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Running head: THE IMPACT OF BODY MASS INDEX IN ADULTS

THE IMPACT OF BODY MASS INDEX AND WAIST CIRCUMFERENCE  
ON LUNG VOLUMES IN THE ADULT POPULATION

By

Sarah Basheer Al Ahmed

A Thesis

Presented in Partial Fulfillment of Requirements for the

Degree of Master of Science In Health Sciences In the

Department of Respiratory Therapy

Under the supervision of Dr. Douglas S. Gardenhire

in

Byrdine F. Lewis College of Nursing and Health Professions

Georgia State University

Atlanta, Georgia 2021

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THE IMPACT OF BODY MASS INDEX AND WAIST CIRCUMFERENCE ON LUNG  
VOLUMES IN THE ADULT POPULATION

By

Sarah Basheer Al Ahmed

(Under the Direction of Dr. Douglas S. Gardenhire)

**ABSTRACT**

**BACKGROUND:** This study aimed to examine the impact of Body Mass Index and Waist. The circumference on Pulmonary Function Test spirometry parameters such as FVC, FEV<sub>1</sub>, PEF and FEF<sub>25-75%</sub> in the adult population.

**METHODS:** Twenty-five adult participants (aged between 18 and 50 years) were involved in this study. The participants completed a questionnaire about their weight, height, gender, waist circumference, and medical history. The height, weight, and waist circumferences were obtained in the pulmonary function test lab. Subjects were instructed to perform at least three acceptable forced vital capacity maneuvers by spirometry to meet the acceptability criteria for the American thoracic society (ATS) testing standards; the FVC and FEV<sub>1</sub> maneuvers should be within 150 ml for the subject to meet the repeatability criteria. The Body mass index was calculated for all subjects.

**RESULTS:** The result shows no significant impact of BMI on FVC, FEV<sub>1</sub>, PEFR, or FEF<sub>25-75%</sub> (P values = 0.056, 0.419, 0.413, 0.843, respectively and r values = 0.4, 0.2, -0.2, -0.04, respectively). Also, there was no significant impact found between WC and FVC, FEV<sub>1</sub>, PEFR, or FEF<sub>25-75%</sub> (P values= 0.397, 0.920, 0.359, 0.727 respectively and r values= 0.2, -0.02, -0.2, -0.1, respectively).

**CONCLUSION:** This study found no significant correlation between BMI and spirometric values (FVC, FEV<sub>1</sub>, PEFR, or FEF<sub>25-75%</sub>), and no correlation found between WC and spirometric values (FVC, FEV<sub>1</sub>, PEFR, or FEF<sub>25-75%</sub>).



## DEDICATION

After twelve stressful months of working on this dissertation, I want to thank God for wisdom, power, health, passion, and all the blessings during the completion of this thesis and throughout my whole life. I'm also deeply thankful to my mother, father, and sisters for their unlimited support, encouragement, motivation, care, and sincere prayers which made me this strong person during graduate school. I'm also incredibly grateful for my husband, who supported me to chase my dreams and came all the way from Saudi Arabia to the United States with me; no words can express my gratitude.

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## TABLE OF CONTENTS

<b>Chapter I.....</b>	<b>1</b>
<b>Introduction .....</b>	<b>1</b>
<b>Background .....</b>	<b>2</b>
<b>Statement of the Problem.....</b>	<b>2</b>
<b>Purpose of the Study.....</b>	<b>3</b>
<b>Research Questions.....</b>	<b>3</b>
<b>Significance of the study.....</b>	<b>3</b>
<b>Assumptions .....</b>	<b>4</b>
<b>Definition of Terms.....</b>	<b>4</b>
<b>Summary .....</b>	<b>4</b>
<b>Chapter II.....</b>	<b>6</b>
<b>Review of the Literature .....</b>	<b>6</b>
<b>Background Information on Obesity.....</b>	<b>6</b>
<b>Central Obesity .....</b>	<b>8</b>
<b>Respiratory Symptoms in Normal Subjects with High Body Mass Index .....</b>	<b>9</b>
<b>Respiratory Comorbidities Related to Obesity.....</b>	<b>10</b>
<b>Spirometry Test .....</b>	<b>11</b>
<b>High Body Mass Index and Lung Volumes.....</b>	<b>11</b>
<b>Central Obesity and Lung Volumes.....</b>	<b>12</b>
<b>Chapter III.....</b>	<b>14</b>
<b>Methodology.....</b>	<b>14</b>
<b>Population.....</b>	<b>14</b>
<b>Subjects Selection .....</b>	<b>15</b>
<b>Data Collection.....</b>	<b>16</b>
<b>Procedure and Time Frame.....</b>	<b>16</b>
<b>Data Analysis.....</b>	<b>17</b>
<b>Data Management and Storage .....</b>	<b>17</b>
<b>Chapter IV.....</b>	<b>18</b>
<b>Results.....</b>	<b>18</b>
<b>CHAPTER V.....</b>	<b>20</b>
<b>Discussion .....</b>	<b>20</b>
<b>Limitation .....</b>	<b>21</b>
<b>Conclusion .....</b>	<b>21</b>
<b>References.....</b>	<b>22</b>

## CHAPTER I

### INTRODUCTION

Obesity is one of the most common medical conditions in the world (Ng et al., 2014). It is defined as a chronic health condition characterized by increased body mass index due to an excessive aggregation of fat in the body. It is determined by Body Mass Index (BMI), which is calculated by dividing the weight of the subject in kilogram (kg) over the square of height in meters (m<sup>2</sup>) (WHO, 1997).

According to previous findings, obese individuals have a higher potential risk of respiratory symptoms, such as dyspnea at rest (Sahebajami, 1998a). In pulmonary function tests (PFTs), the predictive values are usually determined by several factors, such as height, gender, age, and race. Besides, according to Harik-Khan et al. (2001), lung volumes decline with aging, and the lung volumes are bigger in men compared to that in women. Weight has an influence on the respiratory system, especially obesity, which is classified as a restrictive disease process. The effect might include impairment in small airways, limitation in expiratory flow, reduction in the respiratory muscle strength, change in respiratory mechanics, decreased gas exchange, reduction in the chest wall and lung compliance, decreased breathing control, and limitation in exercise capability (Salome et al., 2010).

Most studies used pulmonary function test (PFT) parameters to assess the impact of body mass index on the respiratory system. A study conducted by Jones and Nzekwu (2006) on 373 patients revealed a significant negative effect of high body mass index on lung volumes, especially expiratory reserve volume (ERV) and functional residual capacity (FRC). Another study showed that a high body mass index leads to a reduction in lung compliance and FRC (Pelosi et al., 1998). Therefore, the spirometry test could be used to examine the

amount of the effect of body mass index on spirometric test; this will show if obesity has an approved impact on the respiratory system.

### **Background**

In the United States, obesity is observed in 68.5% of adults who are more than 20 years old (Ogden et al., 2014). Two different types of obesity are known among the general population: central and peripheral obesity. Central obesity is defined as excess adipose tissue in the frontal chest wall, the abdominal wall, and the visceral organs. It is more prevalent in males than in females. In peripheral obesity, the adipose tissue is located in the subcutaneous tissue in extremities, and it is more prevalent in females than in males (McClean et al., 2008).

In central obesity, the excessive buildup of adipose tissue in the abdominal side leads to impaired lung function and the worsening of respiratory symptoms (Wannamethee et al., 2005). Moreover, it causes restrained diaphragmatic activity, diminished air entry in the lung bases, ventilation/perfusion mismatch, and hypoxemia (Babb et al., 2008; Gibson, 2000; Leone et al., 2009; Malhotra & Hillman, 2008; Wannamethee et al., 2005).

### **Statement of the Problem**

According to previous studies, alternations in lung volumes may occur in the early stages of obesity (Babb et al., 2008; Jones & Nzekwu, 2006). The diminished air entry in lung bases leads to a reduction in functional residual capacity (FRC). These changes might occur even in overweight individuals with body mass index  $> 25\text{--}30 \text{ kg/m}^2$  or in lean individuals with waist circumference (WC) above the normal range. Moreover, the site of the accumulated adipose tissue is essential in determining the level of effect of obesity on respiratory mechanics (Leone et al., 2009; Wannamethee et al., 2005).

Most of the studies give considerable attention to the impact of the body mass index on the lung volumes without clarifying the type of obesity or the site of fat accumulation that caused the altered lung volumes

### **Purpose of the Study**

This study aimed to examine the impact of body mass index on the pulmonary function test parameters, for instance, FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub>, in the adult population. It also aimed to examine the influence of central obesity on lung volumes, using the waist circumference as a representative value for central obesity.

