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Sleeping energy expenditure in paediatric patients with obstructive sleep apnoea syndrome

患有阻塞性睡眠呼吸窒息綜合症兒童的睡眠能量消耗模式

Objective. To investigate sleeping energy expenditure in paediatric patients with obstructive sleep apnoea syndrome.

Design. Retrospective study.

Setting. University teaching hospital, Hong Kong.

Patients and methods. A retrospective analysis comparing sleeping energy expenditure in patients with confirmed obstructive sleep apnoea syndrome and control subjects matched for age, sex, and ideal weight for body height. Subjects were recruited from the Paediatric Chest Clinic and all had undergone overnight polysomnography and sleeping energy expenditure measurement by open-circuit indirect calorimetry using a metabolic cart and canopy system. The measurements were taken during slow-wave sleep.

Results. Twenty-four cases with obstructive sleep apnoea syndrome (apnoea hypopnoea index >5) and 23 control subjects were studied. Mean age and ideal weight for body height were 9.4 (standard deviation, 3.9) years and 152.5% (27.2%), respectively. Mean sleeping energy expenditure corrected for body weight for the cases and the control group were 44.83 (standard deviation, 10.49) Kcal/day and 40.71 (10.60) Kcal/day, respectively. Sleeping energy expenditure was not found to be associated with the severity of obstructive sleep apnoea syndrome ($r=0.34$, $P=0.27$).

Conclusion. A trend towards greater sleeping energy expenditure was found in patients with obstructive sleep apnoea syndrome. Further studies on the metabolic aspects of this condition are required.

目的：研究患有阻塞性睡眠呼吸窒息的兒童，其睡眠能量消耗模式。

設計：回顧性研究。

安排：香港一所大學教學醫院。

患者及方法：比較被確定患上阻塞性睡眠呼吸窒息的患者，與年齡、性別及與身高相配的理想體重均相符的對照兒童，就其睡眠能量消耗作回顧性分析。全部患者來自兒科胸肺科門診。研究人員使用新陳代謝輸送以及無線接入系統，進行間接斷路能量量度，為患者記錄通宵多功能睡眠圖像及睡眠能量消耗。所有數據均於慢波睡眠期間收集。

結果：研究了24名阻塞性睡眠呼吸窒息(呼吸暫停的呼吸不足指數大於5)的兒童，以及23名對照兒童。平均年齡為9.4歲(標準差，3.9歲)，與身高相配的理想體重為152.5%(27.2%)。根據體重而調整後，患者的平均睡眠能量消耗為每日44.83千卡(標準差，10.49千卡)，對照組則為每日40.71千卡(10.60千卡)。研究並未發現睡眠能量消耗與阻塞性睡眠呼吸窒息的嚴重性有關($r=0.34$ ， $P=0.27$)。

結論：患上阻塞性睡眠呼吸窒息綜合症的病人，睡眠能量消耗傾向較大；但需要進一步從新陳代謝方面進行研究。

Key words:

Energy expenditure;

Sleep apnea, obstructive

關鍵詞：

能量消耗；

阻塞性睡眠呼吸窒息

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Introduction

Obstructive sleep apnoea syndrome (OSAS) in children is characterised by recurrent events of partial or complete upper airway obstruction during sleep, resulting in disruption of normal ventilation and sleep patterns.¹ The condition is increasingly being recognised, and studies have reported the prevalence to be around 2% to 4% among the paediatric population.^{2,3} If the condition is

unrecognised and left untreated, poor weight gain may result. Early reports quoted a prevalence of failure to thrive of 27% to 56%.^{4,5} Various mechanisms have been proposed to explain the poor growth associated with OSAS. These include dysphagia or anorexia as a result of adenotonsillar hypertrophy,^{6,7} abnormal nocturnal growth hormone secretion,^{8,9} nocturnal hypoxaemia and respiratory acidosis,¹⁰ and increased energy expenditure.^{11,12} However, the mechanism remains unclear.

To further elucidate metabolic aspects of OSAS, a retrospective study to assess the sleeping energy expenditure (SEE) of paediatric patients with obstructive sleep apnoea was planned. It was hypothesised that in patients with OSAS, resting energy expenditure is increased secondary to increased work associated with breathing during sleep.

