

Pulmonary Ventilatory Functions and Obesity in Kuwait

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Key Words

Pulmonary function · Body mass index · Waist-to-hip ratio · Obesity

Abstract

Objective: To study the relationship between obesity and pulmonary ventilatory functions in Kuwaiti adults. **Subjects and Methods:** A total of 200 male and 180 female Kuwaiti adults aged 20–65 years were investigated in six medical centers from April 2004 to March 2006. Parameters measured included forced expiratory volume in 1 s (FEV₁), forced vital capacity (FVC), FEV₁ as a percentage of FVC (FEV₁%); body mass index (BMI in kg/m²) and waist-to-hip ratio (W/H). **Results:** For the whole group, males or females, BMI (kg·m⁻²) and W/H were poor individual predictors of pulmonary ventilatory functions. However, central adiposity (W/H) was associated with restrictive respiratory impairment (10.6–13.9% decrease in FEV₁ and 10–12.3% decrease in FVC), independent of sex, age or height. In obese females and males (BMI >30), increasing severity of obesity was significantly associated ($p < 0.05$, $R^2 > 0.06$) associated with increasing restrictive respiratory impairment (8.7–14.4% decrease in FEV₁ and 8–11.7% decrease in FVC), with no evidence of obstructive disease (FEV₁/FVC >0.8). **Conclu-**

sion: In adult Kuwaiti males and females, increase in body fat at BMI >30 or W/H >1 was associated with a restrictive effect on pulmonary ventilation.

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Introduction

Obesity is a prevalent health problem worldwide [1]. The influence of height, weight, age, sex, and health status on pulmonary ventilatory function has been previously described [2–6]. Most studies have shown that sex, age and height, but not body weight, are significantly correlated to pulmonary ventilation [2–4]. Nonetheless, there has been increasing interest in the relationship between the fat component of body weight and lung functions [7, 8]. Pulmonary ventilation decreases at both extremes of body weight whether in the severely underweight or in the obese [2, 9]. Ventilation has been shown to be affected by obesity [10], the most frequent abnormality being restrictive respiratory impairment. Obesity has been reported to be associated with decreases in chest compliance, reduced lung volumes, impaired airway function, and weakness of thoracic skeletal muscles [11]. Harik-Khan et al. [12] examined the relationship of

waist-to-hip ratio (W/H) to forced expiratory volume in 1 s (FEV₁) and on forced vital capacity (FVC) in a large group of subjects. A strong inverse association between W/H and FEV₁ were found in men but not in women. High W/H was also associated with reductions in FVC in men more than in women. The relationships between pulmonary ventilatory functions, body mass index (BMI) and W/H to the best of our knowledge have not been investigated in Kuwait. Therefore, the aim of this study was to evaluate the possible influences of BMI and W/H on pulmonary ventilatory functions in Kuwaiti adults.

Subjects and Methods

After obtaining permission from the Ministry of Public Health, Kuwait, an announcement was posted at the six medical centers covering all the six Governorates in the State of Kuwait. A total of 380 asymptomatic Kuwaiti volunteers, 200 males and 180 females aged 20–65 years, 150–175 cm, were sequentially admitted to the study after a comprehensive medical history including previous health information, respiratory and sleep-related symptoms was obtained. For all subjects, complete physical examinations, pulmonary function test and the anthropometry were performed by the same physician at the six medical centers, to minimize variability in measurements.

Lung function tests were performed using a COSMED PONY microprocessor-based portable spirometric system (COSMED Srl, Rome, Italy). The system was calibrated at source to read all measurements at body temperature, pressure and water vapor. Spirometric variables, namely FEV₁, FVC and FEV%, were measured and recorded for each subject. The best FVC from at least 3 acceptable attempts was chosen, following the American Thoracic Society criteria [2]. The results of pulmonary function tests were interpreted according to normal ranges recommended by the guidelines of American Thoracic Society [2] and the European Community for Coal and Steel [3].