Understanding the impact of each value separately (BMI and WC) on the Spirometry Test can help to distinguish if the high body mass index specifically is the cause of lung volumes alternations or if the site of fat accumulation can also influence the result.

### **Research Questions**

The following research questions will guide the acquiring of data needed to cover the requirements of the current study:

1. Is the body mass index associated with changes in lung volumes?
2. Is the waist circumference associated with changes in lung volumes?
3. Are the changes in lung volumes associated with the BMI only? Or does the central obesity also have an influence on lung volumes?

### **Significance of the study**

The current study will improve our knowledge on how obesity can impact respiratory mechanics and show the extent of objective alternations that could lead to a restriction in the normal adult population. Moreover, it will provide more understanding of the most affected parameters with obesity by the spirometry test , compare the impact of high body mass index and the central obesity on lung volumes, and clarify the cause of respiratory symptoms and

shortness of breath with an effort in normal subjects with obesity.

### **Assumptions**

This study hypothesized that a high body mass index accompanied by high waist circumference would lead to a reduction in spirometry test parameters (the values that reflect the lung volumes and the values that reflect the flow). Besides, the high body mass index is not necessarily associated with a reduction in lung volumes if the subject has a normal waist circumference.

### **Definition of Terms**

**Body mass index (BMI):** Equation used to classify the obesity level by dividing weight in kilograms (Kg) over the height in meter square ( $m^2$ ).

**Pulmonary function tests:** A group of tests that aims to measure lung volumes, capacities, flow rates, and assess gas exchange in the alveoli.

**Spirometry Test:** Non-invasive test that aims to measure the subject's ability to inhale and exhale air at a specific time and assess the general pulmonary health status.

**Forced vital capacity (FVC):** The total amount of air forcibly expired following a maximal inspiration (volume measurement).

**Forced expiratory volume in the first second ( $FEV_1$ ):** The amount of exhaled air in the first second in forced expiratory attempt (FVC).

**Peak expiratory flow (PEF):** The tested subject's maximum flow during forceful expiration, starting from total lung capacity.

**Forced expiratory flow 25–75 ( $FEF_{25-75\%}$ ):** The average flow during the mid-half of the FVC.

### Summary

The role of research in the medical field is to expand knowledge about anything that could impact people's health, such as obesity. Hence, many studies have been conducted to assess the influence of obesity on all body systems and showed considerable alternations associated with obesity. The spirometry test is a good indicator of the respiratory system's physiologic changes. Therefore, the impact of obesity on respiratory mechanics must be tested by a spirometry test to provide objective results about the expected alternations.

## CHAPTER II

### REVIEW OF THE LITERATURE

The review of the literature provides a comprehensive knowledge of all data involved in the studies conducted by other researchers to establish an evident, solid foundation regarding the impact of obesity on respiratory mechanics. The literature review's ultimate purpose is to clarify the topic from different aspects, show the conflicting viewpoints on the topic, and find the gap of evidence that indicates the necessity of the current study. The databases used to review the literature include Google Scholar, PubMed, EBSCOhost, and CINHALL.

The following keywords were used for the search process: obesity, obesity in adulthood, obesity and quality of life in adults, central obesity, central obesity and waist circumference in adults, obesity and respiratory system, spirometry test, spirometry test validity, test, obesity and lung volumes, central obesity and respiratory function, abdominal obesity, and respiratory function.

#### Background Information on Obesity

Obesity is one of the most popular issues around the world. In 1995, the estimated prevalence of obesity was 200 million in the adult population worldwide. After that, the prevalence had grown to 300 million by the year 2000, and it continued expanding in the following years (Committee, 2004). According to a previous study, increase in weight is associated with poor health status, leading to increased medical outlays. Therefore, successful planning for reducing medical expenditures must involve dealing with obesity (Finkelstein et al., 2012). For instance, Finkelstein et al. (2009) estimated the cost of obesity as 147 billion dollars per year, which is 9% annual medical outlays.

The worldwide epidemic trend of obesity started in developed countries and spread to



be common in developing countries as well (Jayawardena et al., 2013; Lissner et al., 2013; Nicholls, 2013; Philip & James, 2013; Popkin et al., 2012; Swinburn et al., 2011). The global alternations in the food system characterized by a westernized diet and sedentary lifestyle involved the developing countries (Dominguez et al., 2006). Therefore, due to globalization in the food system, obesity is now a common health issue in developing countries in poor and rich populations (Ali et al., 2016; Gupta et al., 2012; Mabchour et al., 2016; Quispe et al., 2016). Moreover, obesity has become one of the most popular health issues in the 21<sup>st</sup> century and is expected to increase cardiovascular complications in developing countries (Raymond et al., 2006).

Notably, obesity is correlated with many health conditions, such as diabetes mellitus, coagulation problems, cerebrovascular and cardiovascular disease, neoplasia, degenerative articulation disease, and sleep apnea (Dixon, 2010; Ojeda et al., 2014; Vucenik & Stains, 2012). Moreover, many studies showed a high association between obesity and mortality risk (Adams et al., 2006; Guh et al., 2009; Must et al., 1999). As stated previously, obesity is marked by excessive accumulation of adipose tissue. However, according to Health (2001), adipose tissue is highly resistant to insulin functioning compared to healthy muscle tissue. Hence, obesity is highly correlated with insulin resistance. As a result, obesity and insulin resistance are contributing factors to cardiovascular disease.

Obesity is a health condition caused by several factors: medical, social, and psychiatric causes (Pimenta et al., 2015). According to Dobrow et al. (2002), obesity was defined as a behavioral disorder that shows a high food consumption by the individual compared to the energy expenditure by the body. Hence, genetic factors must be considered for the initiation and continuation of obesity. The genetic tendency for obesity is higher in some people and lower in others. However, environmental factors play a considerable role (Blakemore & Buxton, 2014; Dubois et al., 2012; Silventoinen et al., 2010).

Many studies showed that obesity is highly associated with low self-esteem and depression (Dobrow et al., 2002). However, regardless of the contributing factor that caused obesity in an individual, the psychological part has a considerable impact on the quality of life in obese people. Previous studies revealed that obese people are negatively influenced by criticism and others' judgments (Puhl & Heuer, 2009).

### **Central Obesity**

According to Kuczmarski (2002), body mass index is commonly used as a parameter that reflects obesity in studies. However, body mass index does not always reflect central obesity (Neovius & Rasmussen, 2008) and does not consider the high value caused by muscle mass, bone, or fat mass (Hall & Cole, 2006). Therefore, the prevalence of obesity obtained using body mass index must be explained, because it is a poor index for fat distribution in the human body (Rankinen et al., 1999). However, waist circumference is strongly associated with central fat deposition (Pouliot et al., 1994); it is a reliable indicator of central obesity. Several studies showed that the excessive fat deposition in the abdominal part of the body is correlated with many serious health issues independent of high-fat deposition in the whole body and reflected by body mass index (Yusuf et al., 2005; Wang et al., 2005; Reis et al., 2009). The prevalence of general obesity that is measured by body mass index as well as central obesity that is measured by waist circumference has increased globally (Flegal et al., 2010; Gutiérrez-Fisac et al., 2012; Li et al., 2007; Macia et al., 2010; Reynolds et al., 2007; Walls et al., 2011; Wardle & Boniface, 2008; Xi et al., 2012). Moreover, studies reveal that central obesity was more prevalent than general obesity in many countries (Booth et al., 2000; Gutiérrez-Fisac et al., 2012; Li et al., 2007; Walls et al., 2011; Xi et al., 2012).

According to previous studies, central obesity is not necessarily associated with a change in BMI. (Li et al., 2007). However, the United States National Institutes of Health recommended measuring the WC only in obese and overweight individuals categorized by

BMI to assess increased disease risk (Health, 1998). Hence, there is a lack of knowledge about the prevalence of central obesity with normal BMI (Li et al., 2007; Walls et al., 2011). Moreover, several studies revealed that WC is correlated with a high risk of myocardial infarction, and different diseases cause mortality within all BMI categories (Jacobs et al., 2010; Yusuf et al., 2005).

### **Respiratory Symptoms in Normal Subjects with High Body Mass Index**

As stated previously, obese and overweight individuals tend to have more respiratory symptoms than individuals with normal BMI, even in the absence of any respiratory disease. According to previous findings, a high level of dyspnea and wheezing on exertion and rest was correlated to obese people than individuals with normal BMI (Babb et al., 2008; El-Gamal et al., 2005; Gibson, 2000).

