Obesity is defined as excess fat storage in the body that is capable of causing various health problems leading to excess mortality. In Malaysia, the prevalence of overweight is plateauing, but obesity is still rising based on the 2015 National Health and Morbidity Survey. The percentage of overweight and obese adult males increased from 16.6% and 4.4%, respectively, in 1996 to 29.1% and 14.0% in 2006, and 30.0% and 17.7% in 2015. Among adult females, the prevalence of obesity was relatively higher; from 7.6% in 1996, to 17.4% in 2006, and 20.6% in 2015.

The obesity epidemic poses a new challenge for health professionals caring for patients with chronic respiratory diseases. Overweight and obesity are known to cause various patterns of alteration to the pulmonary function test (PFT) parameters depending on its severity. Both static and dynamic lung volumes and capacities are compromised in obesity. Obesity is found to decrease the lung volumes and capacities by decreasing both lung and chest wall compliance. There is also an increase in resistance to outflow of air through the airways. Most studies were conducted in healthy individuals of various age groups.

There is a dearth of information on the alteration of the PFT parameters across gender and body mass index (BMI). Therefore, we sought to investigate gender differences in PFT parameters and examine the relationship between BMI and various PFT parameters.

METHODS
We conducted a retrospective study in the Universiti Sains Malaysia (USM) using data recorded from patients referred for PFT to the Physiology Laboratory, School of Medical Sciences, USM, between January and December 2015 by various medical specialties. Selection criteria included males and females between 19 and 90 years old. Patients were excluded if they were referred for pre- and post-bronchodilator assessment. Ethical approval for the usage of these data was obtained from the Human Research Ethics Committee of USM (USM/JEPeM/16110417).

Body weight data were obtained using a standardized electronic weighing machine and recorded to the nearest 0.1 kg. During body weight measurement, patients stood without footwear and wearing only light clothing. The heights of
the patients were measured using the stadiometer and recorded to the nearest centimeter. BMI was calculated using Quetelet's index. Subjects were stratified by BMI ranges as per WHO classification: Underweight (< 18.5 kg/m²), normal weight (18.5 to 25.0 kg/m²), overweight (25.0 to 30.0 kg/m²), and obese (> 30.0 kg/m²).

Spirometry was performed to measure pulmonary function by experienced laboratory technicians using automated testing equipment (Cosmed Pony FX Desktop Spirometer, USA) according to recommended standards by the American Thoracic Society. The test was performed while patients were standing or seated on stiff chairs, in rooms with adequate ventilation and stable temperature (environmental temperature between 29°C and 33°C). Patients were instructed to sit comfortably and breathe normally three times and then take a deep breath and breathe out forcefully. All steps were repeated three times and the best results according to their predicted values were selected and recorded.

Data entry and statistical analysis were performed using SPSS Statistics (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). Values were reported as means±standard deviation (SD) unless otherwise specified. A p-value < 0.050 was considered significant in all analyses. The PFT data was recorded as an absolute value and predicted value based on gender, age, weight, and height. Comparison between genders was performed using Student's t-test while comparison across BMI subgroups was performed using analysis of variance (ANOVA) with post-hoc testing of significant variables with Bonferroni adjustment for multiple comparisons. Pearson's correlation coefficient was used to measure the relationship between BMI and PFT parameters.

RESULTS

Our study included 126 patients (85 males and 41 females) aged 19–90 years referred for a PFT between January and December 2015. Male patients were older than female patients (61.7±13.2 vs. 53.2±14.2 years).

The mean values of PFT parameters of male and female patients are shown in Table 1. There was a significant difference in the mean age between males and females (p = 0.001, 95% confidence interval (CI): 3.44–13.65). There were also significant differences in the mean values for forced vital capacity (FVC)% predicted (p < 0.001, 95% CI: 6.42–20.67), forced expiratory volume in 1 second (FEV₁)% predicted (p = 0.007, 95% CI: 3.14–19.17) and peak expiratory flow (PEF) (p < 0.001, 95% CI: 0.99–2.17). The mean values for FVC% predicted, FEV₁% predicted, and PEF were higher in males compared to females: 71.2±18.4 vs. 57.6±19.9, 67.6±22.2 vs. 56.4±19.1, and 4.5±1.9 vs. 2.9±1.3, respectively. However, the mean values for FEV₁/FVC ratio and BMI between males and females were not significantly different.

