Epidemiology of obstructive sleep apnoea syndrome in Chinese children: a two-phase community study

Albert M Li,[1] Hung K So,[1] Chun T Au,[1] Crover Ho,[2] Joseph Lau,[3] Siu K Ng,[4] Victor J Abdullah,[4] Tai F Fok,[1] Yun K Wing[2]

[1]Department of Paediatrics, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong
[2]Department of Psychiatry, Shatin Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong
[3]Centre for Epidemiology and Biostatistics, The Chinese University of Hong Kong, Shatin, Hong Kong
[4]Department of Otorhinolaryngology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong

Correspondence to
Professor Yun Kwok Wing, Department of Psychiatry, 7th Floor, Shatin Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong; ykwing@cuhk.edu.hk

Received 8 January 2010
Accepted 2 September 2010

ABSTRACT

Objective To determine the prevalence and risk factors of obstructive sleep apnoea syndrome (OSAS) in Chinese children using a two-phase community-based study design.

Methods Children from 13 primary schools were randomly recruited. A validated OSAS screening questionnaire was completed by their parents. Children at high risk of OSAS and a randomly chosen low-risk group were invited to undergo overnight polysomnographic study and clinical examination. The the sex-specific prevalence rate was measured using different cutoffs (obstructive apnoea hypopnoea index $\geq$1, $\geq$1.5, $\geq$3 and $\geq$5 and obstructive apnoea index $\geq$5) and risk factors associated with OSAS were evaluated with logistic regression.

Results 6447 completed questionnaires were returned (out of 9172 questionnaires; 70.3%). 586 children (9.1%; 405 boys and 181 girls) children belonged to the high-risk group. A total of 619 (410 and 209 from the high and low-risk group, respectively) subjects underwent overnight polysomnagraphy. Depending on the cutoffs, the prevalence rate of childhood OSAS varied from 4.8% to 40.3%. Using the International Criteria of Sleep Disorders version II, the OSAS prevalence for boys and girls was 5.8% and 3.8%, respectively. Male gender, body mass index z-score and increased adenoid and tonsil size were independently associated with OSAS.

Conclusions The prevalence rate of OSAS in children was contingent on the cutoff used. The inclusion of symptoms as a part of the diagnostic criteria greatly reduced the prevalence. A further prospective and outcome study is needed to define a clinically significant diagnostic cutoff for childhood OSAS.

Childhood obstructive sleep apnoea syndrome (OSAS) is a sleep-related breathing disorder characterised by intermittent upper airway obstruction that disrupts normal ventilation and sleep patterns.[1] Increasing evidence suggests that childhood OSAS is an important public health problem. Children with OSAS have higher respiratory disease-related morbidity and healthcare utilisation starting from the first year of life until the date of diagnosis.[2] If left untreated, the condition is associated with cardiovascular and neurocognitive consequences with significant long-term clinical implications.[3–8]

The reported prevalence of childhood OSAS varied from 0.1% to 13%.[9] The wide range of prevalence rate was mostly related to methodological issues, including lack of polysomnographic confirmation, different sampling strategies, small sample size and the different diagnostic threshold used for defining childhood OSAS. In addition, there is a suggestion of ethnic difference in the prevalence of OSAS, with African-American children having a higher prevalence compared with white children in the USA.[10 11] In a recent review, the authors commented that additional work in childhood OSAS epidemiology is needed and standardisation of selection and diagnostic criteria across studies would be helpful in future cross-ethnic comparisons.[9] The ascertainment of a reliable and accurate prevalence of childhood OSAS will allow for better healthcare planning, resource allocation and future comparison of data.

The objective of this study was to determine the prevalence of OSAS in Chinese children aged between 5 and 13 years in the general population, thus reducing the potential selection biases introduced by recruiting hospital attendants. The study had a two-phase design; the first phase involved completion of a validated screening questionnaire by parents of randomly selected subjects. Subjects at high risk of OSAS together with a control group then underwent detailed clinical examination, upper airway assessment and overnight sleep study for confirmation of their OSAS status.