Furthermore, according to Babb et al. (2008), dyspnea is highly correlated with increased work of breathing. The study revealed a 70% increase in oxygen demand in obese dyspneic females than in the obese control group with less dyspnea. Moreover, other studies showed that respiratory muscle function in obese individuals tends to deteriorate in a way similar to that observed in chronic pulmonary illnesses like chronic obstructive pulmonary disease (COPD). This was explained by the reduction in fat-free mass (muscle mass) in both cases (Franssen et al., 2008; Laghi & Tobin, 2003). This reduction might lead to more oxygen demand needed for respiration and increase in breathlessness in obese people. However, some studies revealed that weight loss contributes to restoring respiratory muscle function. Hence, the increased mechanical load of obesity can compromise breathing muscles by increased work of breathing as well as decreased breathing muscles functioning (Gibson, 2000; Laghi & Tobin, 2003).

El-Gamal et al. (2005) studied the increased respiratory drive seen in normocapnic obese individuals, which causes a sensation of breathlessness and reduced lung volumes. The

study revealed that respiratory symptoms and functions improved after bariatric surgery. This approves that weight loss can improve impaired pulmonary functions and reverse dyspnea commonly seen in obese people.

### **Respiratory Comorbidities Related to Obesity**

Several respiratory conditions were found in previous studies which are highly correlated with obesity. Obstructive Sleep Apnea (OSA) is one of the widespread respiratory conditions in obese individuals. According to Lettieri et al. (2008), in morbidly obese individuals with a BMI of more than 40 kg/m<sup>2</sup>, the risk of developing OSA lies between 55% and 90%.

In OSA, the upper airway closes at specific critical closing pressure. It is expected that the alternations in the neural control of the pharyngeal dilatory muscles fail to protect the upper airway against the high luminal pressures (Horner, 2007). In obese individuals, high fat deposition on the tongue and neck's soft tissues leads to increased mechanical pressure, which causes a higher risk of upper airway collapse (Patil et al., 2007). Furthermore, high BMI levels could worsen nocturnal hypoxemia in OSA patients because of the increased oxygen demand caused by obesity. Besides, during apnea events, obese individuals desaturate faster than people with normal BMI (Sato et al., 2008). Moreover, Zammit et al. (2010) stated that obesity is a leading cause of Obesity Hypoventilation Syndrome (OHS).

According to previous studies, a high BMI could cause further worsening of some pre-existing respiratory conditions. For instance, evidence shows a considerable correlation between obesity and increase in reported symptoms in asthma patients, such as wheezing and breathlessness. Moreover, a meta-analysis by Beuther & Sutherland (2007) concluded that asthma is more prevalent in obese individuals. The study showed that the prevalence of asthma was higher by 92% in obese individuals and 38% in overweight individuals.

### **Spirometry Test**

Generally, pulmonary function tests are used in clinical practice to diagnose and monitor disease progression. The alternations in lung function in the report can be classified as obstructive, restrictive, or a combination of obstructive and restrictive impairment (Ries, 1989). According to Ferguson et al. (2000), the obstructive pattern can be detected using spirometry alone by showing FEV<sub>1</sub>/FVC ratio less than the predictive value for the tested subject. However, evidence revealed that spirometry is less accurate in detecting restrictive impairments (Aaron et al., 1999). A reduction in FVC seen in the report on a spirometry test can be considered a clue for a restrictive pattern, but it is not conclusive since it can be seen in severe obstruction with air-trapping (Gove et al., 1987). If the spirometry test showed a restrictive pattern, the patient would usually be referred to further PFTs to confirm the diagnosis. The restrictive disease's final diagnosis is usually confirmed by detecting a decreased total lung capacity (TLC) (Society, 1991). Lung volumes are measured using body box (plethysmography), either by the helium dilution method or by the nitrogen washout method (Kilburn et al., 1993). However, the spirometry test's ability to predict restrictive diseases has been approved (Aaron et al., 1999).

### **High Body Mass Index and Lung Volumes**

Many studies show that increase in body weight is correlated with reduction in lung volumes (Collins et al., 1995; Pelosi et al., 1998; Ray et al., 1983; Sahebjami, 1998b; Sahebjami & Gartside, 1996; Watson & Pride, 2005). According to the evidence, there is a consensus that high BMI has a small impact on vital capacity (VC) and total lung capacity (TLC). However, the most negatively affected parameters by obesity are functional residual capacity (FRC) and expiratory reserve volume (ERV) (Pelosi et al., 1998; Ray et al., 1983). Moreover, several studies revealed that high BMI is associated with a considerable negative impact on FEV<sub>1</sub> (Carey et al., 1999; Thyagarajan et al., 2008; Zerah et al., 1993).

Generally, the factors that might influence PFTs are gender, age, height, ethnicity, and probably obesity (Shaheen et al., 2011). Therefore, BMI has been added recently as an independent factor in the model for deriving spirometric prediction calculation (Hankinson et al., 1999). The impact of BMI on pulmonary function is shown to be independent of age (Chen et al., 1993; Chinn et al., 1996). However, this effect of BMI has been examined with females and males; the studies showed significantly higher effects in males than in females (Carey et al., 1999; Chen et al., 1993; Wise et al., 1998).

### **Central Obesity and Lung Volumes**

According to Leone et al. (2009), central obesity is strongly associated with reducing FEV<sub>1</sub>, FVC, and TLC. These measurements were found in studies to be significantly reduced in individuals with upper-body fat distribution. Moreover, central obesity was correlated with a reduction in the FEV<sub>1</sub>/FVC ratio, which can indicate the influence of this type of obesity on large airway caliber. Additionally, tidal volume was found to be reduced in severe obesity and cause rapid, shallow breathing patterns (Sampson & Grassino, 1983). This functional alternation was explained by the elastic load that can be duplicated in normal-weight individuals with upper-body fat distribution (Caro et al., 1960). The FRC becomes lower than the closing volume. Hence, airway collapse occurs during tidal breathing, which leads to alveolar collapse. This causes a reduction in the ventilation of the lung bases, ventilation/perfusion, and hypoxemia. Therefore, FRC is related to the alveolar-arterial gradient and the partial pressure of oxygen in the arterial blood (PaO<sub>2</sub>) as well. However, the improvement of respiratory function with weight loss supports the claimed influence of obesity on respiratory mechanics. In addition, after bariatric surgery, the restrictive pulmonary pattern improves significantly with the improvement in the FEV<sub>1</sub>/FVC ratio and FEF<sub>25-75%</sub> as well. Therefore, the obstructive pulmonary pattern (FEV<sub>1</sub>/FVC ratio of less than 80%) tends to improve significantly (Nguyen et al., 2009). In a previously conducted

program, weight loss was associated with an improvement of 92 ml in FVC and 73 ml in FEV<sub>1</sub> for each 10% loss of pre-treatment weight (Aaron et al., 2004).

## CHAPTER III

### METHODOLOGY

This will be a correlational study. The independent variables are waist circumference and body mass index while the dependent variables are FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub>. This study aims to examine the impact of the BMI on FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub>, and the impact of the WC on FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub>.

#### Population

The current research involved twenty five subjects aged between 20 and 36 years old. Informed consent was obtained from participants. They filled a questionnaire about their weight, height, gender, waist circumference, and medical history (Table1).



**Table 1***Anthropometric characteristics of the subjects, including age*

	<b>Males (n=10)</b>	<b>Females (n= 15)</b>	<b>Combined (n=25)</b>
<b>Age (Years)</b>	24 [20-28]	23 [20-36]	23.88 [ 20-36]
<b>Weight (Kg)</b>	58.6 [71-107]	72.4 [45-170]	75.64 [ 45-170]
<b>Height (m)</b>	1.82 [1.70-1.98]	1.6 [1.49-1.84]	1.65 [1.98-1.49]
<b>BMI (Kg/m<sup>2</sup>)</b>	25.4 [22.5-30.5]	27.8 [17.3-58]	27.28 [ 17.30-58]
<b>WC (cm)</b>	92.8 [78-114]	87 [65-139]	88.4 [65-139]

\* Mean (SD). Brackets represent the range. Body mass index (BMI) is calculated by the dividing the weight (kg) by height<sup>2</sup> (meters<sup>2</sup>).

### **Subjects Selection**

The only exclusion criteria for the current study is any chronic lung condition that might influence the accuracy of the results. A convenience sample will be selected as representative for the adult population.

