The interaction of sex and body mass index on ventilatory functions in school children

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Purpose
This study was designed to study the interaction of sex and BMI on ventilatory functions in Egyptian school children.
Design
A cross-sectional study among the school children aged 8–12 years.
Patients and methods
Two hundred and nineteen normal children of both sexes (118 boys and 101 girls), their ages ranged between 8 and 12 years, were selected from one of the Egyptian governmental primary schools, Educational Administration, East Cairo, participated in this study. They were divided into two groups based on their BMI (low BMI 115 and normal BMI 104 consequently). Then each group was subdivided according to the sex (67 boys and 48 girls for low BMI subgroup while in normal BMI subgroup 51 boys and 53 girls were included). Anthropometric measurements were used to calculate the BMI. Ventilatory functions were measured using a spirometer.
Results
The results revealed statistically significant interaction between the effect of sex and BMI on forced vital capacity ($P \leq 0.0001$), forced expiratory volume in the first second ($P \leq 0.0001$) and no statistically significant interaction on forced expiratory volume in the first second/forced vital capacity % ($P=0.44$). Furthermore, there was no difference between boys and girls among the measured ventilatory functions.
Conclusion
There was an interaction between the effect of sex and BMI on ventilatory functions among Egyptian school children. Therefore, healthy nutrition and exercises are highly recommended in children with low BMI.

Keywords:
school children, spirometry, underweight, ventilatory functions

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Introduction

School age is considered a growth and development period which is very important to utilize children stores nutrients in preparation for the rapid growth of adolescence [1]. The growth of children can be measured using pediatric anthropometry as it reflects the nutritional and general health status, physical growth, and motor development of children [2]. BMI is the most anthropometric method commonly used to estimate a healthy body weight based on a child's height [3].

Malnutrition is defined as different forms of poor nutrition leading to both underweight and overweight conditions [1], which have an adverse health effect throughout one's lifespan [4]. Unhealthy weight and variations of BMI either underweight, overweight, or obesity during childhood [4] hinder motor, sensory, cognitive, and social development [5].

Underweight is not a disease, but it is a result of either reduced fat mass or fat-free mass or both. It reduces the diaphragm and respiratory muscle motions by reducing the muscle mass [6] that in turn affect the mechanics of the respiratory system [7] and could be related to the impairment of pulmonary functions [8] that is determined by the interaction of elastic recoil of the lungs, chest wall, and respiratory muscle strength [9].

Assessment of ventilatory functions is essential for the evaluation of physical development [10], detection of early lung disease, and monitoring for normal lung growth and lung function decline [11]. Their values are influenced by race, age, sex, height, weight, as well as environmental, genetic, socioeconomic, and nutritional factors [12].

Spirometric evaluation of ventilatory functions include forced vital capacity (FVC), which is the maximum volume of gas that can be expired when the child exhales as forcefully and as rapidly as possible after a

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maximal inspiration [13] to assess the overall ability to move air in and out of the lungs [14]. Forced expiratory volume in the first second (FEV_1) is the volume of gas expired over a given time interval (the first second) from the beginning of the FVC maneuver that reflects airflow in the large airways [15] and FEV_1/FVC%, which is the relationship between FEV_1 and FVC to determine if the respiratory pattern is an obstructive pattern characterized by airflow obstruction related to pathologic conditions or/a restrictive pattern characterized by reduction of lung volumes without airflow obstruction [13].

The literature review showed several studies on the association of obesity and lung function, others (few) on the effect of underweight and its relation to lung function. Therefore, this study was hypothesized to study the interaction of sex and BMI on ventilatory functions in Egyptian school children.

Patients and methods

Design

Cross-sectional study among school children (8–12 years).

Participants

Two hundred nineteen normal children of both sexes (118 boys and 101 girls) were selected from one of the Egyptian governmental primary schools, Educational Administration, East Cairo, participated in this study. They were divided into two groups based on their BMI (low BMI 115 and normal BMI 104 consequently). Then each group was subdivided according to sex (67 boys and 48 girls for low BMI subgroup while in normal BMI subgroup 51 boys and 53 girls were included). This experimental study was conducted during the period from February 2018 to April 2018 according to the following criteria.