MATERIALS AND METHODS

Study population

Based on our pilot study, the prevalence of OSAS in local healthy children was not greater than 4.5%,[12] A sample size of 6600 would be needed to allow an estimate of OSAS prevalence with a precision of 0.5% and 95% confidence. We recruited subjects from two school districts; Shatin and Tai Po. The two districts had similar social class and income distribution to the rest of the territory, thus the results obtained from this study would be a true representation of Hong Kong (http://www.censtatd.gov.hk/hong_kong_statistics/statistical_tables). There were 76 primary schools in the two districts. Selection of a school was based on computer-generated random numbers, and if the selected school declined to participate, the next randomly selected school was invited. Thirteen primary schools in the two districts were randomly chosen to participate in this study. In each school, two randomly chosen classes from each grade were invited to participate. The number of subjects recruited from this sampling frame would guarantee that the required sample size was obtained. Approval by the ethics committee of the Chinese University of Hong Kong was obtained.

First phase

All parents of children in the randomly selected schools were invited to attend an education forum

during which full explanation of the purpose and flow of the study was given. An envelope containing a validated parent proxy OSAS screening questionnaire[13] and consent was then distributed to parents within a week after the forum. The parents were asked to return the completed questionnaire within a week. For those who failed to return the questionnaire, another copy was given with a self-addressed envelope enclosed for ease of return.

The 54-item questionnaire (HK-CSQ) sought information regarding sleep habits and problems including nocturnal OSAS symptoms (snoring, witnessed apnoea, laboured breathing and oral breathing), parasomniac symptoms (presence and frequency of nocturnal enuresis, night terrors, nightmares, somnambulism, sleep talking and bruxism) and daytime symptoms (morning headache, recurrent upper airway infections, daytime sleepiness in different situations and hyperactivity). In addition, the following information was also obtained: body height and weight, history of allergic rhinitis and asthma, exposure to cigarette smoke, home living environment, family income, number of household members and parental education.

Data from three survey questions, namely snoring, nocturnal mouth breathing and night sweating, answered by a five-point frequency scale (0='never'; 1='rarely' for 0–1 nights per month; 2='sometimes' for 1–2 nights per month, 3='often' for 1–2 nights per week; 4='frequently' for 3 nights or more per week) and a 'do not know' category were used to classify survey participants as having a high or low risk of OSAS. From our previous research, a composite symptom score (summation of the scores of these three questions) of 7 or more has 75.4% sensitivity and 80.5% specificity, compared with polysomnography, to detect OSAS among children aged 5–15 years who had attended our paediatric clinics.[13] Children with a composite symptom score of less than 7 were assigned a computer-generated random number and were invited as a control group with a ratio of 1:2 in the second phase.

All children belonging to the high risk of OSAS group and the randomly selected subjects at low risk of OSAS were invited to undergo examination by an otorhinolaryngologist and overnight polysomnographic study. Children were excluded from the study if they had intercurrent illness within 4 weeks of the polysomnographic study, or if they were reported by their parents to have cardiac, renal or neuromuscular diseases or chromosomal abnormalities, or if they had previously undergone upper airway surgery.