Age, sex, height, body weight, hip and waist circumferences were determined and recorded. Age was verified with the government Civil Identification Certificate (Public Authority for Civil Identification, Kuwait). Subjects were weighed wearing light clothes and no shoes. Body weight was measured with calibrated spring balances (Seca-770 Alpha, Germany). Height was measured using Medart stadiometers (Medart Anthropometric Equipment, USA). Circumferences were measured before meals with the subject in supine position, using a non-stretchable tape, touching but not compressing the skin and avoiding twisting of the tape. Waist circumference was measured at a point midway between the iliac crest and the lower rib margin at the mid-axillary line. Hip circumference was measured with the subject standing erect, feet together and arms falling at the sides, at the maximum circumference over the buttocks. The BMI was calculated as body weight in kilograms divided by height in square meters (kg/m²). The waist-to-hip ratio was calculated as waist circumference divided by hip circumference. Obesity was assessed using the BMI and the W/H according to the World Health

Organization (WHO) criteria: normal: BMI 18.5–25 kg/m², overweight: BMI 25.1–29.9 kg/m², or obese: BMI >30 kg/m²; low risk: W/H <0.9, moderate risk: W/H 0.9–1.0, or high risk: W/H >1.0 [13]. Written consent was obtained from all the subjects.

Subjects with FEV₁ ≥80% were included while those with history of smoking or bronchial asthma, use of steroids or bronchodilators, bronchiectasis, clinical neurological defects, cardiac or pulmonary diseases and chest or spine deformities were all excluded. Classifications of subjects according to the BMI or W/H were done post hoc to all measurements.

Statistical Analysis

All data obtained were entered into a computer and statistical analysis was done using the Statistical Package for the Social Sciences (SPSS, Version 12). Linear regression analyses were carried out to quantify the relationships between the physical characteristics and the pulmonary function tests. Analysis of variance (ANOVA) was used to determine differences between groups. When between-group differences were present, unpaired Student's *t* tests with unequal variances were applied to evaluate the significance of the differences between two means. Differences were considered significant when *p* < 0.05.

Results

The physical characteristics (number of subjects, means ± SE) are presented in table 1. Average BMI, age, or W/H did not differ between males (m) and females (f) but men were taller. When female and male subjects were separately grouped according to BMI (normal, overweight, obese) or W/H (low, moderate, high), group differences in age or height (table 1) were not statistically significant (*p* > 0.1).

FVC and FEV₁ were higher in males (3.52 ± 0.1 l, 3.13 ± 0.09 l) than in females (2.84 ± 0.08 l, 2.55 ± 0.08 l), the difference was statistically significant (*p* < 0.05), but FEV% was independent of sex (table 2). All obese subjects (males and females) had significantly lower FEV₁ (m: 2.94 ± 0.12 l, f: 2.32 ± 0.12 l) and FVC (m: 3.33 ± 0.12 l, f: 2.63 ± 0.07 l) values than subjects with normal BMI (FEV₁, m: 3.22 ± 0.08 l, f: 2.71 ± 0.09 l and FVC, m: 3.62 ± 0.09 l, f: 2.983 ± 0.09 l). Similarly, males or females with high W/H had significantly lower FEV₁ (m: 2.95 ± 0.11 l, f: 2.35 ± 0.07 l) and FVC (m: 3.36 ± 0.13 l, f: 2.65 ± 0.07 l) than those with low W/H (FEV₁, m: 3.31 ± 0.12 l, f: 2.73 ± 0.87 l) and FVC (m: 3.73 ± 0.13 l, f: 3.02 ± 0.09 l) (table 2). There was no difference in FEV% in obese (m: 88.29 ± 0.87%, f: 88.01 ± 0.49%) or high W/H (m: 87.82 ± 0.09%, f: 89.08 ± 0.53%) subjects compared with those in normal subjects, BMI (m: 90.02 ± 0.88%, f: 90.34 ± 0.91%), W/H (m: 89.02 ± 0.88%, f: 90.26 ± 0.83%) (table 2).

The linear regression analysis of FEV₁ or FVC (*R*² = 0.01–0.04) revealed low correlations with BMI or with

Table 1. Means \pm standard errors of physical characteristics by subgroups of BMI and W/H ratio

	BMI subgroup							
	all		normal		overweight		obese	
	males	females	males	females	males	females	males	females
Number	200	180	60	53	65	62	75	65
BMI	28.27 \pm 0.32	28.88 \pm 0.34	23.25 \pm 0.24	23.01 \pm 0.28	27.26 \pm 0.21*	28.01 \pm 0.26*	34.30 \pm 0.47***	35.63 \pm 0.49***
Age, years	40.51 \pm 1.81	40.5 \pm 1.72	39.67 \pm 2.03	39.9 \pm 1.48	40.79 \pm 1.73	40.65 \pm 1.86	41.07 \pm 1.68	40.97 \pm 1.83
HT, cm	167.88 \pm 0.83	160.88 \pm 0.78	167.53 \pm 0.99	161.4 \pm 0.79	168.56 \pm 0.82	160.3 \pm 0.89	167.57 \pm 0.61	160.94 \pm 0.66

