

The effects of obesity on pulmonary function

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Aims: (1) To determine the predominant pulmonary function abnormality in our population of obese children; and (2) to assess the correlation between the severity of lung function impairment and the degree of obesity as assessed by dual energy x ray absorptiometry (DEXA).

Methods: Sixty four obese patients underwent physical examination, standardised pulmonary function tests (spirometry, lung volumes, and single breath diffusion capacity for carbon monoxide), and DEXA scan measurements. The trunk and subtotal (total – head) body fat mass were used as surrogate index of body adiposity.

Results: Sixteen girls and 48 boys with median age and body mass index (BMI) of 12 years (interquartile range (IQR): 10–14) and 30.1 kg/m² (IQR: 27.2–32.8) respectively were studied. None of the patients had clinical evidence of cardiopulmonary disease. Reduction in functional residual capacity (median FRC 93% predicted, IQR: 68.5–116.5%) and impairment of diffusion capacity (median DLco 83.5% predicted, IQR: 70.0–100.7%) were the most common abnormalities in our cohort, being observed in 30 (46%) and 21 (33%) patients respectively. Obstructive ventilatory impairment was found in three patients. There was significant negative correlation between the degree of reduction of FRC but not DLco with DEXA scan measurements, but such a relation was not found when BMI was used as the indicator of obesity.

Conclusion: Reduction in FRC and diffusion impairment were the commonest abnormalities found in our cohort of obese patients. Reduction in static lung volume was correlated with the degree of obesity.

An increase in the prevalence of obesity in children has been seen around the world.¹ A survey of 25 000 Hong Kong children in 1993 showed that 13.4% of boys and 10.5% of girls aged 6–18 years were obese (defined as >120% median weight for height using local reference ranges).² There is no doubt that the percentages are even greater nowadays because of physical inactivity and westernisation in diet. In adults, pulmonary function abnormalities are well reported complications of obesity; the most frequently reported abnormalities are reductions in lung volumes and expiratory flow rates.^{3–7} Similar data in the paediatric population are however, limited and conflicting. Marcus and colleagues,⁸ in their study of 17 patients, found only two to have abnormal lung function. One had restrictive deficit and the other obstructive abnormality. Inselman and colleagues,⁹ on the other hand, found reductions in DLco and ventilatory muscle endurance to be common among the 13 obese children they studied. Mallory and colleagues¹⁰ found that pulmonary deficit was common among their cohort of obese children and obstructive abnormality was the main problem detected. However, Bosisio and colleagues¹¹ and Chaussain and colleagues¹² were not able to find any significant pulmonary abnormalities in their study of obese children.

The aim of our study is twofold: (1) to determine the predominant pulmonary function abnormality in our local population of obese children; and (2) to assess the correlation between the severity of lung function impairment and the degree of obesity. Unlike previous studies, we used dual energy x ray absorptiometry (DEXA) in the assessment of total and regional adiposity.

METHODS

Children aged 7–18 years with primary obesity were recruited from our obesity and lipid disorder clinic. All obese patients presenting at the clinic for assessment and advice on healthy living were eligible, except those with obesity secondary to an

organic condition, a chronic cardiorespiratory problem, skeletal abnormalities, or congenital defects. Our study was reviewed and approved by the Ethics Committee of the Chinese University of Hong Kong. Informed consent from the subjects and their parents was obtained at the beginning of the assessment. In this study an obese subject was defined as one whose body mass index (BMI) was above the 95th centile according to our local sex and age specific BMI reference range.¹³

Each child was examined by one of the two investigators (AL, DC) to assess their cardiopulmonary status. Their weight (kg) and standing height (cm) were measured with a calibrated weighing scale and stadiometer by standard anthropometric methods.¹⁴

The lung function tests were carried out by the same team of technicians according to the recommended standard.¹⁵ Spirometry was measured by a SensorMedics 2130 spirometer using the Enhanced Spirometry Program. The best of at least three technically acceptable values for forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), maximum mid-expiratory flow rate (MMEFR), and flow-volume curves were selected. Functional residual capacity (FRC), residual volume (RV), and total lung capacity (TLC) were measured by body plethysmography (SensorMedics 6200) and expressed in litres corrected for body temperature, atmospheric pressure, and saturation with water vapour. Diffusion capacity of carbon monoxide was measured by single breath technique and the values obtained were corrected for haemoglobin concentration (SensorMedics 6200 Autobox DL,

Abbreviations: BMI, body mass index; DEXA, dual energy x ray absorptiometry; DLco, diffusion capacity of the lung; FEV₁, forced expiratory volume in one second; FRC, functional residual capacity; FVC, forced vital capacity; IQR, interquartile range; MMEFR, maximum mid-expiratory flow rate; MVV, maximum voluntary ventilation; RV, residual volume; TLC, total lung capacity