Inclusion criteria

(1) The age of children were from 8 to 12 years.
(2) BMI less than 24.9 kg/m^2 to exclude obesity.
(3) All children selected for the study were very cooperative and were informed of all procedures of the study.
(4) Parent's informed consent.

Exclusion criteria

Children were excluded from the study if they had any of the following:

(1) Overweight and obesity.
(2) Spinal deformities such as scoliosis and kyphosis.
(3) Congenital or acquired chest wall deformities (e.g. straight chest and pectus carnatus).
(4) Cardiopulmonary diseases (e.g. rheumatic and congenital heart disease, bronchial asthma, and chronic obstructive pulmonary disease).
(5) Athletic children.

Materials

(1) Standard weight and height scale (Seca apparatus 'SMIG') was used to measure body weight and height of all children to exclude obese children (BMI $<$24.9 Kg/m^2) and to introduce height of the child to fit the spirometer.
(2) Vitalograph ALPHA (Alpha ???, Model 6000) with disposable mouthpieces and filter was used for measuring the volume of air inspired and expired by the lungs over a specified period of time. The following parameters were evaluated: FVC (L), FEV_1 (L), and FEV_1/FVC % based on Venkateshaiah and Bhat [9].

Procedures

(1) Physical examination of the spine by the forward bending test to exclude any spinal deformities such as scoliosis and kyphosis.
    (a) Each child was asked to bend his back forward from standing position with knees extension, then visually scan each level of the spine to assess symmetry. If there is rib hump, it indicates scoliosis while if there is excessive trunk flexion, it indicates kyphosis.
(2) All children were informed about the purpose and nature of the study.
    (a) Each child was instructed to keep an erect posture as much as possible during measurement of body weight and height to calculate BMI to exclude obese children and to confirm that each child was matching the inclusion criteria.
    (b) Body weight (kg) was measured in an upright posture for each child.
    (c) Height (m) was measured with each child (standing barefoot in an upright position).
    (d) BMI was calculated by dividing weight (kg) by height (m^2) [BMI=weight (kg)/height (m^2)] according to Kouda *et al.* [16].
(3) Calibration of the machine was done before measuring ventilatory function test.
(4) Introduction 10 of time and date was done daily before tests.
(5) The child's physical data were recorded: name, age (years), height (m), and sex to allow the vitalograph

compact to calculate the predicted values of the measured parameters.

(6) A new disposable mouthpiece was used for each child to make sure of the hygiene principles before tests.

(7) Spirometry is a test that measures the airflow and the lung volumes during inspiratory and expiratory maneuvers through full expiration and inspiration, respectively [17]. It provides useful information on respiratory muscle function [18]. It was explained to all children to allow them to practice as prescribed prior to data collection to gain proper application of the test. Then each child was asked to:
   - (a) Stand in an upright straight posture.
   - (b) Grasp the mouth unit, keeping it in a vertical position.
   - (c) Insert the mouthpiece into his/her mouth, clamping it between his/her teeth and close his/her lips round the mouthpiece.
   - (d) Inhale as deeply as possible.
   - (e) Exhale as fast and forcefully as possible into the mouthpiece and try to keep exhalation for at least 6 s or until he/she was asked to stop, then inhale as much rapid as possible into the mouthpiece.

(8) Each child was asked to perform three successive trials then the best was recorded.

All procedures of this study were approved by the ethical standards of the Committee of the Faculty of Physical Therapy, Beni-Suef University, Egypt. Educational administration and school approval were obtained before the beginning of the study. Also, parent's informed consent was obtained for all the children before the study.