	W/H subgroups							
	all		low risk		moderate risk		high risk	
	males	females	males	females	males	females	males	females
Number	200	180	63	54	67	62	70	64
W/H	0.94 \pm 0.01	0.95 \pm 0.01	0.83 \pm 0.01	0.81 \pm 0.02	0.97 \pm 0.01*	0.96 \pm 0.01*	1.10 \pm 0.01***	1.09 \pm 0.01***
Age, years	40.51 \pm 1.81	40.5 \pm 1.72	38.12 \pm 2.47	38.51 \pm 1.47	39.37 \pm 1.76	38.37 \pm 1.64	40.05 \pm 1.38	40.78 \pm 1.29
HT, cm	167.88 \pm 0.83	160.88 \pm 0.78	166.89 \pm 1.32	160.37 \pm 1.06	167.68 \pm 0.95	160.03 \pm 0.86	168.1 \pm 0.45	160.45 \pm 0.68

BMI = Body mass index; W/H = waist-to-hip ratio; Number = number of subjects in each subgroup; HT = height.

* p < 0.05 vs. normal BMI/low W/H; ** p < 0.05 vs. overweight BMI/moderate W/H.

Table 2. Means \pm standard errors of the means of FEV by subgroups of BMI and W/H ratio

	BMI subgroups							
	all		normal		overweight		obese	
	males	females	males	females	males	females	males	females
Number	200	180	60	53	65	62	75	65
FEV ₁ , l	3.13 \pm 0.09	2.55 \pm 0.08	3.22 \pm 0.08	2.71 \pm 0.09	3.22 \pm 0.08	2.62 \pm 0.09	2.94 \pm 0.12*	2.32 \pm 0.06*
FVC, l	3.52 \pm 0.1	2.84 \pm 0.08	3.62 \pm 0.09	2.98 \pm 0.09	3.62 \pm 0.09	2.92 \pm 0.09	3.33 \pm 0.12*	2.63 \pm 0.07*
FEV%	89.44 \pm 0.87	89.29 \pm 0.74	90.02 \pm 0.88	90.34 \pm 0.91	90.02 \pm 0.88	89.53 \pm 0.84	88.29 \pm 0.87	88.01 \pm 0.49

	W/H subgroups							
	all		low risk		moderate risk		high risk	
	males	females	males	females	males	females	males	females
Number	200	180	63	54	67	62	70	64
FEV ₁ , l	3.13 \pm 0.09	2.55 \pm 0.08	3.31 \pm 0.12	2.73 \pm 0.87	3.17 \pm 0.07	2.61 \pm 0.08	2.95 \pm 0.11*	2.35 \pm 0.07*
FVC, l	3.52 \pm 0.1	2.84 \pm 0.08	3.73 \pm 0.13	3.02 \pm 0.09	3.57 \pm 0.07	2.91 \pm 0.08	3.36 \pm 0.13*	2.65 \pm 0.07*
FEV%	89.44 \pm 0.87	89.29 \pm 0.74	89.02 \pm 0.88	90.26 \pm 0.83	88.59 \pm 0.61	89.75 \pm 0.82	87.82 \pm 0.09	89.08 \pm 0.53

BMI = Body mass index; W/H = waist-to-hip ratio; Number = number of subjects in each subgroup; FEV₁ = forced expiratory volume in 1 s; FVC = forced vital capacity; FEV% = forced expiratory volume in 1 s as a percentage of forced vital capacity; l = liters at body temperature, pressure and water saturated.

* p < 0.05 vs. normal BMI/low W/H.

W/H, in females as well as in males: the coefficients of determination (R^2) for these relationships observed in all males and in all females did not differ significantly from 0 ($p > 0.5$) (table 3).

However, stepwise multiple regression analysis for FEV₁ ($R^2 = 0.41$) showed that in addition to the well-

known contributions of sex (std $\beta = -0.26$ with males = 1, females = 2), height (std $\beta = +0.39$) and age (std $\beta = -0.29$), W/H (std $\beta = -0.12$) and BMI (std $\beta = +0.03$) also contributed independently to account for part of the FEV₁ variability in the 380 studied subjects. Similar results were obtained for FVC.