Informative measures and comparative measures will be obtained to conduct the current study. Informative measures will consist of gender and medical history. Comparative

measures (will be used for comparison) consist of weight, height, waist circumference, FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub>.

### **Data Collection**

The data needed for the current study will be obtained in the Pulmonary Function Test lab at Georgia State University. The obtained data will be protected in a password protected file and it will be used to answer the predetermined research questions. The study will be conducted after the IRB approval from the ethics committee.

### **Procedure and Time Frame**

First, the height (in cm) and weight (in kg) of the involved subjects will be measured with the health-o-meter scale in light clothing without shoes. Second, the pulmonary function test lab practitioner will explain the procedure to the involved subjects in the study and three forced vital capacity maneuvers will be performed by medi-soft spirometry for each subject to meet the acceptability criteria for the American Thoracic society (ATS) testing standards. Repeatability will be checked if three acceptable FVC maneuvers are obtained (FVC and FEV<sub>1</sub> maneuvers should be within 150 ml for each subject). If not, the involved subject will be instructed to repeat the maneuver until three acceptable maneuvers are obtained (without exceeding eight maneuvers). This procedure aims to obtain FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub> for involved subjects.

Third, the BMI will be calculated for all subjects. Fourth, the waist circumference will be measured (in cm) by the measuring tape horizontally, in the torso's narrowest area, between the costal border and iliac crest. Fifth, the statistics will be conducted to examine the impact of BMI on lung volumes and flows. Sixth, the statistics will be conducted to examine the impact of WC on lung volumes and flows. The time frame of the study will be discussed with the Respiratory Therapy department at Georgia State University.

### **Data Analysis**

The analysis will be performed using a Statistical Package for the Social Sciences (IBM SPSS, 26.0). The collected data will be used to measure the impact of the BMI and WC on FVC, FEV<sub>1</sub>, PEF, and FEF<sub>25-75%</sub> by Pearson's correlation.

### **Data Management and Storage**

The research proposal will be submitted to the Georgia State University Institutional Review Board (IRB) to obtain approval. All data will be double-checked to guarantee the accuracy of the results.

## CHAPTER IV

### RESULTS

Twenty-five adult subjects were recruited from Georgia State University over one month in 2021 (Table 1). All the twenty-five subjects completed the test. All the involved subjects claimed to be healthy with no chronic respiratory condition.

The study assessed the impact of the body mass index (BMI) and the waist circumference (WC) on four spirometric variables: Forced Vital Capacity (FVC), Forced Expiratory Volume in the first second (FEV<sub>1</sub>), Peak Expiratory Flow Rate (PEFR), and Forced Expiratory Flow 25-75% (FEF<sub>25-75%</sub>) using spirometry.

This study found no significant correlation between BMI and FVC, FEV<sub>1</sub>, PEFR, or FEF<sub>25-75%</sub> (P values= 0.056, 0.419, 0.413, 0.843, respectively), (r values= 0.4, 0.2, -0.2, -0.04 respectively) (Figure 1). Furthermore, there was no significant impact found between WC and FVC, FEV<sub>1</sub>, PEFR, or FEF<sub>25-75%</sub> (P values= 0.397, 0.920, 0.359, 0.727 respectively), (r values= 0.2, -0.02, -0.2, -0.1 respectively).

Power analysis was conducted based on the observed r-values to find the participants' needed number to reach significance. For the impact of BMI on spirometric values, 34 more subjects are required to detect significance in FVC, 150 more subjects are needed to detect significance in FEV<sub>1</sub>, 150 more subjects are needed to detect significance in PEFR 3860 more subjects are required to detect significance in FEF<sub>25-75%</sub>.

For the impact of WC on spirometric values, 150 more subjects are needed to detect significance in FVC, 15452 more subjects are needed to detect significance in FEV<sub>1</sub>, 150 more subjects are needed to detect significance in PEFR, and 614 more subjects are needed to detect significance in FEF<sub>25-75%</sub>. Based on this analysis, the associations which this research is looking for are very weak, and this paper was underpowered to detect the effects.

The impact of the BMI on FVC is the only close association to significance. However,

all other associations needed 150 or more participants to reach significance (Table 2).

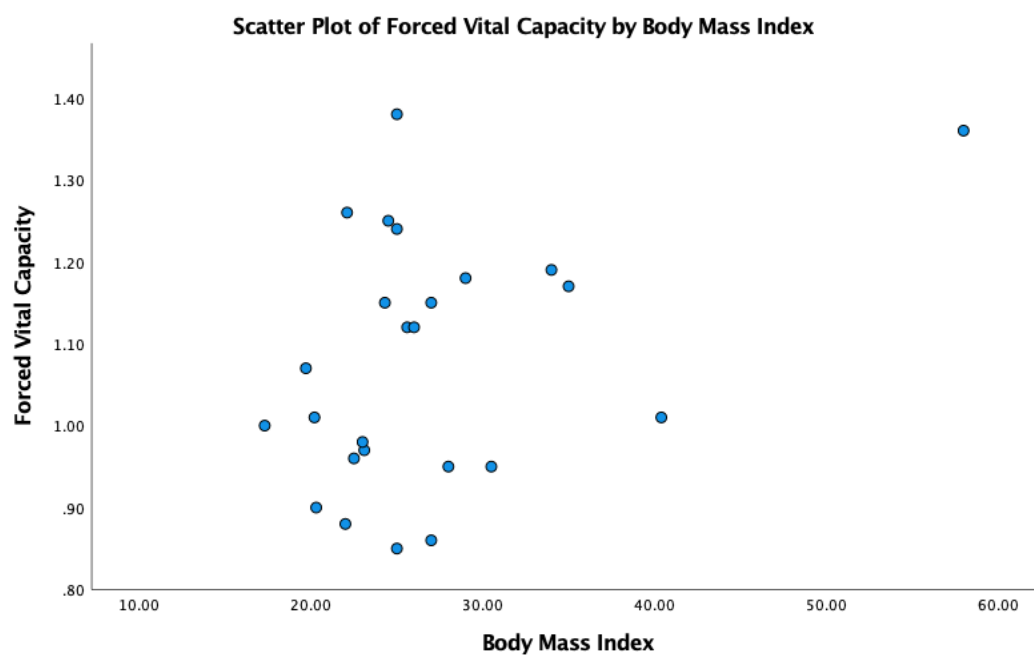
**Table 2**

*Number of participants needed to detect significance*

	<b>BMI (n needed)</b>	<b>WC (n needed)</b>
<b>FVC</b>	34	150
<b>FEV<sub>1</sub></b>	150	15452
<b>PEFR</b>	150	150
<b>FEF<sub>25-75%</sub></b>	3860	614

**Figure 1**

*The association between BMI and FVC.*



## CHAPTER V

### DISCUSSION

In the current study, there was no significant relationship found between BMI and lung function. However, lung function is usually influenced by several factors, such as smoking status, obesity, gender, and age. The impact of smoking status, gender, and age on pulmonary function has been approved (Crapo & Jensen, 2003; Pelzer & Thomson, 1966). However, no definitive research confirmed the impact of obesity on lung function, and this can be explained by various obese standards and different races (Wang et al., 2017). Besides, Schoenberg et al. (1978) state that due to increased muscle strength associated with obesity, lung function initially improved with weight gain, and then the impaired chest wall mobility causes a reduction in pulmonary function parameters.

Additionally, according to Sekhri et al. (2008), obesity may have a more significant influence on pulmonary function parameters in older subjects because of the deposition of body fat that changes with aging. As the body ages, the production of growth hormone reduces, and the basal metabolic rate decreases, causing a reduction in lean body mass and increased body fat (Rudman et al., 1990). This may explain the result of the current study, which found no significant impact of BMI and WC on spirometric values, perhaps because all participants were between 20 to 36 years old.

Interestingly, in a study conducted by (Pekkarinen et al., 2012), BMI was correlated with FVC only in men and the correlation was not found in women. However, this study found an association between WC on FVC in women.

In a meta-analysis that involved ten papers conducted by Wehrmeister et al. (2012), there was an adverse impact of WC on lung function parameters. The effect was more

significant in men. The meta-regression in this study identified gender as the characteristic that caused the heterogeneity most.