Patients and methods

Patients

Twenty-four consecutive paediatric cases with confirmed OSAS attending the Prince of Wales Hospital Paediatric Chest Clinic were studied. The cases were matched according to sex, age, and ideal weight for body height with a control group free from OSAS. Those patients with a known syndrome, chronic lung disease, neurological or craniofacial abnormalities, and those who had had previous upper airway surgery were excluded. Children studied had undergone physical examination, overnight polysomnography (PSG), and SEE assessed by indirect calorimetry, after informed consent was obtained from the parents. None of the subjects were on medications that would interfere with the polysomnographic sleep study or SEE assessment.

Methods

A complete physical examination was carried out on each child to assess physical state, especially growth parameters (height and weight), and signs of pulmonary hypertension or cor pulmonale.

An overnight PSG was performed on each child, using a 16-channel recorder (Oxford Medilog MPA-S; Oxford Instruments Ltd, Oxford, UK). In each PSG study, the stage of sleep was assessed by electroencephalography, bilateral electro-oculography, and submental electromyography. Chest wall and abdominal movements were measured by respiratory impedance plethysmography; and airflow through the nose was measured with a thermistor. Oxygen saturation was measured by pulse oximetry and body movements were recorded by a body-position sensor.

Sleep stage was scored by trained personnel and followed standard criteria.¹³ An obstructive event was defined as cessation of airflow, with an increase in irregular respiratory and abdominal movement for more than two consecutive breaths. Central apnoea was defined as cessation of

breathing with no respiratory effort for more than 10 seconds, associated with desaturation, arousal, or heart rate changes. Apnoeic episodes with features of both obstructive and central events were categorised as mixed apnoea. Hypopnoea was defined as a reduction in oronasal flow by more than 50%, associated with arousal and/or desaturation. The apnoea hypopnoea index (AHI) was defined as the total number of episodes of apnoea and hypopnoea per hour of sleep. The number of times oxygen saturation decreased by more than 4% from baseline per hour of sleep was also noted (oxygen desaturation index). An AHI cut-off level of greater than five was viewed as diagnostic of sleep apnoea.

Energy expenditure during sleep was measured during PSG by indirect calorimetry, using a Deltatrac metabolic monitor (Deltatrac II MBM-200; Instrumentarium Corp, Helsinki, Finland). During measurements, the subject was covered with an airtight transparent plastic canopy. The metabolic monitor generated a constant airflow through the canopy and back to the monitor of 3 L/minute. All exhaled gases were collected in this constant flow. Oxygen consumption and carbon dioxide production were calculated every minute from the difference in the oxygen and carbon dioxide concentration of the inhaled and exhaled gases, respectively, after adjustment to standard temperature (0°C) and pressure (760 mm Hg or 101.3 kPa) conditions. The calculation of SEE was based on the Weir formula.¹⁴ Each measurement was continued for 30 minutes, and the mean value of each variable obtained. All measurements were carried out during slow-wave sleep. None of the subjects were sedated.

Statistical analysis

The values were calculated as a mean \pm standard deviation (SD) for the cases and controls. Variables were compared by the paired *t* test. The correlation between PSG results and SEE was assessed by the Pearson correlation coefficient. Analyses were performed using the Statistical Package for the Social Sciences (Windows version 10.1; SPSS Inc., Chicago, US). The level of significance was set at 5% for all comparisons, and all statistical testing was two-sided.

Results

Demographic data for the 24 cases and 23 controls are shown in Table 1. None of the subjects had features of pulmonary hypertension or cor pulmonale on physical examination.

Table 1. Demographic data of the subjects (n=47)

	Mean	SD
Age (years)	9.4	3.9
Sex ratio		
Cases (male/female)	20/4	-
Controls (male/female)	20/3	-
Weight (kg)	60.7	21.2
Height (cm)	150.0	10.0
Ideal weight for height (%)	152.5	27.2

Table 2. Polysomnographic and sleeping energy expenditure results

	Cases (n=24)*	Controls (n=23)*
Apnoea hypopnoea index (per hour)	9.6 (18.7)	2.3 (1.6) [†]
Oxygen desaturation index (per hour)	9.8 (21.4)	1.2 (1.1) [†]
Arousal index	6.6 (3.7)	4.7 (2.3)
Sleeping energy expenditure (Kcal/kg/day)	44.83 (10.49)	40.71 (10.60)

* Data are shown as mean (standard deviation)

[†] P<0.05 for comparison

All subjects slept well in the sleep laboratory, with a mean sleep efficiency of 84.6%. The measurement of SEE did not appear to affect sleep quality. The cases with OSAS had a higher AHI than the control group (9.6±18.7 versus 2.3±1.6; P<0.05). The oxygen desaturation index was also significantly higher in the cases than the control subjects (9.8±21.4 versus 1.2±1.1; P<0.05). Central and mixed apnoea were rare. There were no statistical differences in sleep architecture between the two groups.