Table 3. Coefficients of determination (R^2) for regressions of FEV on BMI and W/H ratio

	BMI subgroups							
	all		normal		overweight		obese	
	males	females	males	females	males	females	males	females
Number	200	180	60	53	65	62	75	65
R ² FEV ₁ , l	0.02	0.03	0.03	0.04	0.01	0.01	0.07*	0.06*
R ² FVC, l	0.01	0.03	0.02	0.04	0.01	0.01	0.09*	0.09*
	W/H subgroups							
	all		low risk		moderate risk		high risk	
	males	females	males	females	males	females	males	females
Number	200	180	63	54	67	62	70	64
R ² FEV ₁ , l	0.04	0.04	0.04	0.04	0.03	0.02	0.07*	0.06*
R ² FVC, l	0.01	0.02	0.02	0.03	0.01	0.01	0.07*	0.07*

BMI = Body mass index; W/H = waist-to-hip ratio; Number = number of subjects in each subgroup; FEV₁ = forced expiratory volume in 1 s; FVC = forced vital capacity; FEV% = forced expiratory volume in 1 s as a percentage of FVC; l = liters at body temperature, pressure and water saturated.

* Significant at $p < 0.05$.

In obese males with increasing BMI (>30), the regressions of FEV₁ or FVC on BMI were negative (fig. 1), and the determination coefficients ($R^2 = 0.05$ and 0.09 , respectively; table 3) were statistically significant ($p < 0.05$). These R^2 are in contrast to the lower, not significant R^2 values found for the regressions of FEV₁ or FVC on BMI observed in normal and overweight subjects. Similarly, in obese females the regressions of FEV₁ or FVC on BMI were negative with R^2 (0.06 and 0.09 , respectively) significantly different from 0 ($p < 0.05$); this in contrast to the lower, not significant R^2 values found for similar regressions in normal or overweight females (table 3). In all the obese subjects, the ratio FEV₁/FVC was ≥ 0.8 indicative of normal airway resistance. Linear regression analysis of FEV₁ or FVC against W/H in subjects with W/H >1 also showed negative trends (fig. 2) and statistically significant ($p < 0.05$) coefficients of determination (0.07 and 0.07 in males, 0.06 and 0.07 in females). The R^2 values for regressions of FEV₁ or FVC on W/H were not statistically significant in subjects with low or moderate W/H, whether males or females (table 3).

Discussion

Most previous studies have shown that the association between ventilatory pulmonary function and body weight is weak or non-significant [2, 7, 14, 15]. The additional

variance explained by BMI in linear regression models with FEV₁ or FVC has been found to be modest in adults [16, 17]. However, the lung functions have been shown to be affected by obesity, the most frequently described abnormalities being restrictive respiratory impairment, decreased compliance of the chest wall and dysfunction of thoracic skeletal muscles [11, 12].

In our study, stepwise linear regression analysis of FEV₁ or FVC revealed that independently of height, age and sex, the higher the W/H, the lower the FEV₁ or the FVC (at FEV₁/FVC >0.8), while the BMI had a weak direct and independent correlation with these variables. These data are consistent with the idea that while central body fat affects negatively the pulmonary ventilation causing restrictive impairment, the BMI can influence it positively through differences in lean body or muscle mass, particularly in non-obese subjects.

Simple linear regression analysis of BMI against FEV₁ in normal, overweight and obese groups showed that the R^2 for the negative regression observed between BMI and FEV₁ in the obese groups were greater and statistically significant compared with the slightly positive and not significant values found in the overweight and normal groups of males and females (FEV% was >80% in all these subjects). These data indicate that in the obese with BMI >30 kg/m², increases in body fat lead to restrictive respiratory impairment, perhaps through decrease in chest wall compliance, associated with the deposition of