Table 1 Shapiro–Wilk test for normality of data

Variables	Groups	Statistic value	*P* value
FVC (L)	Boys (*n*=118)	0.979	0.08
	Girls (*n*=101)	0.978	0.07
FEV_1 (L)	Boys (*n*=118)	0.978	0.07
	Girls (*n*=101)	0.982	0.1
FEV_1/FVC (%)	Boys (*n*=118)	0.981	0.09
	Girls (*n*=101)	0.979	0.08

FEV_1, forced expiratory volume in the 1 s; FVC, forced vital capacity. *Significant at α=0.05.

Table 2 Levene's test for equality of variances

Variables	*F* value	*P* value
FVC (L)	2.11	0.08
FEV_1 (L)	1.77	0.15
FEV_1/FVC (%)	1.46	0.22

FEV_1, forced expiratory volume in the 1 s; FVC, forced vital capacity. *Significant at α=0.05.

Statistical analysis

Data of this study were analyzed using descriptive statistics and 2*2 factorial experimental with two independent variables which are the sex (boys vs. girls) and BMI (low vs. normal); the dependent variables were FVC, FEV_1, and FEV_1/FVC%. The software used for statistical analysis was the IBM SPSS, version 21 (IBM) (IBM Corp., Released 2012, IBM SPSS Statistics for Windows, Version 21.0, Armonk, NY: IBM Corp.). The *P* value was set at 0.05.

All data of the dependent variables are normally distributed as revealed by Shapiro–Wilk test ($P>0.05$) as presented in Table 1 and all data showed no violations of the assumptions of equality of variance as revealed by Levene's test ($P>0.05$) as demonstrated in Table 2. The differences in demographic characteristics for both groups were assessed using unpaired *t* test. A preliminary power analysis with a power of 80% determined a sample size of 45 participants in each subgroup according to the G* power software (Heinrich-Heine-Universität, Düsseldorf, Germany).

Results

The demographic data of the children (age, weight, height, BMI) are presented in Table 3, which showed no statistical differences between both groups.

Descriptive statistics of FVC, FEV_1, and FEV_1/FVC % are demonstrated in Table 4.

The 2*2 factorial experimental demonstrated a statistically significant interaction between the effect of sex and BMI on FVC and FEV_1, where F=18.02, 17.27, and *P* value less than or equal to 0.0001, 0.0001, respectively. Analysis of the simple main effects

Table 3 Demographic data of the children

Demographic data	BMI class	Boys (*n*=118)	Girls (*n*=101)	*P* value
Age (years)	Low (*n*=115)	10.13±1.26	10.02 ±1.32	0.64
	Normal (*n*=104)	10.56±1.18	10.86 ±1.17	0.2
Weight (kg)	Low (*n*=115)	31.48±4.96	31.31 ±4.78	0.85
	Normal (*n*=104)	47.13±7.77	49.63±7.3	0.9
Height (m)	Low (*n*=115)	1.39±0.07	1.37±0.08	0.19
	Normal (*n*=104)	1.46±0.09	1.49±0.08	0.1
BMI (Kg/m^2)	Low (*n*=115)	15.99±1.17	16.39 ±1.11	0.07
	Normal (*n*=104)	21.74±1.84	22.14 ±2.01	0.29

*Significant at α=0.05.

Table 4 Descriptive statistics of forced vital capacity, forced expiratory volume in the first second, and forced expiratory volume in the first second/forced vital capacity % for both groups

Variables	Groups	Low BMI (n=115)	Normal BMI (n=104)
FVC (L)	Boys (n=118)	2.09±0.3	2.31±0.44
	Girls (n=101)	1.89±0.36	2.55±0.4
FEV_1 (L)	Boys (n=118)	1.91±0.27	2.12±0.38
	Girls (n=101)	1.76±0.35	2.36±0.38
FEV_1/FVC (%)	Boys (n=118)	91.49±3.67	92.01±4.6
	Girls (n=101)	92.95±4.28	92.58±4.46

FEV_1, forced expiratory volume in the 1 s; FVC, forced vital capacity.