Single Breath Diffusion Capacity DLco SB Program).¹⁶ The pulmonary function results were expressed as percentages of predicted normal values.¹⁷ For the purpose of this study, the threshold of abnormality was identified as under 80% of the predicted value. Restrictive disease was defined as a reduction in TLC to less than 80%; diffusion impairment as a reduction in DLco to less than 80%; and obstructive airway disease as reduced FEV₁/FVC ratio to less than 80%. The various pulmonary deficits were classified as "mild" (>70%), "moderate" (<70% and >60%), "moderately severe" (<60% and >50%), and "severe" (<50%).¹⁸

DEXA measurements were performed with a total body scanner (QDR4500A; Hologic, Waltham, MA, USA) using array mode. This equipment used a switched pulse stable dual energy x ray operating at 100 and 140 kV. An automatic internal reference system with a calibration wheel achieved the bone density measurement. Data were analysed using software version V8.26a:3. The equipment determined whole body as well as regional measurements of bone mass, lean mass, and fat mass. Total fat mass was expressed in kg and as a percentage of body mass. These were calculated by integrating the measurements for the whole body and different automatic default regions as arms, trunk, and legs. The trunk region consists of the area bordered by a horizontal line below the chin, vertical borders lateral to the ribs, and oblique lines passing through the femoral necks. The leg region included all tissue below these oblique lines. The measurements used for correlation assessment were subtotal (total – head) and trunk body fat as a percentage of body mass. The total radiation dose per scan was <1 mSv.

Statistical methods

Percentage predicted was calculated for each respiratory impairment. Median and interquartile range were presented for various interval parameters, including anthropometric measurements and pulmonary function parameters. The BMI values were converted to exact Z scores from the three smooth age specific curves *L* (lambda), *M* (mu), and *S* (sigma) values derived using the LMS method, with the formula:

$$Z = \frac{\left[\frac{BMI}{M}\right]^L - 1}{LS}$$

where the *M* and *S* curves correspond to the median and coefficient of variation of BMI at each age, and the *L* curve allows for the substantial age dependent skewness in the distribution of BMI.^{13–19} Spearman's rank correlation coefficient was used to assess the association between the DEXA measurements, BMI standard deviation score, and the various pulmonary function parameters. SPSS for Windows statistical software (release 10.1, SPSS Inc., Chicago, IL) was used in the analyses. The level of significance was set at 5% in all comparisons, and all statistical testings were two sided.

RESULTS

Sixty four children (16 girls, 48 boys) with primary obesity were recruited. None had evidence of cardiopulmonary disease on history review or clinical examination. Their median age was 12 years (interquartile range (IQR) 10–14) and the median BMI and standard deviation score were 30.1 kg/m² (IQR 27.2–32.8) and 2.42 (IQR 2.13–2.66) respectively. Table 1 shows the demographic characteristics and the results of spirometric, lung volume testing, diffusion capacity, and DEXA scan of the study population. All subjects underwent spirometric and lung volume testing but only 62 had diffusion capacity assessment. Thirty children (46%) were found to have reduced FRC. Abnormal diffusion capacity was detected in 21 subjects (33% of the study population). The deficit was of

Table 1 Demographic data and results of investigations

	Median	(Interquartile range)
Age (years)	12.0	(10.0–14.0)
Weight (kg)	70.8	(57.9–84.1)
Height (cm)	152.0	(142.3–161.0)
Body mass index (kg/m ²)	30.1	(27.2–32.8)
Body mass index standard deviation score	2.42	(2.13–2.66)
FVC (% predicted)	106.5	(97.0–114.8)
FEV ₁ (% predicted)	95.5	(88.0–105.8)
FEV ₁ /FVC (% predicted)	83.0	(78.0–87.0)
FEV _{25%–75%} (% predicted)	91.5	(74.3–102.8)
TLC (% predicted)	103.0	(91.0–115.0)
RV (% predicted)	109.5	(76.8–150.0)
FRCN2 (% predicted)	93.0	(68.5–116.0)
DLco (adjusted) (% predicted)	76.5	(64.0–85.0)
Trunk body fat (% body mass)	39.2	(36.1–41.9)
Subtotal body fat (% body mass)	40.4	(37.1–43.3)

Table 2 Spearman's correlation between the various parameters

	BMI SD score	Trunk	Subtotal
Trunk	0.480**		
Subtotal	0.510**	0.892**	
FVC	0.211	0.037	0.069
FEV ₁	0.210	–0.144	–0.130
FEV ₁ /FVC	–0.220	–0.130	–0.158
FEV _{25%–75%}	–0.127	–0.216	–0.217
TLC	–0.021	–0.264*	–0.268*
RV	–0.133	–0.290*	–0.298*
FRCN2	–0.133	–0.337**	–0.367**
DLco	–0.150	0.099	0.008

*p<0.05; **p<0.01.

moderate severity. Three children had obstructive abnormalities documented on their lung function. They were of mild severity and all had a BMI greater than 34 kg/m².