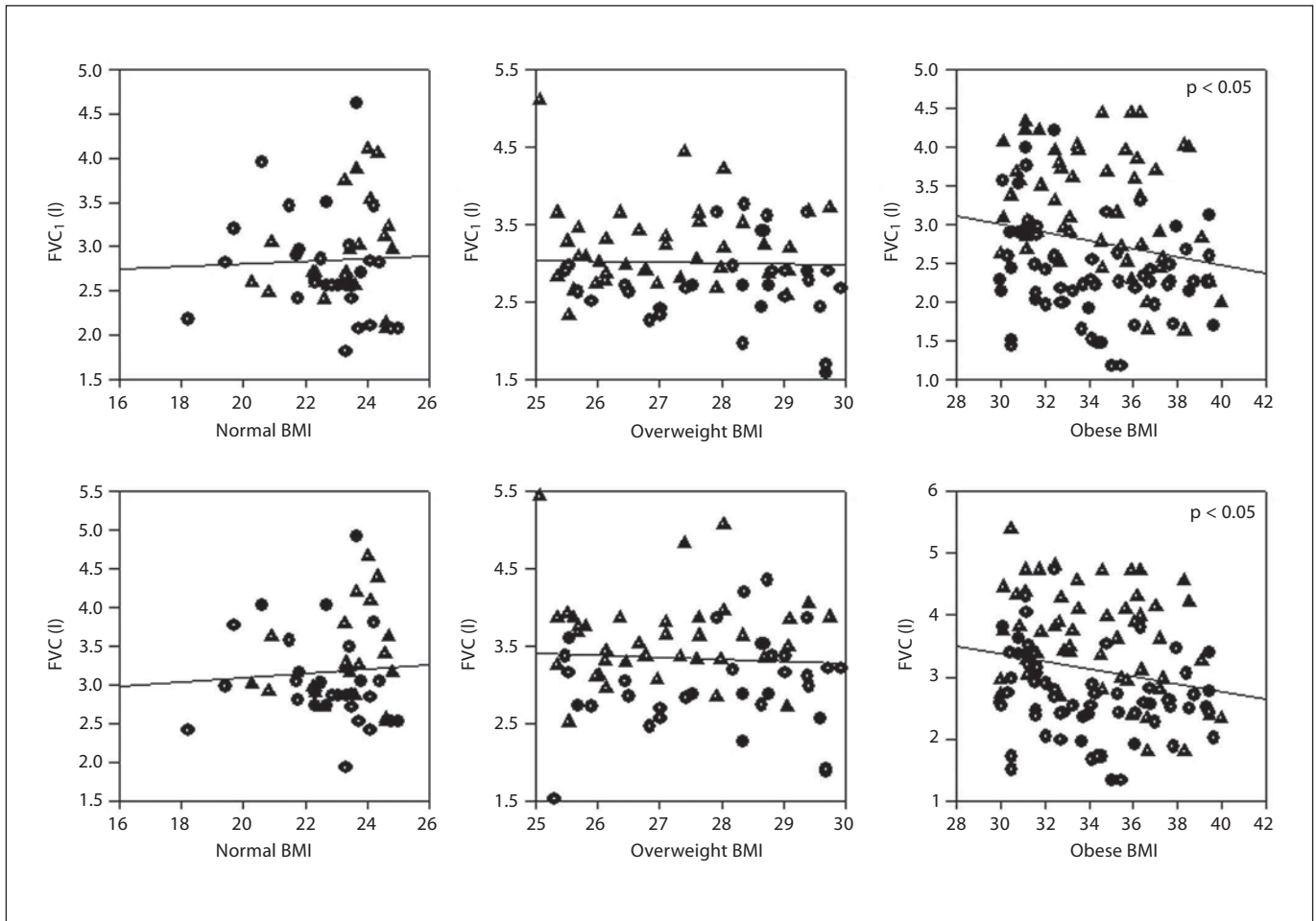


Fig. 1. Linear regressions of forced expired volumes on BMI by subgroups (▲ = males; ● = females).

adipose tissue around the chest and in the abdomen. This effect seems to be stronger than any increase in lean or muscle mass which may occur in these obese subjects. The number of subjects in each BMI or W/H group happens to be close to each other by chance. The high incidence of overweight and obesity in Kuwait partially explains the large number of subjects in these groups but is not exactly representative of the Kuwaiti population at large, where obesity occurs in 30% of the population [18].

Harik-Khan et al. [12] showed that there was an inverse association between FEV₁ and W/H in males but not in females. Increasing W/H was found to be related to greater reductions in FVC in males than in females. In our study, the inverse association between FEV₁ or FVC and W/H in obese subjects was found to occur independently of sex. The variation between the two studies

could be explained by differences of the lifestyle, socio-economic and environmental factors affecting the different female population studied, particularly if the incidence of obesity differs. Santana et al. [8] suggested that age-related changes in body composition, such as increased visceral fat and decreased skeletal muscle mass, were associated with the lung impairment observed in the elderly. In our study, independently of age, the degree of abdominal obesity, as reflected by the W/H, was found to be a determinant of restrictive pulmonary impairment. The clinical relevance of our finding relates to the medical management of obese patients that consult for breathing difficulties. They are often misdiagnosed with obstructive diseases and are often improperly treated. We therefore advise in most of these cases changes in lifestyle and weight reduction rather than pharmaceutical treatment.