Table 5 The 2*2 factorial experimental results

Source of variance	F value	P value
FVC (L)		
Main effect of sex	0.13	0.71
Main effect of BMI	72.73	0.0001*
Interaction between sex and BMI	18.02	0.0001*
FEV_1 (L)		
Main effect of sex	0.79	0.37
Main effect of BMI	73.12	0.0001*
Interaction between sex and BMI	17.27	0.0001*
FEV_1/FVC (%)		
Main effect of sex	3.12	0.07
Main effect of BMI	0.01	0.89
Interaction between sex and BMI	0.59	0.44

FEV_1, forced expiratory volume in the 1 s; FVC, forced vital capacity. *Significant at α=0.05.

showed that there was no difference between boys and girls on FVC and FEV_1 as F=0.13, 0.79, and P value equals to 0.71, 0.37, respectively, but there was a significant difference between low and normal BMI on FVC and FEV_1 as F=72.73, 73.12 and P value less than or equal to 0.0001, 0.0001, respectively as presented in Table 5.

However, FEV_1/FVC% the 2*2 factorial experiment showed that there was no statistically significant interaction between the effect of sex and BMI on FEV_1/FVC% where F=0.59 and P=0.44. Furthermore, analysis of the simple main effects showed that there was no difference between boys and girls on FEV_1/FVC% as F=3.12 and P=0.07, and also there was no significant difference between low and normal BMI as F=0.01 and P=0.89 as presented in Table 5.

Discussion

The aim of this study was to determine the interaction of sex and BMI on ventilatory functions in Egyptian school children based on the hypothesis that there is no difference between boys and girls on ventilatory functions and underweight in children will lead to a decrement in the ventilatory functions.

The results of the present study have shown a statistically significant interaction between the effect of sex and BMI on FVC, FEV_1 and no statistically significant interaction between the effect of sex and BMI on FEV_1/FVC%.

Height is one of the most important data needed for the spirometric procedure as it influences the values of lung functions. In fact, variation in height per year during the study period (8–12 years) was observed either for boys or/girls, and BMI was estimated by weight (kg) divided by height (m^2); thus, it was expected that the difference in height with aging among sex will affect the calculated BMI and lung functions, respectively.

Moreover, a significant interaction between the effect of sex and BMI on FVC and FEV_1 may be attributed to small rib cage dimension and shorter diaphragm across girls and, number of alveoli (boys > girls) affect the lung functions among the two sexes who have the same height and age [19].

However, in the present study, there was no statistically significant interaction between the effect of sex and BMI in FEV_1/FVC% that indicates no airflow limitation obtained [20] as it was observed that FVC was reduced more than FEV_1.

It was confirmed that the restrictive pattern was characterized by reducing both FEV_1 and FVC in equal proportions with no lowering of FEV_1/FVC% [21]. It matches with the changes in ventilatory functions in this study.

Furthermore, the current results showed no statically significant difference between boys and girls among the selected ventilatory functions (FVC, FEV_1, and FEV_1/FVC%) during this school-age period (8–12 years). These findings can be attributed to different factors. First, values of ventilatory functions that are known to be affected by hormonal changes at the age of pubertal growth [22,23]. Second, the ventilatory functions may depend on the strength of respiratory muscles and in turn its difference between boys and girls which may increase according to the age [24] and onset of puberty [25].

In contrast, the cross-sectional study done by Budhiraja *et al.* [12] concluded that the mean values of FVC and FEV_1 were higher in Indian boys as compared with that of girls aged 6–15 years.

Belacy *et al.* [26] stated that there was a difference between Saudi men and women aged 18–25 years among FVC and FEV_1 with significant lower values in women than men because of differences in fat-free mass, chest dimensions, and power of respiratory muscles. Soundariya and Neelambikai [27] found that Indian men and women aged 18–21 years were significantly different in FVC, FEV_1, and FEV_1% with higher values in men due to greater respiratory muscle strength and greater compliance in men in relation to women.