Second phase: polysomnography

A single attended overnight polysomnography was performed in a dedicated sleep laboratory with a CNS 1000P polygraph (CNS, Inc, Chanhassen, Minnesota, USA) as described in our previous publication.[4 5 15] All computerised sleep data were further manually edited by experienced polysomnography technologists and clinicians according to standardised criteria.[15] An obstructive apnoea was defined as the absence of airflow with persistent respiratory effort lasting longer than two baseline breaths, irrespective of arterial oxygen saturation changes. A mixed apnoea was defined as the absence of airflow for a duration of at least two breath cycles without inspiratory effort in the initial portion of the event, followed by resumption of inspiratory effort in the second portion of the event. An obstructive hypopnoea was defined as a reduction of 50% or more in the amplitude of the airflow signal with persistent respiratory effort. It was only quantified if it was longer than two baseline breaths and was associated with oxygen desaturation of at least 4% and/or arousals. The obstructive apnoea index (OAI) was defined as the number of obstructive apnoeas and mixed apnoeas per hour of sleep. The obstructive apnoea hypopnoea index (OAHI) was defined as the total number of obstructive apnoeas, mixed apnoeas and obstructive hypopnoeas per hour of sleep. All computerised sleep data were manually edited by experienced polysomnography technologists and clinicians according to standardised criteria.[16] A successful polysomnography study was defined as total sleep time of over 6 h and a sleep efficiency (total sleep time/time in bed ×100%) of over 70%.

Childhood OSAS was defined by using different diagnostic criteria: OAHI ≥1, ≥1.5, ≥3, ≥5, OAI ≥1 and International Criteria of Sleep Disorders version II (ICSD-II) criteria (OAHI ≥1 plus habitual snoring plus at least one more OSAS-related symptom).[17] Habitual snoring was defined as parental report of snoring for at least 3 nights a week in the past 12 months. OSAS-related symptoms included night sweating, nocturnal enuresis, morning headaches, daytime tiredness and restless sleep. These cutoffs are widely used to describe childhood OSAS, but it is not well standardised in children[18], and the clinical importance of any particular cutoff is still undetermined. Although in our experiences an apnoea hypopnoea index of 5 or greater correlated best with cardiovascular outcome in cross-sectional studies.[4 5]

Clinical examination

Standing height (in metres) without shoes was measured using a Harpenden stadiometer (Holtain, UK) to the nearest 0.1 cm.

Table 1 Demographic and socioeconomic characteristics of the respondents

	Boys n=3260	Girls n=3187	p Value
Age, years	9.2 (1.8)	9.2 (1.8)	0.798
Height, cm	134 (13.5)	134 (13.2)	0.539
Weight, kg	31.7 (9.7)	30.3 (8.9)	<0.0001
Body mass index, kg/m^2	17.3 (3.3)	16.5 (2.8)	<0.0001
No of family members	4.6 (1.2)	4.5 (1.1)	0.002
No of siblings	1.3 (1.1)	1.2 (1.0)	<0.0001
Household area per person, sq ft	127.4 (56.1)	123.3 (56.6)	0.006
Allergic rhinitis, %	50.1	38.9	<0.0001
Asthma, %	6.5	4.0	<0.0001
Nocturnal oral breathing,* %	12.0	7.5	<0.0001
Nocturnal sweating,* %	15.8	7.7	<0.0001
Snoring,* %	19.6	12.3	<0.0001
Weight group, %			<0.0001
Overweight	16.3	12.3	
Obese	11.5	9.5	
Family income, %			0.004
≤HK$10 000	28.8	32.3	
HK$10 001–15 000	22.3	22.8	
>HK$15 000	48.8	44.9	
Household area, %			0.116
≤400 sq ft	30.7	32.8	
401–600 sq ft	32.9	32.8	
>600 sq ft	36.4	34.3	
Paternal education, %			<0.0001
Primary or below	18.4	19.1	
Secondary	63.8	67.3	
Tertiary or above	17.8	13.7	
Maternal education, %			0.008
Primary or below	18.6	20.3	
Secondary	70.3	70.8	
Tertiary or above	11.1	8.9	

*Symptoms were considered to be positive if reported to be present for at least one night per week in the past 12 months.

Body weight (in kg) was measured with the lightest clothing to the nearest 0.1 kg by an electronic weighing scale (Seca model 708; Vogel & Halke GmbH & Co, Hamburg, Germany). Body mass index was calculated as kg/m^2 and converted to a z score according to local reference.[19] Overweight and obese children were defined as a body mass index z score greater than 1.036 and 1.645, corresponding to the 85th and 95th percentile (relative to age and gender), respectively. Each child also underwent physical examination by an experienced paediatrician (AML) before polysomnographic study.