Another study conducted by YueChen et al. (2007) revealed a significant impact of WC on FVC and FEV<sub>1</sub>. In this study, a one cm increase in WC was correlated with a reduction in FVC by 15 mL for men and 11 mL for women. However, the difference between genders was not significant. This study's result is consistent with another study conducted by R. Chen et al., (2001) and involved 971 females and 865 males aged between 25 to 64. The results show that WC is negatively correlated with FVC by 7 mL/cm in females and 8 mL/cm in males, and with FEV<sub>1</sub> by 9 mL/cm in females and 17 mL/cm in males.

### **Limitation**

The current study result cannot be generalized because it involved only 25 participants and several factors must be assessed. It seems that gender and age can impact the extent of the effect of obesity on adults and must be assessed as potential confounding factors in future research. Further studies with bigger samples must be conducted to reach more conclusive results.

### **Conclusion**

This study provides no evidence for the effect of BMI and WC on lung function. The result might provide a clue about the influence of obesity (which is usually accompanied by mechanical changes in the respiratory system) on pulmonary function parameters and clarify the cause of shortness of breath with physical effort in people with obesity. More research is needed to confirm whether BMI affects lung function.

### References

- Aaron, S. D., Dales, R. E., & Cardinal, P. (1999). How accurate is spirometry at predicting restrictive pulmonary impairment? *Chest*, *115*(3), 869–873.  
<https://doi.org/10.1378/chest.115.3.869>, PubMed: 10084506.
- Aaron, S. D., Fergusson, D., Dent, R., Chen, Y., Vandemheen, K. L., & Dales, R. E. (2004). Effect of weight reduction on respiratory function and airway reactivity in obese women. *Chest*, *125*(6), 2046–2052. <https://doi.org/10.1378/chest.125.6.2046>, PubMed: 15189920.
- Adams, K. F., Schatzkin, A., Harris, T. B., Kipnis, V., Mouw, T., Ballard-Barbash, R., Hollenbeck, A., & Leitzmann, M. F. (2006). Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. *New England Journal of Medicine*, *355*(8), 763–778. <https://doi.org/10.1056/NEJMoa055643>, PubMed: 16926275.
- Ali, M. K., Bhaskarapillai, B., Shivashankar, R., Mohan, D., Fatmi, Z. A., Pradeepa, R., Masood Kadir, M., Mohan, V., Tandon, N., & Venkat Narayan, K. M. (2016). Socioeconomic status and cardiovascular risk in urban South Asia: The CARRS Study. *European Journal of Preventive Cardiology*, *23*(4), 408–419.  
<https://doi.org/10.1177/2047487315580891>, PubMed: 25917221.
- Babb, T. G., Ranasinghe, K. G., Comeau, L. A., Semon, T. L., & Schwartz, B. (2008). Dyspnea on exertion in obese women: Association with an increased oxygen cost of breathing. *American Journal of Respiratory and Critical Care Medicine*, *178*(2), 116–123. <https://doi.org/10.1164/rccm.200706-875OC>, PubMed: 18420968.
- Babb, T. G., Wyrick, B. L., DeLorey, D. S., Chase, P. J., & Feng, M. Y. (2008). Fat distribution and end-expiratory lung volume in lean and obese men and women. *Chest*, *134*(4), 704–711. <https://doi.org/10.1378/chest.07-1728>, PubMed: 18641101.



- Beuther, D. A., & Sutherland, E. R. (2007). Overweight, obesity, and incident asthma: A meta-analysis of prospective epidemiologic studies. *American Journal of Respiratory and Critical Care Medicine*, *175*(7), 661–666. <https://doi.org/10.1164/rccm.200611-1717OC>, PubMed: 17234901.
- Blakemore, A. I., & Buxton, J. L. (2014). *Obesity, genetic risk, and environment*. British Medical Journal Publishing Group.
- Booth, M. L., Hunter, C., Gore, C. J., Bauman, A., & Owen, N. (2000). The relationship between body mass index and waist circumference: Implications for estimates of the population prevalence of overweight. *International Journal of Obesity and Related Metabolic Disorders*, *24*(8), 1058–1061. <https://doi.org/10.1038/sj.ijo.0801359>, PubMed: 10951546.
- Carey, I. M., Cook, D. G., & Strachan, D. P. (1999). The effects of adiposity and weight change on forced expiratory volume decline in a longitudinal study of adults. *International Journal of Obesity and Related Metabolic Disorders*, *23*(9), 979–985. <https://doi.org/10.1038/sj.ijo.0801029>, PubMed: 10490805.
- Caro, C. G., Butler, J., & DuBois, A. B. (1960). Some effects of restriction of chest cage expansion on pulmonary function in man: An experimental study. *Journal of Clinical Investigation*, *39*(4), 573–583. <https://doi.org/10.1172/JCI104070>, PubMed: 13807830.
- Chen, R., Tunstall-Pedoe, H., Bolton-Smith, C., Hannah, M. K., & Morrison, C. (2001). Association of dietary antioxidants and waist circumference with pulmonary function and airway obstruction. *American Journal of Epidemiology*, *153*(2), 157–163. <https://doi.org/10.1093/aje/153.2.157>, PubMed: 11159161.

- Chen, Y., Horne, S. L., & Dosman, J. A. (1993). Body weight and weight gain related to pulmonary function decline in adults: A six year follow up study. *Thorax*, *48*(4), 375–380. <https://doi.org/10.1136/thx.48.4.375>, PubMed: 8511735.
- Chen, Y., Rennie, D., Cormier, Y. F., & Dosman, J. (2007). Waist circumference is associated with pulmonary function in normal-weight, overweight, and obese subjects. *The American Journal of Clinical Nutrition*, *85*(1), 35–39. <https://doi.org/10.1093/ajcn/85.1.35>, PubMed: 17209174.
- Chinn, D. J., Cotes, J. E., & Reed, J. W. (1996). Longitudinal effects of change in body mass on measurements of ventilatory capacity. *Thorax*, *51*(7), 699–704. <https://doi.org/10.1136/thx.51.7.699>, PubMed: 8882076.
- Collins, L. C., Hoberty, P. D., Walker, J. F., Fletcher, E. C., & Peiris, A. N. (1995). The effect of body fat distribution on pulmonary function tests. *Chest*, *107*(5), 1298–1302. <https://doi.org/10.1378/chest.107.5.1298>, PubMed: 7750322.
- Crapo, R. O., & Jensen, R. L. (2003). Standards and interpretive issues in lung function testing. *Respiratory Care*, *48*(8), 764–772. PubMed: 12890296.
- Dixon, J. B. (2010). The effect of obesity on health outcomes. *Molecular and Cellular Endocrinology*, *316*(2), 104–108. <https://doi.org/10.1016/j.mce.2009.07.008>, PubMed: 19628019.
- Dobrow, I. J., Kamenetz, C., & Devlin, M. J. (2002). Psychiatric aspects of obesity. *Revista Brasileira de Psiquiatria*, *24*(Suppl. III), 63–67.
- Dominguez, L. J., Galioto, A., Ferlisi, A., Pineo, A., Putignano, E., Belvedere, M., Costanza, G., & Barbagallo, M. (2006). Ageing, lifestyle modifications, and cardiovascular disease in developing countries. *Journal of Nutrition Health and Aging*, *10*(2), 143.
- Dubois, L., Ohm Kyvik, K., Girard, M., Tatone-Tokuda, F., Pérusse, D., Hjelmberg, J., Skytthe, A., Rasmussen, F., Wright, M. J., & Lichtenstein, P. (2012). Genetic and

environmental contributions to weight, height, and BMI from birth to 19 years of age:

An international study of over 12,000 twin pairs. *PLOS ONE*, 7(2), e30153.

<https://doi.org/10.1371/journal.pone.0030153>, PubMed: 22347368.

El-Gamal, H., Khayat, A., Shikora, S., & Unterborn, J. N. (2005). Relationship of dyspnea to respiratory drive and pulmonary function tests in obese patients before and after weight loss. *Chest*, 128(6), 3870–3874. <https://doi.org/10.1378/chest.128.6.3870>, PubMed: 16354856.

Expert Panel on Detection (2001). Executive summary of the third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). *JAMA*, 285(19), 2486–2497. <https://doi.org/10.1001/jama.285.19.2486>, PubMed: 11368702.

Ferguson, G. T., Enright, P. L., Buist, A. S., & Higgins, M. W. (2000). Office spirometry for lung health assessment in adults: A consensus statement from the National Lung Health Education Program. *Chest*, 117(4), 1146–1161.

<https://doi.org/10.1378/chest.117.4.1146>, PubMed: 10767253.

Finkelstein, E. A., Khavjou, O. A., Thompson, H., Trogon, J. G., Pan, L., Sherry, B., & Dietz, W. (2012). Obesity and severe obesity forecasts through 2030. *American Journal of Preventive Medicine*, 42(6), 563–570.