Energy expenditure during sleep (corrected for body weight) for the cases and the control group were 44.83 (SD, 10.49) Kcal/day and 40.71 (SD, 10.60) Kcal/day, respectively (Table 2). There was no correlation found between SEE and the severity of OSAS ($r=0.34$; $P=0.27$).

Discussion

Obstructive sleep apnoea syndrome is caused by a collapse of the upper airway during sleep, when muscle tone of the upper respiratory tract decreases. It is therefore prone to occur in patients with narrowing of the upper airway.

In the paediatric population, common causes for upper airway narrowing are adeno-tonsillar hypertrophy and obesity. If OSAS remains untreated, it may lead to a variety of complications, one of which is growth failure. Although the exact cause of this growth failure is unknown, various mechanisms have been proposed. These include anorexia or dysphagia as a result of adeno-tonsillar hypertrophy, abnormal nocturnal growth hormone secretion, nocturnal hypoxaemia, and nocturnal respiratory acidosis.⁶⁻¹⁰ Marcus et al¹¹ demonstrated substantial reduction in SEE in 14 children with OSAS after adeno-tonsillectomy. This decrease in SEE was accompanied by an increase in weight gain. Children with OSAS have laboured breathing, using their accessory muscles of respiration, and often have paradoxical inward rib cage motion during inspiration. Like children with other types of respiratory disease, they have increased work associated with breathing, and hence hypermetabolism. As suggested by Marcus et al,¹¹ this might explain the poor weight gain seen in cases of OSAS. Stenlof et al¹² studied five adult subjects with OSAS using a whole body calorimeter, and showed that SEE and 24-hour energy expenditure were significantly increased relative to controls and declined after treatment. However, Bland et al¹⁵ in a subsequent study measured total energy expenditure (TEE) in 11 children with OSAS and found no significant difference in TEE between patients and

controls. Differences in TEE within patients observed before and after adeno-tonsillectomy were minor and not statistically significant.

In our series of 24 subjects with 23 controls matched for age, sex, and ideal weight for body height, cases had greater SEE than controls, but this difference between the groups did not reach statistical significance. This may suggest that increased energy expenditure during sleep could partly account for the poor weight gain seen in some paediatric patients with OSAS. However, we did not find a positive correlation between severity of sleep apnoea and resting energy expenditure. This could be explained by the small sample size of the study or may reflect the possibility that poor weight gain in paediatric patients with OSAS involves an interplay of multiple factors. Bar et al¹⁶ in their recent study measured changes in the insulin growth factor-1 (IGF-1) axis before and after surgery in 10 children with OSAS. They showed that there was a significant increase in serum IGF-1 levels after surgery, which were associated with improvements in nutritional status.

There are certain limitations to the current study that should be noted. Firstly, the measurement of SEE was taken during slow-wave sleep only. This is a major weakness of our study, as childhood sleep apnoea has been shown to be most severe during rapid eye movement (REM) sleep.¹ A better reflection of actual SEE could be obtained if data were recorded for the total duration of sleep. Due to limited resources and manpower, we were not able to monitor SEE beyond the first 90 minutes of sleep, and during that timeframe a less than representative amount of REM sleep was recorded. Secondly, important information could be gained by assessing TEE and dietary intake. That would again entail much greater resources and personnel than was possible in this study. Lastly, there were only 24 cases in the study. Though it is the largest number of paediatric cases reported to date, a larger study population may be required to demonstrate significant differences between cases and controls.

It is likely that growth failure seen in some cases of OSAS involves a complex interaction between various pathophysiological mechanisms, with increased resting energy expenditure only one of several. As OSAS becomes better recognised, further investigation of metabolic aspects of this condition may be undertaken in studies involving larger numbers of patients.

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