Upper airway examination

The size of tonsils and adenoids was measured by endoscopic examination by means of a flexible fibrescope (Olympus 3 mm; Olympus, Japan). The examination was performed by an otorhinolaryngologist who was blinded to the group allocation and polysomnographic result of the subjects. The examination was carried out in the morning after overnight polysomnographic study. Tonsil size was reported as a percentage of the oropharyngeal airway while adenoid size was assessed as a percentage of the nasopharyngeal airway.

Statistics

The distributions of all the continuous data for parametric analyses were confirmed to be normal by normal probability plot (Q–Q plot). Continuous data were expressed as means (SD) while categorical data were expressed as percentages. Student's t test and the χ^2 test were used for comparisons of continuous data and categorical data, respectively. The weighted prevalence of OSAS based on different diagnostic criteria was calculated. Logistic regression analyses were performed to assess the association between potential risk factors and childhood OSAS as defined by OAHI of 5 or greater or ICSD-II criteria. The association was first assessed in a univariate model and then in a multivariate model constructed by forward selection (likelihood ratio) method. SPSS for Windows 14 was used in the analysis, and the level of significance was set at 5% for all comparisons.

RESULTS

A total of 9172 students was invited to participate. Six thousand four hundred and forty-seven completed questionnaires were returned and scored (response rate 70.3%). The demographic, socioeconomic and sleep symptoms data of the questionnaire respondents according to gender are shown in table 1.

Five hundred and ninety-one (9.2%; 410 boys) children had a composite score of 7 or greater, of whom 410 (70%; 288 boys) agreed to take part in the second phase of our study. A comparison of demographic and socioeconomic data between subjects with a composite score of 7 or greater who agreed to undergo overnight polysomnography and those who refused did not reveal any significant differences (table 2). Six hundred and eighteen subjects (out of 5856) from the low-risk group (composite score <7) were approached and finally 209 (108 boys) agreed to participate in the second phase. Their baseline characteristics did not have significant differences compared with those with a composite score of less than 7, but were not selected to participate in the second phase (table 2). A total of 619 children underwent overnight polysomnography to ascertain their OSAS status, and polysomnography was successful in all cases. None of the subjects had cardiopulmonary abnormalities detected on clinical examination. No significant gender differences were found in age, body size, total sleep time and sleep efficiency. Boys had a significantly greater proportion of sleep stage 1 (7.5±4.0 vs 6.8±3.3%, p=0.018) but less sleep stage 2 (47.8±5.6 vs 49.4±5.2, p=0.002). They also had significantly higher OAHI (0.9 (0.1 to 2.5) vs 0.4 (0 to 1.2), p<0.001), OAI (0.4 (0 to 1.3) vs 0.2 (0 to 0.6), p<0.001), arousal index (6.8 (5.1 to 8.8) vs 6.1 (4.8 to 8.0), p=0.017) and lower arterial oxygen saturation nadir (91.6±3.4 vs 92.4±2.9, p=0.008) compared with girls. Furthermore, boys had a greater prevalence of