<https://doi.org/10.1016/j.amepre.2011.10.026>, PubMed: 22608371.

Finkelstein, E. A., Trogon, J. G., Cohen, J. W., & Dietz, W. (2009). Annual Medical Spending Attributable To Obesity: Payer-And Service-Specific Estimates: Amid calls for health reform, real cost savings are more likely to be achieved through reducing obesity and related risk factors. *Health Affairs*, 28(5)(Suppl. 1), w822–w831.

<https://doi.org/10.1377/hlthaff.28.5.w822>, PubMed: 19635784.

- Flegal, K. M., Carroll, M. D., Ogden, C. L., & Curtin, L. R. (2010). Prevalence and trends in obesity among US adults, 1999–2008. *JAMA*, *303*(3), 235–241.  
<https://doi.org/10.1001/jama.2009.2014>, PubMed: 20071471.
- Franssen, F. M. E., O'Donnell, D. E., Goossens, G. H., Blaak, E. E., & Schols, A. M. (2008). Obesity and the lung: 5· Obesity and COPD. *Thorax*, *63*(12), 1110–1117.  
<https://doi.org/10.1136/thx.2007.086827>, PubMed: 19020276.
- Gibson, G. J. (2000). Obesity, respiratory function and breathlessness. *Thorax*, *55*(Suppl. 1), S41–S44. [https://doi.org/10.1136/thorax.55.suppl\\_1.s41](https://doi.org/10.1136/thorax.55.suppl_1.s41), PubMed: 10943638.
- Gove, R. I., Shepherd, J., & Burge, P. S. (1987). Variability and reversibility of the slow and forced vital capacity in chronic airflow obstruction. *British Journal of Diseases of the Chest*, *81*(2), 182–185. [https://doi.org/10.1016/0007-0971\(87\)90137-9](https://doi.org/10.1016/0007-0971(87)90137-9), PubMed: 3651310.
- Guh, D. P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L., & Anis, A. H. (2009). The incidence of comorbidities related to obesity and overweight: A systematic review and meta-analysis. *BMC Public Health*, *9*(1), 88. <https://doi.org/10.1186/1471-2458-9-88>, PubMed: 19320986.
- Gupta, R., Deedwania, P. C., Sharma, K., Gupta, A., Guptha, S., Achari, V., Asirvatham, A. J., Bhansali, A., Gupta, B., & Gupta, S. (2012). Association of educational, occupational and socioeconomic status with cardiovascular risk factors in Asian Indians: A cross-sectional study. *PLOS ONE*, *7*(8), e44098.  
<https://doi.org/10.1371/journal.pone.0044098>, PubMed: 22952886.
- Gutiérrez-Fisac, J. L., Guallar-Castillón, P., León-Muñoz, L. M., Graciani, A., Banegas, J. R., & Rodríguez-Artalejo, F. (2012). Prevalence of general and abdominal obesity in the adult population of Spain, 2008–2010: The ENRICA study. *Obesity Reviews*, *13*(4), 388–392. <https://doi.org/10.1111/j.1467-789X.2011.00964.x>, PubMed: 22151906.

- Hall, D. M., & Cole, T. J. (2006). What is the BMI. *Archives of Disease in Childhood*, *91*(283), 6.
- Hankinson, J. L., Odencrantz, J. R., & Fedan, K. B. (1999). Spirometric reference values from a sample of the general US population. *American Journal of Respiratory and Critical Care Medicine*, *159*(1), 179–187.  
<https://doi.org/10.1164/ajrccm.159.1.9712108>, PubMed: 9872837.
- Harik-Khan, R. I., Wise, R. A., & Fleg, J. L. (2001). The effect of gender on the relationship between body fat distribution and lung function. *Journal of Clinical Epidemiology*, *54*(4), 399–406. [https://doi.org/10.1016/s0895-4356\(00\)00318-8](https://doi.org/10.1016/s0895-4356(00)00318-8), PubMed: 11297889.
- Health, N.I. of (2001). *Third Report of the National Cholesterol Education Program Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III)*. Bethesda, MD: National Institutes of Health, 285, 2486–2497.
- Horner, R. L. (2007). Contributions of passive mechanical loads and active neuromuscular compensation to upper airway collapsibility during sleep. *Journal of Applied Physiology*, *102*(2), 510–512. <https://doi.org/10.1152/jappphysiol.01213.2006>, PubMed: 17082360.
- Jacobs, E. J., Newton, C. C., Wang, Y., Patel, A. V., McCullough, M. L., Campbell, P. T., Thun, M. J., & Gapstur, S. M. (2010). Waist circumference and all-cause mortality in a large US cohort. *Archives of Internal Medicine*, *170*(15), 1293–1301.  
<https://doi.org/10.1001/archinternmed.2010.201>, PubMed: 20696950.
- James, P. T. (2004). Obesity: The worldwide epidemic. *Clinics in Dermatology*, *22*(4), 276–280. <https://doi.org/10.1016/j.clindermatol.2004.01.010>, PubMed: 15475226.
- Jayawardena, R., Byrne, N. M., Soares, M. J., Katulanda, P., & Hills, A. P. (2013). Prevalence, trends and associated socio-economic factors of obesity in South Asia.

- Obesity Facts*, 6(5), 405–414. <https://doi.org/10.1159/000355598>, PubMed: 24107686.
- Jones, R. L., & Nzekwu, M-M. U. (2006). The effects of body mass index on lung volumes. *Chest*, 130(3), 827–833. <https://doi.org/10.1378/chest.130.3.827>, PubMed: 16963682.
- Kilburn, K. H., Miller, A., & Warshaw, R. H. (1993). Measuring lung volumes in advanced asbestosis: Comparability of plethysmographic and radiographic versus helium rebreathing and single breath methods. *Respiratory Medicine*, 87(2), 115–120. [https://doi.org/10.1016/0954-6111\(93\)90138-p](https://doi.org/10.1016/0954-6111(93)90138-p), PubMed: 8497680.
- Kuczarski, R. J. (2002). CDC Growth Charts for the United States: Methods and development. *R Journal*, 2000. Department of Health and Human Services, Centers for Disease Control and. . .
- Laghi, F., & Tobin, M. J. (2003). Disorders of the respiratory muscles. *American Journal of Respiratory and Critical Care Medicine*, 168(1), 10–48. <https://doi.org/10.1164/rccm.2206020>, PubMed: 12826594.
- Leone, N., Courbon, D., Thomas, F., Bean, K., Jégo, B., Leynaert, B., Guize, L., & Zureik, M. (2009). Lung function impairment and metabolic syndrome: The critical role of abdominal obesity. *American Journal of Respiratory and Critical Care Medicine*, 179(6), 509–516. <https://doi.org/10.1164/rccm.200807-1195OC>, PubMed: 19136371.
- Lettieri, C. J., Eliasson, A. H., & Greenburg, D. L. (2008). Persistence of obstructive sleep apnea after surgical weight loss. *Journal of Clinical Sleep Medicine*, 4(4), 333–338. <https://doi.org/10.5664/jcsm.27233>, PubMed: 18763424.
- Li, C., Ford, E. S., McGuire, L. C., & Mokdad, A. H. (2007). Increasing trends in waist circumference and abdominal obesity among US adults. *Obesity*, 15(1), 216–224. <https://doi.org/10.1038/oby.2007.505>, PubMed: 17228050.