Table 2 shows Spearman's correlation between the various parameters. A significant correlation was found between BMI standard deviation score and trunk/subtotal body fat ($r = 0.48$ and $r = 0.51$ respectively, $p < 0.01$). BMI was not correlated to any of the pulmonary abnormalities. We were however, able to show significant negative correlation between both trunk and subtotal body fat with FRC, TLC, and RV but not with DLco.

DISCUSSION

In our cohort of children with primary obesity, we found reduction in FRC to be the commonest pulmonary abnormality. We were also able to show a statistically significant negative correlation between this abnormality and the degree of obesity as assessed by DEXA scan. Such a relation was however, not found when BMI was used as a marker of obesity. Previous studies in obese children were also unable to establish a relation between pulmonary deficit and anthropometric assessments of obesity.^{9–10, 20} In fact the use of anthropometric and skinfold measurements has been criticised as being unreliable and inaccurate; they are unable to adequately assess visceral adiposity and are liable to operator bias.^{21–25} DEXA scan is a more objective and reliable method of assessing adiposity. Using this technique, a total body scan is obtained with dual beam x rays of relatively low energy. From the absorbed energy at the two energy levels, different aspects of body composition can be calculated. This method requires little cooperation of the subject and involves minimal radiation. The procedure can be performed relatively quickly

(scanning time 10–25 minutes) and the results are immediately available. This method allows total body fat to be better assessed, and its use in children has been validated and confirmed to be accurate and precise.^{21–25}

Classically obesity does not affect spirometric values other than maximum voluntary ventilation (MVV) until vital capacity becomes reduced in extreme cases. It has been shown that severely obese adults, with BMI of 45 or above, had a reduction in FVC and FEV₁ compared with age matched controls. They were also found to have increased RV and RV:TLC ratio, and a higher TLC by plethysmography than by helium dilution, indicating air trapping.²⁶ In our series of 64 patients, only three had evidence of obstructive pulmonary deficit and in all cases their BMI was more than 34 kg/m², representing the more severe end of obesity among our study population. This finding supports the notion that obstructive deficit becomes a problem in the group with severe obesity.

Diminished DLco was also found to be a common abnormality in our study population. This may reflect intrinsic changes within the lung in the presence of obesity. Lipid deposition, cellular hyperplasia, alveolar enlargement, and reductions in alveolar surface area relative to lung volume occur in the lung of immature rat made obese by dietary manipulation.²⁷ The reduction in DLco seen in our group of children may suggest structural changes in the interstitium of the lung resulting from lipid deposition and/or decreased alveolar surface area. Interestingly, we found the DEXA scan result to have a negative correlation with static lung volumes but not with DLco. It is possible that reduction in static lung volumes in obese individuals is simply a mass effect which DEXA scan is capable of determining accurately, whereas deficit in DLco is more complex and may involve more than one pathophysiological mechanisms.^{27 28}

There are certain limitations to our study. Firstly, there was no control group. Although data from a control group would provide further confirmation of the abnormalities detected, we considered it unreasonable to subject normal children to unnecessary radiation. Secondly, our study was a cross sectional assessment of lung function at one time point. To better understand the progress and natural history of the abnormalities identified in this cohort, it would be ideal to undertake a longitudinal study to assess the changes in lung function in relation to body composition over time.

In summary, we found pulmonary abnormalities to be common among obese children, and that reduction in static lung volume was found to be significantly correlated with the degree of obesity. The clinical significance of such a finding in this group of asymptomatic obese children remains unknown. It is important to assess the longitudinal changes and tracking into adulthood of such abnormalities in order to provide appropriate management.