Table 2 Characteristics of subjects with and without polysomnography

	Composite score <7			Composite score ≥7		
	PSG n=209	No PSG n=5647	p Value	PSG n=410	No PSG n=181	p Value
Age, years	9.2 (1.8)	9.3 (1.8)	0.475	8.9 (1.7)	8.7 (1.8)	0.131
Height, cm	133 (13)	134 (13)	0.332	132 (13)	131 (16)	0.491
Weight, kg	31.1 (9.1)	30.9 (9.3)	0.815	31.5 (9.6)	31.2 (10.0)	0.720
Body mass index, kg/m^2	17.2 (3.3)	16.8 (3.0)	0.111	17.5 (3.3)	17.7 (3.6)	0.402
No of family members	4.6 (1.2)	4.6 (1.2)	0.968	4.4 (1.1)	4.3 (1.1)	0.402
No of siblings	1.2 (0.9)	1.3 (1.0)	0.267	1.0 (0.8)	1.0 (0.9)	0.974
Household area per person, sq ft	123.8 (58.4)	123.8 (55.5)	0.995	141.7 (59.7)	137.2 (63.8)	0.422
Family income, %			0.187			0.091
≤HK$10 000	28.6	31.5		19.8	27.5	
HK$10 001–15 000	19.4	22.9		20.3	20.8	
>HK$15 000	51.9	45.6		59.9	51.7	
Household area, %			0.505			0.181
≤400 sq ft	35.6	32.3		23.3	29.9	
401–600 sq ft	29.8	33.2		32.5	27.1	
>600 sq ft	34.6	34.5		44.3	42.9	
Paternal education, %			0.59			0.151
Primary or below	19.0	19.5		10.1	14.7	
Secondary	60.0	65.1		69.3	69.9	
Tertiary or above	18.0	15.3		20.5	15.3	
Maternal education, %			0.967			0.298
Primary or below	19.6	20.4		10.0	14.5	
Secondary	70.6	69.9		77.0	72.7	
Tertiary or above	9.8	9.7		13.0	12.7	

Table 3 Distribution of symptoms in children with OSAS by different diagnostic cutoffs

	OAHI <1		OAHI ≥1		OAHI ≥1.5		OAHI ≥3		OAHI ≥5		OAI ≥1	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Symptoms (%)	n=202	n=151	n=194	n=72	n=150	n=47	n=80	n=22	n=52	n=15	n=115	n=37
Nocturnal sweating	50.2	33.8	43.0	22.2	40.9	21.3	40.0	18.2	38.5	20.0	37.4	21.6
Nocturnal oral breathing	47.5	44.4	52.6	45.8	53.3	46.8	55.0	40.9	57.7	53.3	47.8	43.2
Snoring	63.4	47.0	57.2	61.1	59.3	70.2	62.5	77.3	59.6	80.0	51.3	62.2
Habitual snoring*	32.7	24.5	33.0	37.5	36.0	48.9	41.3	54.5	36.5	46.7	31.3	43.2
Difficulty in getting to sleep	17.0	19.6	11.0	18.3	12.9	14.9	10.0	18.2	11.5	13.3	10.6	16.2
Feeling tired in daytime	21.3	24.5	23.3	23.9	69.3	63.8	22.8	13.6	19.6	0	15.8	16.7
Restless sleep	73.7	63.6	69.0	63.9	21.5	21.3	76.6	59.1	72.5	53.3	67.3	62.2
Prone sleep	35.9	28.6	38.2	26.1	38.5	26.7	40.5	27.3	36.5	33.3	37.3	22.2
Bruxism	28.7	22.5	25.4	16.9	23.0	11.9	24.3	4.8	20.8	0	24.8	9.1
Nocturnal enuresis	6.4	1.4	3.1	1.4	3.4	2.1	1.3	4.5	1.9	6.7	1.7	2.8
Sleep talking	22.4	19.3	10.8	19.1	10.3	17.8	9.3	4.5	4.0	0	8.1	17.1
Nightmares	10.3	13.6	10.6	16.4	8.4	13.6	7.8	14.3	9.8	7.1	6.3	11.8
Early morning awakening	2.5	6.8	3.7	4.2	3.4	2.1	1.3	0	0	0	2.7	2.8
Morning dry mouth	23.9	23.9	26.0	18.3	25.4	16.2	26.4	23.5	25.0	25.0	22.5	17.9
Day napping	6.0	15.6	6.2	11.3	4.7	17.4	3.8	19.0	3.8	13.3	5.3	16.7
Morning headache	4.2	3.4	3.3	5.8	3.6	2.2	3.9	0	4.0	0	2.7	2.8
Allergic rhinitis†	80.2	62.9	75.0	58.3	73.8	53.2	71.3	40.9	67.3	40.0	71.1	45.9
Asthma†	8.9	8.6	11.5	9.9	12.1	8.7	12.5	9.5	11.5	0	10.5	5.6