Our results showed no significant differences in the mean values for FVC% predicted, FEV₁% predicted, and PEF were higher in males compared to females: 71.2±18.4 vs. 57.6±19.9, 67.6±22.2 vs. 56.4±19.1, and 4.5±1.9 vs. 2.9±1.3, respectively. However, the mean values for FEV₁/FVC ratio and BMI between males and females were not significantly different.

Our results showed no significant differences in the mean values for FVC% predicted, FEV₁% predicted, and PEF were higher in males compared to females: 71.2±18.4 vs. 57.6±19.9, 67.6±22.2 vs. 56.4±19.1, and 4.5±1.9 vs. 2.9±1.3, respectively. However, the mean values for FEV₁/FVC ratio and BMI between males and females were not significantly different.

Table 1: Mean values of PFT parameters among male and female patients.

| Parameter          | Male (n = 85) | Female (n = 41) | Mean difference (95% CI) | t-statistic (df) | p-value* |
|--------------------|--------------|----------------|--------------------------|------------------|----------|
| Age, years         | 61.7 ± 13.2  | 53.2 ± 14.2    | 8.55 (3.44–13.65)        | 3.31 (124.0)     | 0.001    |
| BMI                | 24.8 ± 5.1   | 25.4 ± 6.2     | -0.53 (-2.61–1.54)       | -0.51 (124.0)    | 0.612    |
| FVC% predicted     | 71.2 ± 18.4  | 57.6 ± 19.9    | 13.54 (6.42–20.67)       | 3.76 (124.0)     | < 0.001  |
| FEV₁% predicted    | 67.6 ± 22.2  | 56.4 ± 19.1    | 11.16 (3.14–19.17)       | 2.76 (124.0)     | 0.007    |
| FEV₁/FVC ratio     | 74.6 ± 13.4  | 82.6 ± 12.4    | -4.60 (-10.41–1.21)      | -1.57 (124.0)    | 0.119    |
| PEF, L/sec         | 4.5 ± 1.9    | 2.9 ± 1.3      | 1.59 (0.99–2.17)         | 5.34 (107.1)     | < 0.001  |

*PFT: pulmonary function test; CI: confidence interval; BMI: body mass index; FVC: forced vital capacity; FEV₁: forced expiratory volume in 1 second; PEF: peak expiratory flow.

Values are means ± standard deviation unless otherwise specified.

*p < 0.050 by independent t-test.
and between BMI and PEF. There were no significant correlations between BMI and the other parameters.

Table 3: Pearson correlation between BMI and PFT parameters.

| Correlation of BMI with | Pearson correlation coefficient, r | p-value |
|------------------------|-----------------------------------|---------|
| FEV₁ % predicted       | 0.079                             | 0.379   |
| Male                   | 0.093                             | 0.398   |
| Female                 | 0.097                             | 0.548   |
| FVC% predicted         | -0.033                            | 0.716   |
| Male                   | -0.029                            | 0.792   |
| Female                 | -0.003                            | 0.983   |
| FEV₁/FVC ratio         | 0.262                             | 0.003** |
| Male                   | 0.277                             | 0.010*  |
| Female                 | 0.234                             | 0.142   |
| PEF, L/sec             | 0.282                             | 0.001** |
| Male                   | 0.308                             | 0.004** |
| Female                 | 0.408                             | 0.008** |

**DISCUSSION**

Our study had three main findings: 1) male patients had higher mean values of all PFT parameters compared to females, 2) there were no significant differences in the mean values of PFT parameters among various BMI categories, and 3) there were significant weak positive correlations between BMI and FEV₁/FVC ratio, as well as between BMI and PEF. The effects of BMI on PFT parameters were more pronounced in males than females.