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REFERENCES

- 1 **WHO**. *Obesity: preventing and managing the global epidemic: report of a WHO consultation*. WHO technical report series; 894. Geneva: The Office of Publication, World Health Organisation, 1999.
- 2 **Leung SS**, Chan SM, Lui S, *et al*. Growth and nutrition of Hong Kong children. *Singapore Paediatr J* 1999;**38**:61–6.
- 3 **Koenig SM**. Pulmonary complications of obesity: a review. *Am J Med Sci* 2001;**321**:249–79.
- 4 **Biring MS**, Lewis MI, Liu JT, *et al*. Pulmonary physiological changes of morbid obesity. *Am J Med Sci* 1999;**318**:293–7.
- 5 **Lazarus R**, Sparrow D, Weiss ST. Effect of obesity and fat distribution on ventilation function: the normative aging study. *Chest* 1997;**111**:891–8.
- 6 **Collins LC**, Hoberty PD, Walker JF, *et al*. The effect of body fat distribution on pulmonary function tests. *Chest* 1995;**107**:1298–302.
- 7 **Jenkins SC**, Moxham J. The effects of mild obesity on lung function. *Respir Med* 1991;**85**:309–11.
- 8 **Marcus CL**, Curtis S, Koerner CB, *et al*. Evaluation of pulmonary function and polysomnography in obese children and adolescents. *Pediatr Pulmonol* 1996;**21**:176–83.
- 9 **Inselman LS**, Milanese A, Deurloo A. Effect of obesity on pulmonary function in children. *Pediatr Pulmonol* 1993;**16**:130–7.
- 10 **Mallory GB**, Fiser DH, Jackson R. Sleep associated breathing disorders in morbidly obese children and adolescents. *J Pediatr* 1989;**115**:892–7.
- 11 **Bosisio E**, Sergi M, di Natale B, *et al*. Ventilatory volumes, flow rates, transfer factor and its components (membrane component, capillary volume) in obese adults and children. *Respiration* 1984;**45**:321–6.
- 12 **Chaussain M**, Gamaïn B, La Torre AM, *et al*. Respiratory function at rest in obese children. *Bull Eur Physiopathol Respir* 1977;**13**:599–609.
- 13 **Leung SS**, Cole TJ, Tse LY, *et al*. Body mass index reference curves for Chinese children. *Ann Hum Biol* 1998;**25**:169–74.
- 14 **Tanner JM**. Physical growth and development. In: Forfar JO, Arneil GC, eds. *Textbook of paediatrics*. Edinburgh: Churchill Livingstone, 1984:304–5.
- 15 **British Thoracic Society**, and Association of Respiratory Technicians and Physiologists. Topical review: guidelines for the measurement of respiratory function. *Respir Med* 1994;**88**:165–94.
- 16 **Cotes JE**, Dabbs JM, Elwood PC, *et al*. Iron deficiency: its effect on transfer factor. *Clin Sci* 1972;**42**:325–35.
- 17 **Ip MS**, Karlberg EM, Karlberg JP, *et al*. Lung function reference values in Chinese children and adolescents in Hong Kong. *Am J Respir Crit Care Med* 2000;**162**:424–9.
- 18 **American Thoracic Society**. Lung function testing: selection of reference values and interpretative strategies. *Am Rev Respir Dis* 1991;**144**:1202–18.
- 19 **Cole TJ**, Bellizzi MC, Flegal KM, *et al*. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 1999;**320**:1240–3.
- 20 **Ho TF**, Tay JS, Yip WC, *et al*. Evaluation of lung function in Singapore obese children. *J Singapore Paediatr Soc* 1989;**31**:46–52.
- 21 **Goufing A**, Taylor RW, Gold E, *et al*. Regional body fat distribution in relation to pubertal stage: a dual-energy X-ray absorptiometry study of young women. *Am J Clin Nutr* 1996;**64**:546–51.
- 22 **Pulicino E**, Coward W, Stubbs RJ, *et al*. Bedside and field methods for assessing body composition: comparison with the deuterium dilution technique. *Eur J Clin Nutr* 1990;**44**:753–62.
- 23 **Roubenoff R**, Kehayias JJ, Dawson-Hughes B, *et al*. Use of dual energy X-ray absorptiometry in body composition studies: not yet a “gold standard”. *Am J Clin Nutr* 1993;**58**:589–91.
- 24 **Panotopoulos G**, Charles RJ, Guy GB, *et al*. Dual X-ray absorptiometry, bioelectrical impedance, and near infrared interactance in obese women. *Med Sci Sports Exerc* 2001;**33**:665–70.
- 25 **Svendsen OL**, Hassager C, Bergmann I, *et al*. Measurement of abdominal and intra-abdominal fat in postmenopausal women by dual energy X-ray absorptiometry and anthropometry: Comparison with computerized tomography. *Int J Obes* 1993;**17**:45–51.
- 26 **Rubenstein I**, Zamei N, Dubarry L, *et al*. Airflow limitation in morbidly obese, nonsmoking men. *Ann Intern Med* 1990;**112**:828–32.
- 27 **Inselman LS**, Padilla-Burgos LB, Teichberg S, *et al*. Alveolar enlargement in obesity-induced hyperplastic lung growth. *J Appl Physiol* 1988;**65**:2291–6.
- 28 **Luce JM**. Respiratory complications of obesity. *Chest* 1980;**78**:626–31.