A symptom was considered as positive if the parental-reported questionnaire revealed that the symptom had been present for at least one day/night per week in the past 12 months.
*Habitual snoring was defined as snoring for at least three nights per week in the past 12 months.
†Symptoms of allergic rhinitis and asthma were considered to be positive if the questionnaire revealed the presence of any of these symptoms.
OAHI, obstructive apnoea hypopnoea index; OAI, obstructive apnoea index; OSAS, obstructive sleep apnoea syndrome.

nocturnal sweating (46.7 vs 30.0%, p<0.0001) and snoring (60.4 vs 51.6%, p=0.035) compared with girls.

Two hundred and sixty-six (194 boys), 197 (150 boys), 102 (80 boys) and 67 children (52 boys) were found to have OAHI of 1 or greater, 1.5 or greater, 3 or greater and 5 or greater, respectively. One hundred and fifty-two children (115 boys) were found to have OAI of 1 or greater. Table 3 shows the prevalence of OSAS symptoms in children with OSAS according to different diagnostic cutoffs.

Weighted prevalence of childhood OSAS based on different diagnostic criteria

The mean composite score of the three survey questions of subjects belonging to the low-risk group was 1.94 (SD 1.89). The mean composite score of the 209 subjects was 3.55 (SD 2.05). In order to allow for a more reliable and accurate calculation of a weighted prevalence, the 209 subjects were further subdivided into those with composite scores less than 4 (low-low risk) and those with a score between 4 or greater and less than 7 (low risk).

The weighted prevalence of OSAS based on different diagnostic criteria was calculated using the following equation:

$$\text{Prevalence} = \left[\left(N_{cs+7p} * / N_{cs+7p} \times N_{cs+7}\right) + \left(N_{cs-7ap} * / N_{cs-7ap} \times N_{cs-7a}\right) + \left(N_{cs-7bp} * / N_{cs-7bp} \times N_{cs-7b}\right)\right] / N_q$$

where N_q is the number of questionnaires returned; N_{cs+7} is the number of subjects with a composite score of 7 or greater; N_{cs-7a} is the number of subjects with a composite score less than 4; N_{cs-7b} is the number of subjects with a composite score of 4 or greater and less than 7; N_{cs+7p} is the number of subjects with a composite score of 7 or greater who underwent polysomnography; N_{cs-7ap} is the number of subjects with a composite score less than 4 who underwent polysomnography; N_{cs-7bp} is the number of subjects with a composite score of 4 or greater and less than 7 who underwent polysomnography; $N_{cs+7p}{}^*$ is the number of subjects with a composite score of 7 or greater and a positive diagnosis of OSAS; $N_{cs-7ap}{}^*$ is the number of subjects with a composite score less than 4 and a positive diagnosis of OSAS; $N_{cs-7bp}{}^*$ is the number of subjects with a composite score of 4 or greater and less than 7 and a positive diagnosis of OSAS.