In addition, Behera *et al.* [28] reported that Indian men had higher mean values of FVC, FEV_1, and FEV_1/FVC% than women aged 20–65 years as they explain that men have bigger lungs for the same height than women; muscularity in men accounts higher values of lung functions; and sex hormones in addition to the anatomical and physiological differences may also be responsible for the sex difference in lung functions, which come in accordance with Wang *et al.* [29], who suggested that the mean values of FVC and FEV_1 were significantly higher in Chinese men than women aged 18–80 years and Kohli *et al.* [30] showed higher mean value of FVC in Indian men than women aged 18–25 years.

On the other hand; the current results have shown significant difference between low and normal BMI on FVC, FEV_1, and no significant difference between low and normal BMI on FEV_1/FVC% during this school-age period (8–12 years). These findings can be referred to that low BMI (underweight) tend to have low body fat [6] and a depletion of body resources of proteins, calories which are associated with wasting of skeletal muscles including respiratory muscles [9] and diaphragm; therefore, malnutrition is the main factor of impaired respiratory muscles contractility force affecting lung development and its volumes [20]. However; in normal BMI, the lung functions increase in parallel with weight gain due to the increase in muscle strength [27].

There was no significant difference between low and normal BMI in FEV_1/FVC% indicating no airflow limitation obtained [20] as observed in the restrictive pattern characterized by reducing both FEV_1 and FVC in equal proportions with no lowering of FEV_1/FVC% [21].

The findings of our study come in agreement with the findings of Nair *et al.* [31] and Kaur *et al.* [20] who stated that FVC, FEV_1 were significantly diminished in Indian thin children than normal weight children aged 6–12 and 7–14 years, respectively, with no significant difference in FEV_1/FVC% for both groups of children.

However in the adolescence studies, Das *et al.* [7] showed that there was a statistically significant decrease in values of FVC and FEV_1 among thin boys aged 12–16 years compared with normal boys and a positive correlation of BMI with the same parameters in thin boys. The results were interpreted as undernutrition leads to a decrease in muscle mass, it weakens the respiratory muscle and thereby lowering the ventilatory functions.

Moreover in the adult studies, Soundariya and Neelambikai [27] and Wang *et al.* [29] recommended that the Indian and Chinese underweight participants aged 18–21 years and 18–80 years, respectively, had significantly decreased values of FVC, FEV_1, and no significant difference of FEV_1/FVC% value compared with the normal weight participants. They contributed their results to the same explanation of Venkateshaiah and Bhat [9].

Lad *et al.* [32] reported a significant difference between underweight and normal weight students aged 18–21 years in FVC and FEV_1 with lesser mean values of both sexes in the underweight group. Also, in underweight individuals of both sexes, BMI had a significant positive correlation with FVC and FEV_1.

Kohli *et al.* [30] supported a significant decrease of FVC value among the Indian candidates aged 18–25 years with lower BMI (underweight) in comparison to candidates with normal BMI.

However, Shah *et al.* [6] reported that both extremes of BMI affects ventilatory function that was demonstrated in the U-shaped relationship; however, normal BMI remains within the normal range.

On the other hand, Mannino *et al.* [33] stated that obstructive lung disease, restrictive lung disease, and respiratory symptoms are associated with a highly significant risk of functional impairment (e.g. unable to walk a quarter of a mile, unable to lift 10 pounds, and needs help with daily activities) and fair or poor health status. This can explain the hazardous effect of impaired ventilatory functions on the general health of children.

Conclusion

It could be concluded that there was an interaction between the effect of sex and BMI on ventilatory functions among Egyptian school children (East Cairo state). Sex has no effect on lung functions while low BMI (underweight) are susceptible to lung function impairment at this school-age period (8–12 years). Healthy diet and chest exercise programs are recommended for general health and improvement of lung functions among low BMI (underweight) school children aged 8–12 years.

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Conflicts of interest
There are no conflicts of interest.

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