- Lissner, L., Visscher, T. L., Rissanen, A., & Heitmann, B. L. (2013). Monitoring the obesity epidemic into the 21st century-weighing the evidence. *Obesity Facts*, 6(6), 561–565. <https://doi.org/10.1159/000357539>, PubMed: 24356471.
- Mabchour, A. E., Delisle, H., Vilgrain, C., Larco, P., & Sodjinou, R. (2016). Abdominal obesity and other cardiometabolic risk biomarkers: Influence of socioeconomic status and lifestyle on two African-origin population groups, Cotonou (Benin) and Port-au-Prince (Haiti). *The Pan African Medical Journal*, 24, 306–306. <https://doi.org/10.11604/pamj.2016.24.306.8530>, PubMed: 28154661.
- Macia, E., Duboz, P., & Gueye, L. (2010). Prevalence of obesity in Dakar. *Obesity Reviews*, 11(10), 691–694. <https://doi.org/10.1111/j.1467-789X.2010.00749.x>, PubMed: 20854327.
- Malhotra, A., & Hillman, D. (2008). Obesity and the lung: 3· Obesity, respiration and intensive care. *Thorax*, 63(10), 925–931. <https://doi.org/10.1136/thx.2007.086835>, PubMed: 18820119.
- McClellan, K. M., Kee, F., Young, I. S., & Elborn, J. S. (2008). Obesity and the lung: 1· Epidemiology. *Thorax*, 63(7), 649–654. <https://doi.org/10.1136/thx.2007.086801>, PubMed: 18587034.
- Must, A., Spadano, J., Coakley, E. H., Field, A. E., Colditz, G., & Dietz, W. H. (1999). The disease burden associated with overweight and obesity. *JAMA*, 282(16), 1523–1529. <https://doi.org/10.1001/jama.282.16.1523>, PubMed: 10546691.
- Neovius, M., & Rasmussen, F. (2008). Evaluation of BMI-based classification of adolescent overweight and obesity: Choice of percentage body fat cutoffs exerts a large influence. The COMPASS study. *European Journal of Clinical Nutrition*, 62(10), 1201–1207. <https://doi.org/10.1038/sj.ejcn.1602846>, PubMed: 17684527.

- Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E. C., Biryukov, S., Abbafati, C., & Abera, S. F. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 384(9945), 766–781. [https://doi.org/10.1016/S0140-6736\(14\)60460-8](https://doi.org/10.1016/S0140-6736(14)60460-8), PubMed: 24880830.
- Nguyen, N. T., Hinojosa, M. W., Smith, B. R., Gray, J., & Varela, E. (2009). Improvement of restrictive and obstructive pulmonary mechanics following laparoscopic bariatric surgery. *Surgical Endoscopy*, 23(4), 808–812. <https://doi.org/10.1007/s00464-008-0084-9>, PubMed: 18806943.
- Nicholls, S. G. (2013). Standards and classification: A perspective on the “obesity epidemic.” *Social Science and Medicine*, 87, 9–15. <https://doi.org/10.1016/j.socscimed.2013.03.009>, PubMed: 23631773.
- Health, N. I. of (1998). Clinical guidelines for the identification, evaluation, and treatment of overweight and obesity in adults-the evidence report. *Obesity Research*, 6(2), 51S–209S.
- Committee, G. B. P. H. of C.H. (2004). *Obesity, Third Report of Session 2003–04, Vol. I. The Stationery Office*.
- Ochs-Balcom, H. M., Grant, B. J., Muti, P., Sempos, C. T., Freudenheim, J. L., Trevisan, M., Cassano, P. A., Iacoviello, L., & Schünemann, H. J. (2006). Pulmonary function and abdominal adiposity in the general population. *Chest*, 129(4), 853–862. <https://doi.org/10.1378/chest.129.4.853>, PubMed: 16608930.
- Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011–2012. *JAMA*, 311(8), 806–814. <https://doi.org/10.1001/jama.2014.732>, PubMed: 24570244.



- Ojeda, E., Lopez, S., Rodriguez, P., Moran, L., Rodriguez, J. M., & DeLucas, P. (2014). Prevalence of sleep apnea syndrome in morbidly obese patients. *Chest, 145*(3), 601A–601A. <https://doi.org/10.1378/chest.1781090>.
- Patil, S. P., Schneider, H., Marx, J. J., Gladmon, E., Schwartz, A. R., & Smith, P. L. (2007). Neuromechanical control of upper airway patency during sleep. *Journal of Applied Physiology, 102*(2), 547–556. <https://doi.org/10.1152/jappphysiol.00282.2006>, PubMed: 17008440.
- Pekkarinen, E., Vanninen, E., Länsimies, E., Kokkarinen, J., & Timonen, K. L. (2012). Relation between body composition, abdominal obesity, and lung function. *Clinical Physiology and Functional Imaging, 32*(2), 83–88. <https://doi.org/10.1111/j.1475-097X.2011.01064.x>, PubMed: 22296626.
- Pelosi, P., Croci, M., Ravagnan, I., Tredici, S., Pedoto, A., Lissoni, A., & Gattinoni, L. (1998). The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. *Anesthesia and Analgesia, 87*(3), 654–660. <https://doi.org/10.1097/00000539-199809000-00031>, PubMed: 9728848.
- Pelzer, A. M., & Thomson, M. L. (1966). Effect of age, sex, stature, and smoking habits on human airway conductance. *Journal of Applied Physiology, 21*(2), 469–476. <https://doi.org/10.1152/jappl.1966.21.2.469>, PubMed: 5934450.
- Philip, W. P., & James, T. (2013). Obesity—A modern pandemic: The burden of disease. *Endocrinologia y Nutricion: Organo de la Sociedad Espanola de Endocrinologia y Nutricion, 60*(Suppl. 1), 3–6. [https://doi.org/10.1016/s1575-0922\(13\)70015-9](https://doi.org/10.1016/s1575-0922(13)70015-9), PubMed: 24490215.
- Pimenta, F. B., Bertrand, E., Mograbi, D. C., Shinohara, H., & Landeira-Fernandez, J. (2015). The relationship between obesity and quality of life in Brazilian adults. *Frontiers in Psychology, 6*, 966. <https://doi.org/10.3389/fpsyg.2015.00966>, PubMed: 26236255.

- Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition Reviews*, *70*(1), 3–21.  
<https://doi.org/10.1111/j.1753-4887.2011.00456.x>, PubMed: 22221213.
- Pouliot, M. C., Després, J. P., Lemieux, S., Moorjani, S., Bouchard, C., Tremblay, A., Nadeau, A., & Lupien, P. J. (1994). Waist circumference and abdominal sagittal diameter: Best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *The American Journal of Cardiology*, *73*(7), 460–468. [https://doi.org/10.1016/0002-9149\(94\)90676-9](https://doi.org/10.1016/0002-9149(94)90676-9), PubMed: 8141087.
- Puhl, R. M., & Heuer, C. A. (2009). The stigma of obesity: A review and update. *Obesity*, *17*(5), 941–964. <https://doi.org/10.1038/oby.2008.636>, PubMed: 19165161.
- Quispe, R., Benziger, C. P., Bazo-Alvarez, J. C., Howe, L. D., Checkley, W., Gilman, R. H., Smeeth, L., Bernabé-Ortiz, A., Miranda, J. J., & Casas, J. P. (2016). The relationship between socioeconomic status and CV risk factors: The CRONICAS cohort study of Peruvian adults. *Global Heart*, *11*(1), 121–130.e2.  
<https://doi.org/10.1016/j.gheart.2015.12.005>, PubMed: 27102029.
- Rankinen, T., Kim, S. Y., Pérusse, L., Després, J. P., & Bouchard, C. (1999). The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. *International Journal of Obesity and Related Metabolic Disorders*, *23*(8), 801–809. <https://doi.org/10.1038/sj.ijo.0800929>, PubMed: 10490780.
- Ray, C. S., Sue, D. Y., Bray, G., Hansen, J. E., & Wasserman, K. (1983). Effects of obesity on respiratory function. *American Review of Respiratory Disease*, *128*(3), 501–506.  
<https://doi.org/10.1164/arrd.1983.128.3.501>, PubMed: 6614644.
- Raymond, S. U., Leeder, S., & Greenberg, H. M. (2006). Obesity and cardiovascular disease in developing countries: A growing problem and an economic threat. *Current Opinion*

*in Clinical Nutrition and Metabolic Care*, 9(2), 111–116.

<https://doi.org/10.1097/01.mco.0000214568.52192.91>, PubMed: 16477174.

Reis, J. P., Macera, C. A., Araneta, M. R., Lindsay, S. P., Marshall, S. J., & Wingard, D. L. (2009). Comparison of overall obesity and body fat distribution in predicting risk of mortality. *Obesity*, 17(6), 1232–1239. <https://doi.org/10.1038/oby.2008.664>, PubMed: 19197258.

Reynolds, K., Gu, D., Whelton, P. K., Wu, X., Duan, X., Mo, J., He, J., & Group, I. C. (2007). Prevalence and risk factors of overweight and obesity in China. *Obesity*, 15(1), 10–18. <https://doi.org/10.1038/oby.2007.527>, PubMed: 17228026.

Ries, A. L. (1989). Measurement of lung volumes. *Clinics in Chest Medicine*, 10(2), 177–186. PubMed: 2661117.