The gender-specific and overall weighted prevalence of OSAS according to various diagnostic cutoffs are presented in figure 1. Boys had a higher prevalence of OSAS than girls. The overall weighted prevalence varied from 4.8% to 40.3% depending on

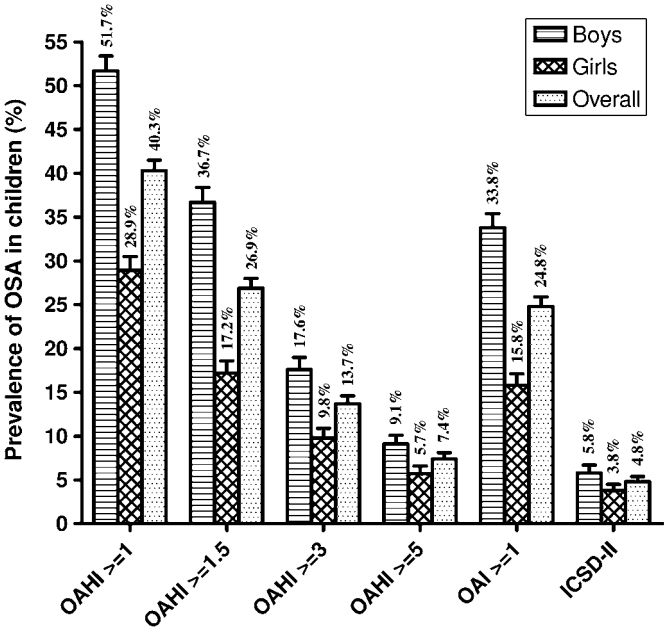

Figure 1 Weighted prevalence of obstructive sleep apnoea (OSA) in children by gender and different diagnostic cutoffs. The error bars depicted the upper limit of the 95% CI of the prevalence. ICSD-II, International Criteria of Sleep Disorders version II; OAHI, obstructive apnoea hypopnoea index.

the cutoff chosen. Using ICSD-II recommendations, the OSAS prevalence (95% CI) for boys, girls and overall was 5.8% (5.1 to 6.7), 3.8% (3.2 to 4.5) and 4.8% (4.3 to 5.4), respectively.

Risk factors associated with OSAS

On multiple logistic regression analysis male gender, obesity and tonsil size were independently associated with OSAS using OAHI of 5 or greater as the cutoff. Whereas using ICSD-II criteria, obesity, the composite symptom score and tonsil size were significantly associated with a diagnosis of OSAS (table 4).

DISCUSSION

To the best of our knowledge, this is the first prevalence study that used a two-phase design with laboratory confirmation of OSAS in a large population-based sample of Chinese children. OSAS, as defined by the latest ISCD-II guidelines, is prevalent among both boys and girls aged between 5 and 13 years, the rates are 5.8% and 3.8%, respectively.

The criteria for diagnosing childhood OSAS have not been standardised, and the different cutoffs used could explain the wide range of prevalence rates reported in the literature.[9 16] Although these cutoffs are statistically abnormal, their validity as predictors of long-term outcome has not been established.[18] A few studies have chosen to use an apnoea hypopnoea index of 5 or greater as a clinically relevant cutoff.[4 5 19 20] The need to include the presence of symptoms in diagnosing OSAS is another issue that needs to be clarified. The latest ICSD-II guidelines require the presence of habitual snoring plus one other OSAS symptom together with an OAHI of 1 or greater as diagnostic for childhood OSAS.[17] In adults, OSAS is defined as OAHI of 5 or greater in conjunction with hypersomnolence or related problems in daytime function.[21] The necessity of daytime complaints to be included in the definition of OSAS in adults has recently been challenged. The milestone OSAS epidemiological study from the Wisconsin Sleep cohort reported a minimal prevalence rate of 2% and 4% for men and women.

Table 4 Factors associated with childhood OSAS defined as OAHI of 5 or greater or ICSD-II criteria*