Our data analyses on the mean values of PFT parameters between genders revealed significant gender differences for FVC% predicted, FEV₁ % predicted, and PEF despite no difference in their BMI. Our results correspond with other studies that reported higher mean values of PFT parameters in male patients compared to females.¹⁰⁻¹¹ This trend, however, contrasts with another report where females exhibited higher PFT parameters compared to males.¹² Several other studies, reported no significant gender differences in the pulmonary function profiles in the sample studied.¹³⁻¹⁶ Possible explanations on the gender differences include differences in lung geometry between the genders; females, on average, would be expected to have smaller airways and lung geometry.
volumes than males.\textsuperscript{17} Hormonal differences may be another contributing factor.\textsuperscript{18}

Despite no significant difference in the PFT parameters among the various BMI categories, the \( \frac{\text{FEV}_1}{\text{FVC}} \) ratio demonstrated an increasing trend with increasing BMI ranges in our study. We also found a significant, albeit weak, positive correlation between BMI and \( \frac{\text{FEV}_1}{\text{FVC}} \) ratio as well as between BMI and PEF. These findings suggest the restrictive effects of increased BMI as all our patients exhibited FVC < 80%. This phenomenon has also been reported in other earlier studies.\textsuperscript{12,19–21}

A previous study looked at the relationship between obesity and airway obstruction and found that obese participants were at lower risk for airflow obstruction.\textsuperscript{19} The authors concluded that mechanisms other than airflow obstruction may be responsible for dyspnea in their obese population.\textsuperscript{19}

In another study, the effect of BMI on pulmonary function in Japanese patients attending general clinics was investigated.\textsuperscript{20} The researchers found that patients with higher BMI had less obstructive pulmonary dysfunction compared to normal BMI patients and concluded that high BMI status alone might be inappropriate as a predictor of obstructive lung dysfunction, particularly in populations with a low prevalence of obesity.

Moreover, one study found a restrictive pulmonary function profile in obesity specific to non-asthmatics.\textsuperscript{21} Similar findings were noted in another study whereby a significant increase in the \( \frac{\text{FEV}_1}{\text{FVC}} \) ratio demonstrated throughout increasing BMI ranges is suggestive of the restrictive effects of increased BMI.\textsuperscript{12}

Other investigators found that obesity does not have an effect on the spirometry tests (except PEF) among healthy non-smoking Saudi adults.\textsuperscript{22} This discrepancy could be due to the differences in the study populations as our study included both smokers and non-smokers. In addition, Biring et al.\textsuperscript{14} found a reduction in expiratory reserve volume, FVC, \( \text{FEV}_1 \), functional residual capacity, forced expiratory flow 25–75%, and maximum voluntary ventilation in their study on adults with extreme obesity. Our study population categorized adults with BMI > 30.0 kg/m\textsuperscript{2} as obese and did not further subcategorized obese into class I (30.0 to < 35.0), II (35.0 to < 40.0), and III or extreme obesity (40.0 or higher).

**CONCLUSION**

Males have higher mean values of PFT parameters than females, and a higher BMI seems to be associated with a restrictive pattern on spirometry.

**Disclosure**

The authors declared no conflict of interest. No funding was received for this study.