Rudman, D., Feller, A. G., Nagraj, H. S., Gergans, G. A., Lalitha, P. Y., Goldberg, A. F., Schlenker, R. A., Cohn, L., Rudman, I. W., & Mattson, D. E. (1990). Effects of human growth hormone in men over 60 years old. *New England Journal of Medicine*, 323(1), 1–6. <https://doi.org/10.1056/NEJM199007053230101>, PubMed: 2355952.

Sahebji, H. (1998a). Dyspnea in obese healthy men. *Chest*, 114(5), 1373–1377. <https://doi.org/10.1378/chest.114.5.1373>, PubMed: 9824017.

Sahebji, H., & Gartside, P. S. (1996). Pulmonary function in obese subjects with a normal FEV1/FVC ratio. *Chest*, 110(6), 1425–1429. <https://doi.org/10.1378/chest.110.6.1425>, PubMed: 8989055.

Salome, C. M., King, G. G., & Berend, N. (2010). Physiology of obesity and effects on lung function. *Journal of Applied Physiology*, 108(1), 206–211. <https://doi.org/10.1152/jappphysiol.00694.2009>, PubMed: 19875713.

Sampson, M. G., & Grassino, A. E. (1983). Load compensation in obese patients during quiet tidal breathing. *Journal of Applied Physiology: Respiratory, Environmental and*

*Exercise Physiology*, 55(4), 1269–1276. <https://doi.org/10.1152/jappl.1983.55.4.1269>, PubMed: 6629961.

Sato, M., Suzuki, M., Suzuki, J., Endo, Y., Chiba, Y., Matsuura, M., Nakagawa, K., Mataka, S., Kurosaki, N., & Hasegawa, M. (2008). Overweight patients with severe sleep apnea experience deeper oxygen desaturation at apneic events. *Journal of Medical and Dental Sciences*, 55(1), 43–47. PubMed: 19845149.

Schoenberg, J. B., Beck, G. J., & Bouhuys, A. (1978). Growth and decay of pulmonary function in healthy blacks and whites. *Respiration Physiology*, 33(3), 367–393. [https://doi.org/10.1016/0034-5687\(78\)90063-4](https://doi.org/10.1016/0034-5687(78)90063-4), PubMed: 705072.

Sekhri, V., Abbasi, F., Ahn, C. W., DeLorenzo, L. J., Aronow, W. S., & Chandy, D. (2008). Impact of morbid obesity on pulmonary function. *Archives of Medical Science*, 4(1), 66.

Shaheen, A. A., El-Sobeky, S. B., & Ibrahim, A. H. M. (2011). Anthropometric measurements and ventilatory function in obese and non-obese female college students. *Middle East Journal of Scientific Research*, 7(5), 634–642.

Silventoinen, K., Rokholm, B., Kaprio, J., & Sørensen, T. I. (2010). The genetic and environmental influences on childhood obesity: A systematic review of twin and adoption studies. *International Journal of Obesity*, 34(1), 29–40. <https://doi.org/10.1038/ijo.2009.177>, PubMed: 19752881.

Society, A. T. (1991). Lung function testing: Selection of reference values and interpretative strategies. *The American Review of Respiratory Disease*, 144(5), 1202–1218. <https://doi.org/10.1164/ajrccm/144.5.1202>, PubMed: 1952453.

Swinburn, B. A., Sacks, G., Hall, K. D., McPherson, K., Finegood, D. T., Moodie, M. L., & Gortmaker, S. L. (2011). The global obesity pandemic: Shaped by global drivers and

- local environments. *The Lancet*, 378(9793), 804–814. [https://doi.org/10.1016/S0140-6736\(11\)60813-1](https://doi.org/10.1016/S0140-6736(11)60813-1), PubMed: 21872749.
- Thyagarajan, B., Jacobs, D. R., Apostol, G. G., Smith, L. J., Jensen, R. L., Crapo, R. O., Barr, R. G., Lewis, C. E., & Williams, O. D. (2008). Longitudinal association of body mass index with lung function: The CARDIA study. *Respiratory Research*, 9(1), 31. <https://doi.org/10.1186/1465-9921-9-31>, PubMed: 18394165.
- Vucenik, I., & Stains, J. P. (2012). Obesity and cancer risk: Evidence, mechanisms, and recommendations. *Annals of the New York Academy of Sciences*, 1271(1), 37–43. <https://doi.org/10.1111/j.1749-6632.2012.06750.x>, PubMed: 23050962.
- Walls, H. L., Stevenson, C. E., Mannan, H. R., Abdullah, A., Reid, C. M., McNeil, J. J., & Peeters, A. (2011). Comparing trends in BMI and waist circumference. *Obesity*, 19(1), 216–219. <https://doi.org/10.1038/oby.2010.149>, PubMed: 20559295.
- Wang, S., Sun, X., Hsia, T. C., Lin, X., & Li, M. (2017). The effects of body mass index on spirometry tests among adults in Xi'an, China. *Medicine*, 96(15), e6596. <https://doi.org/10.1097/MD.0000000000006596>, PubMed: 28403098.
- Wang, Y., Rimm, E. B., Stampfer, M. J., Willett, W. C., & Hu, F. B. (2005). Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *The American Journal of Clinical Nutrition*, 81(3), 555–563. <https://doi.org/10.1093/ajcn/81.3.555>, PubMed: 15755822.
- Wannamethee, S. G., Shaper, A. G., & Whincup, P. H. (2005). Body fat distribution, body composition, and respiratory function in elderly men. *The American Journal of Clinical Nutrition*, 82(5), 996–1003. <https://doi.org/10.1093/ajcn/82.5.996>, PubMed: 16280430.

- Wardle, J., & Boniface, D. (2008). Changes in the distributions of body mass index and waist circumference in English adults, 1993/1994 to 2002/2003. *International Journal of Obesity*, 32(3), 527–532. <https://doi.org/10.1038/sj.ijo.0803740>, PubMed: 17923859.
- Watson, R. A., & Pride, N. B. (2005). Postural changes in lung volumes and respiratory resistance in subjects with obesity. *Journal of Applied Physiology*, 98(2), 512–517. <https://doi.org/10.1152/jappphysiol.00430.2004>, PubMed: 15475605.
- Wehrmeister, F. C., Menezes, A. M. B., Muniz, L. C., Martínez-Mesa, J., Domingues, M. R., & Horta, B. L. (2012). Waist circumference and pulmonary function: A systematic review and meta-analysis. *Systematic Reviews*, 1(1), 55. <https://doi.org/10.1186/2046-4053-1-55>, PubMed: 23153289.
79. Wise, R. A., Enright, P. L., Connett, J. E., Anthonisen, N. R., Kanner, R. E., Lindgren, P., O'Hara, P., Owens, G. R., Rand, C. S., & Tashkin, D. P. (1998). Effect of weight gain on pulmonary function after smoking cessation in the Lung Health Study. *American Journal of Respiratory and Critical Care Medicine*, 157(3 Pt 1), 866–872. <https://doi.org/10.1164/ajrccm.157.3.9706076>, PubMed: 9517604.
- World Health Organization (1997). *World Health Organization. Obesity: Preventing and managing the global epidemic: Report of the WHO consultation of obesity*. Geneva: World Health Organization.
- Xi, B., Liang, Y., He, T., Reilly, K. H., Hu, Y., Wang, Q., Yan, Y., & Mi, J. (2012). Secular trends in the prevalence of general and abdominal obesity among Chinese adults, 1993–2009. *Obesity Reviews*, 13(3), 287–296. <https://doi.org/10.1111/j.1467-789X.2011.00944.x>, PubMed: 22034908.
- Yusuf, S., Hawken, S., Ounpuu, S., Bautista, L., Franzosi, M. G., Commerford, P., Lang, C. C., Rumboldt, Z., Onen, C. L., & Lisheng, L. (2005). Obesity and the risk of myocardial infarction in 27 000 participants from 52 countries: A case-control study.

*The Lancet*, 366(9497), 1640–1649. [https://doi.org/10.1016/S0140-6736\(05\)67663-5](https://doi.org/10.1016/S0140-6736(05)67663-5),

PubMed: 16271645.

Zammit, C., Liddicoat, H., Moonsie, I., & Makker, H. (2010). Obesity and respiratory diseases. *International Journal of General Medicine*, 3, 335–343.

<https://doi.org/10.2147/IJGM.S11926>, PubMed: 21116339.

Zerah, F., Harf, A., Perlemuter, L., Lorino, H., Lorino, A. M., & Atlan, G. (1993). Effects of obesity on respiratory resistance. *Chest*, 103(5), 1470–1476.

<https://doi.org/10.1378/chest.103.5.1470>, PubMed: 8486029.