44	0.852
FeNO (ppb)	18.00±2.99	17.00±1.96	0.779	16 (9-69)	25 (11-34)	0.511
X_5 (%predicted)	-568.2 (-8353-211412)	-521.3(-791.6 - -239.4)	0.735	-1029 (-5564-31646)	-685.8(-7448-554.5)	0.887

Values expressed are mean ± SD (Unpaired *t*-test) or median with inter-quartile range (Mann-Whitney test). **P* <0.05, ***P* <0.01 and ****P* <0.001 statistically significant. SVC-slow vital capacity, FVC-forced vital capacity, FEV_1-forced expiratory volume at 1st second, PEF-peak expiratory flow, X_5-reactance at 5Hz

Table 9: Effect of neck circumference (NC) on spirometry and impulse oscillometry parameters

Parameters	Males		*P*	Females		*P*
	NC ≥36.55 (*n*=16)	NC <36.55 (*n*=07)		NC ≥34.05 (*n*=08)	NC <34.05 (*n*=14)	
SVC (%predicted)	85.18±3.12	81.23±4.94	0.498	91.03±2.34	86.84±2.53	0.283
FVC (%predicted)	89.27±3.56	85.74±3.47	0.556	95.05±2.84	90.20±1.48	0.110
FEV_1 (%predicted)	84.20±4.04	80.84±4.47	0.628	83.33±2.99	86.26±2.35	0.455
PEF (% predicted)	86.57±5.48	67.20±7.37	0.057	72.64±7.64	81.34±5.87	0.379
FeNO (ppb)	14.50 (10.5-21.25)	21 (11-23)	0.261	17 (12.5-28.75)	16 (14-28)	0.919
R_5 [kPa/(L/S)]	0.37 (0.33-0.44)	0.35 (0.28-0.39)	0.402	0.469±0.03	0.429±0.02	0.424
R_5 (%predicted)	146.6±10.93	130.3±10.87	0.378	139.7±11.47	130±9.21	0.522
R_{20} [kPa/(L/S)]	0.324±0.02	0.300±0.023	0.556	0.370±0.02	0.356±0.01	0.664
R_{20} (%predicted)	141.7±11.87	129.4±11.59	0.538	133.3±7.92	133.7±7.72	0.972
X_5 [kPa/(L/S)]	-0.11±0.005	-0.118±0.016	0.623	-0.161±0.02	-0.157±0.01	0.856
X_5 (%predicted)	-521.7(-763.9-167.1)	-568.2(-712.3-[-339.4])	0.616	-1079(-2070-2352)	-900.9(-3518-160.7)	0.432
X_{20} [kPa/(L/S)]	0.04±0.006	0.054±0.01	0.295	0.032 (0.003-0.05)	0.047 (0.02-0.10)	0.272
X_{20} (%predicted)	44.60 (33.63-73.13)	62.10 (47-100.3)	0.141	23.75±12.53	49.21±13.87	0.234
Ax[kPa/L]	0.527±0.05	0.457±0.13	0.557	0.903±0.20	0.743±0.13	0.505
Fres [1/S]	15.84±0.64	13.88±1.42	0.161	16.88±1.24	15.40±1.10	0.405

Values expressed are mean ± SD (Unpaired *t*-test) or median with inter-quartile range (Mann-Whitney test). $^*P<0.05$ statistically significant. SVC-slow vital capacity, FVC-forced vital capacity, FEV_1-forced expiratory volume at 1st second, PEF-peak expiratory flow, R_5-resistance at 5Hz, R_{20}-resistance at 20Hz, Fres-resonant frequency, Ax-area of reactance, X_5-reactance at 5Hz, X_{20}-reactance at 20Hz

Table 10: Correlation of lung function parameters with obesity indices in males

	BMI		WHR		WC		NC	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
‡SVC	-0.1049	0.6337	0.1761	0.4217	0.1028	0.6407	0.1789	0.4140
‡FVC	-0.1012	0.6460	-0.02394	0.9137	0.06082	0.7828	0.1699	0.4384
‡FEV_1	-0.1220	0.5793	0.001874	0.9932	0.06112	0.7817	0.1985	0.3640
‡FEV_1/FVC	-0.1642	0.4539	-0.1360	0.5359	-0.1102	0.6165	0.2076	0.3419
‡PEF	-0.1800	0.4111	0.1597	0.4666	-0.004938	0.9822	0.2501	0.2498
ΠFENO	#0.1036	0.6549	-0.1036	0.6550	0.04270	0.8542	-0.07548	0.7450

$^*P<0.05$ and $^{**}P<0.01$ statistically significant (‡pearson correlation, Πspearman correlation). SVC-slow vital capacity, FVC-forced vital capacity, FEV_1-forced expiratory volume at 1st second, PEF-peak expiratory flow

Table 11: Correlation of lung function parameters with obesity indices in females

	BMI		WHR		WC		NC	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
‡SVC	0.2366	0.2547	-0.2071	0.3205	-0.01162	0.9561	0.00044	0.9983
‡FVC	0.03462	0.8695	-0.2637	0.2028	-0.07406	0.7250	-0.1878	0.3687
‡FEV_1	-0.1004	0.6329	-0.1642	0.4328	0.7250	0.3884	-0.3100	0.1316
‡FEV_1/FVC	-0.1991	0.3401	-0.07931	0.7063	-0.2800	0.1753	-0.3241	0.1140
‡PEF	-0.01994	0.9246	0.1293	0.5381	-0.08358	0.6912	0.0066	0.9747
ΠFENO	-0.2278	0.3342	-0.2811	0.2300	-0.3543	0.1253	-0.1023	0.6679

$^*P<0.05$ and $^{**}P<0.01$ statistically significant (‡Pearson correlation, Πspearman correlation). SVC-slow vital capacity, FVC-forced vital capacity, FEV_1-forced expiratory volume at 1st second, PEF-peak expiratory flow