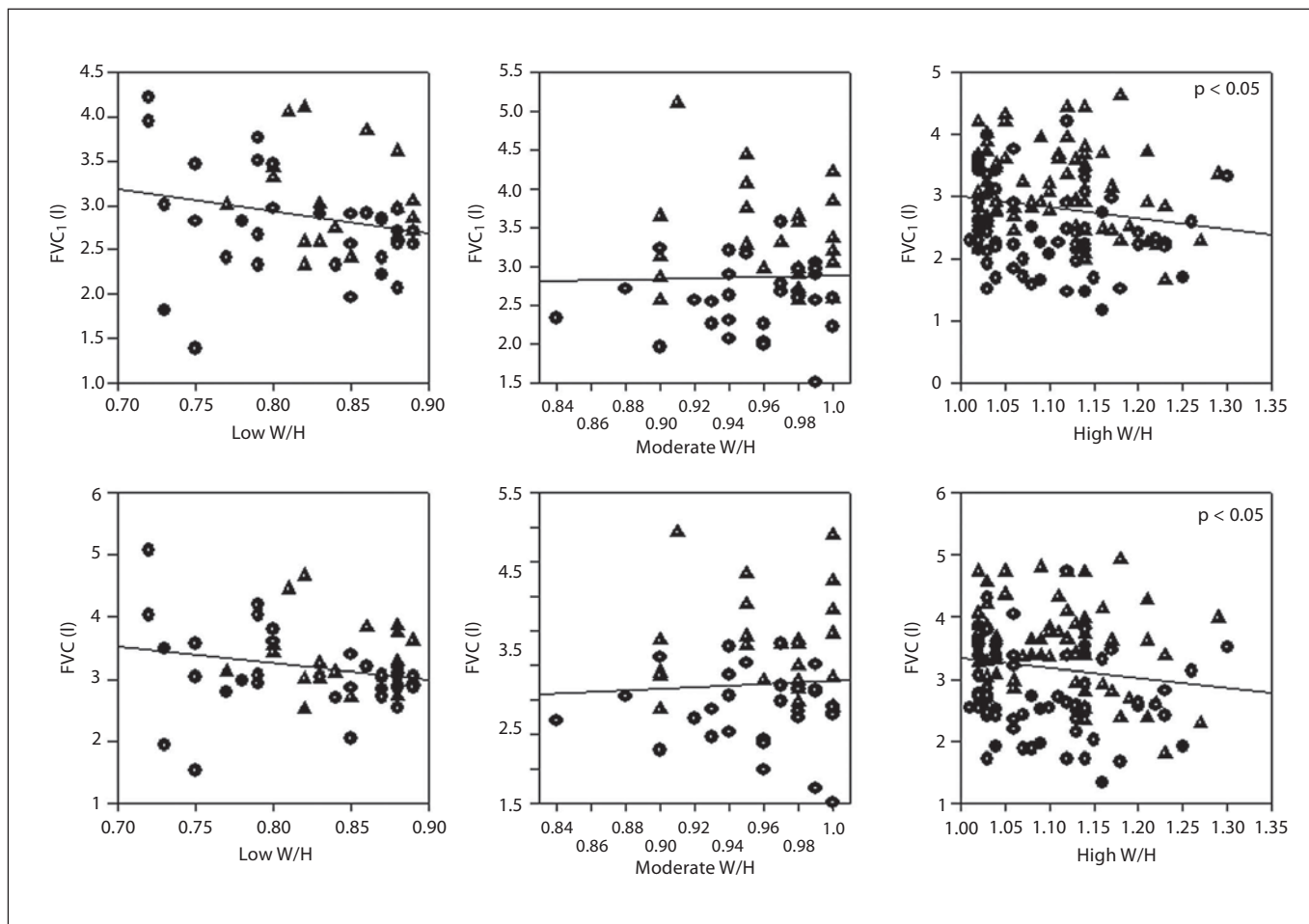


Fig. 2. Linear regressions of forced expired volumes on W/H by subgroups (▲ = males; ● = females).

Conclusion

BMI and W/H were found to be poor individual predictors of pulmonary ventilatory function in Kuwaiti adults between 20 and 65 years. However, central adiposity ($W/H > 1$) was associated with restrictive respiratory impairment, independently of sex, age and height of the subjects. In obese subjects, $BMI > 30$ were also found to be associated with ventilatory restriction that may lead to symptomatic dyspnea.

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