**REFERENCES**

1. Sørensen TI. Obesity defined as excess storage of inert triglycerides--do we need a paradigm shift? Obes Facts 2011;4(2):91-94.
2. Institute for Public Health (IPH) National Health and Morbidity Survey 2015 (NHMS 2015). Vol. II: Non-Communicable Diseases, Risk Factors & Other Health Problems. Kuala Lumpur: Ministry of Health Malaysia; 2015: page 49.
3. Fatimah S, Tahir A, Siri S, Maimunah AH. Nutritional status of adults aged 18 years and above, the Second National Health and Morbidity Survey, Ministry of Health Malaysia, Putrajaya, 1997.
4. Institute for Public Health (IPH) The Third National Health and Morbidity Survey (NHMS III) 2006, Nutritional Status. Kuala Lumpur: Ministry of Health Malaysia; 2006: page 59-60.
5. Poulin M, Doucet M, Major GC, Drapeau V, Sériès F, Boulet LP, et al. The effect of obesity on chronic respiratory diseases: pathophysiology and therapeutic strategies. CMAJ 2006 Apr;174(9):1293-1299.
6. Naimark A, Cherniack RM. Compliance of the respiratory system and its components in health and obesity. J Appl Physiol 1960 May;15:377-382.
7. Rubinstein I, Zamel N, DuBarry L, Hoffstein V. Airflow limitation in morbidly obese, nonsmoking men. Ann Intern Med 1990 Jun;112(11):828-832.
8. Garrow JS, Webster J. Quetelet's index (W/H2) as a measure of fatness. Int J Obes 1985;9(2):147-153.
9. American Thoracic Society. Standardization of spirometry: 1994 update. Am J Respir Crit Care Med 1995 Sep;152(3):1107-1136.
10. Ostrowski S, Barud W. Factors influencing lung function: are the predicted values for spirometry reliable enough? J Physiol Pharmacol 2006 Sep;57(Suppl 4):263-271.
11. Shinray AJ, Kanan W, Jamatia SN, Roel S, Kom LB, Oumanath F, et al. Gender difference in spirometric lung functions in chronic obstructive pulmonary disease patients attending rims hospital out-patient department. IOSR-JDNR 2014 Sep;13(9):49-51.
12. Banerjee J, Roy A, Singhahapatra A, Dey PK, Ghosal A, Das A. Association of body mass index (BMI) with lung function parameters in non-asthmatics identified by spirometric protocols. J Clin Diagn Res 2014 Feb;8(2):12-14.
13. Emigil C, Sobol BJ. The effects of weight reduction on pulmonary function and the sensitivity of the respiratory center in obesity. Am Rev Respir Dis 1973 Oct;108(4):831-842.
14. Biring MS, Lewis MJ, Liu JT, Mohsenifar Z. Pulmonary physiologic changes of morbid obesity. Am J Med Sci 1999 Nov;318(5):293-297.
15. Zerah F, Harf A, Perlemuter L, Lorino H, Lorino AM, Atlan G. Effects of obesity on respiratory resistance. Chest 1993 May;103(5):1470-1476.
16. Jones RL, Nzekwu MM. The effects of body mass index on lung volumes. Chest 2006 Sep;130(3):827-833.
17. Brooks LJ, Byard PJ, Helms RC, Fouke JM, Strohl KP.
Relationship between lung volume and tracheal area as assessed by acoustic reflection. J Appl Physiol (1985) 1988 Mar;64(3):1050-1054.

18. Celedon JC, Speizer FE, Drazen JM, Weiss ST, Campbell EJ, Carey VJ, et al. Bronchodilator responsiveness and serum total IgE levels in families of probands with severe early-onset COPD. Eur Respir J 1999 Nov;14(5):1009-1014.

19. Sin DD, Jones RL, Man SF. Obesity is a risk factor for dyspnea but not for airflow obstruction. Arch Intern Med 2002 Jul;162(13):1477-1481.

20. Fukahori S, Matsue H, Tukamura N, Tsuchida T, Kawano T, Fukushima C, et al. Body mass index correlated with forced expiratory volume in 1 second/forced vital capacity in a population with a relatively low prevalence of obesity. Chin Med J (Engl) 2010 Oct;123(20):2792-2796.

21. Andrew J, Debbie B, Ali B. The association of body mass index with airway obstruction in non-asthmatics: Implications for the inaccurate differential diagnosis of asthma in obesity. Canadian Journal of Respiratory Therapy 2011;47(2):11-22.

22. Al Ghobain M. The effect of obesity on spirometry tests among healthy non-smoking adults. BMC Pulm Med 2012 Mar;12:10.