	OAHI ≥5				ICSD-II			
	Univariate		Multivariate†		Univariate		Multivariate†	
	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value
Age, years	0.9 (0.8 to 1.1)	0.414			0.9 (0.8 to 1.1)	0.248		
Male gender	2.1 (1.2 to 3.8)	0.016	2.4 (1.2 to 4.7)	0.012	1.4 (0.8 to 2.6)	0.227		
Composite score	1.1 (1.0 to 1.2)	0.015			1.2 (1.1 to 1.4)	<0.001	1.1 (1.0 to 1.3)	0.046
Weight group								
Normal weight	Reference				Reference			
Overweight	2.1 (1.1 to 4.0)	0.021	1.8 (0.9 to 3.8)	0.103	1.1 (0.5 to 2.5)	0.755	1.1 (0.5 to 2.6)	0.784
Obese	3.7 (2.0 to 6.7)	<0.001	2.9 (1.4 to 5.8)	0.003	4.4 (2.4 to 8.1)	<0.001	2.9 (1.4 to 5.8)	0.003
Atopic symptoms								
AR (past 12 months)	0.6 (0.3 to 1.0)	0.044			1.2 (0.6 to 2.2)	0.613		
Asthma (past 12 months)	0.9 (0.4 to 2.2)	0.801			1.2 (0.5 to 2.9)	0.609		
Soft tissue sizes								
Tonsil								
0–25%	Reference				Reference			
26–50%	2.0 (1.0 to 3.8)	0.036	1.6 (0.8 to 3.4)	0.168	3.4 (1.7 to 6.6)	<0.001	2.6 (1.2 to 5.4)	0.012
51–75%	8.1 (4.1 to 16.0)	0.000	6.9 (3.3 to 14.6)	<0.001	8.5 (4.0 to 18.0)	<0.001	6.2 (2.8 to 13.9)	<0.001
76–100%	5.0 (1.3 to 19.6)	0.022	5.7 (1.2 to 26.4)	0.026	1.9 (0.2 to 15.7)	0.549	2.4 (0.3 to 21.4)	0.433
Adenoid								
0–25%	Reference				Reference			
26–50%	1.1 (0.6 to 2.0)	0.880			1.7 (0.9 to 3.2)	0.109		
51–75%	3.5 (1.6 to 7.5)	0.002			3.5 (1.5 to 8.1)	0.003		
76–100%	4.3 (1.7 to 11.1)	0.003			2.7 (0.9 to 8.6)	0.087		
Socioeconomic factors								
Paternal education								
Primary or below	Reference				Reference			
Secondary	0.6 (0.2 to 1.5)	0.275			0.9 (0.4 to 2.2)	0.889		
Tertiary or above	1.5 (0.9 to 2.8)	0.152			1.1 (0.5 to 2.2)	0.813		
Maternal education								
Primary or below	Reference				Reference			
Secondary	0.3 (0.1 to 0.9)	0.036			0.9 (0.4 to 2.1)	0.783		
Tertiary or above	0.8 (0.3 to 1.8)	0.552			0.7 (0.3 to 1.8)	0.452		
Home area								
≤400 sq ft	Reference				Reference			
401–600 sq ft	0.8 (0.4 to 1.6)	0.533			1.1 (0.5 to 2.2)	0.882		
>600 sq ft	1.2 (0.7 to 2.2)	0.534			1.4 (0.7 to 2.7)	0.351		
Family income								
≤HK$10 000	Reference				Reference			
HK$10 001–15 000	1.0 (0.4 to 2.2)	0.925			0.4 (0.2 to 1.1)	0.076		
>HK$15 000	1.3 (0.7 to 2.6)	0.399			0.8 (0.4 to 1.4)	0.418		

*ICSD-II, International Criteria of Sleep Disorders version II (ICSD-II) criteria required an obstructive apnoea hypopnoea index (OAHI) of 1 or greater plus habitual snoring plus at least one more obstructive sleep apnoea syndrome (OSAS)-related symptom to define OSAS.
†Multivariate models were constructed by forward selection (likelihood ratio) method.
AR, allergic rhinitis.

The rate would inflate to 9% and 24%, respectively, when symptoms were excluded in the definition.[21] The 18-year mortality follow-up from the same cohort showed that untreated subjects with a high apnoea hypopnoea index at baseline were at increased risk of cardiovascular mortality, irrespective of symptoms of sleepiness.[22] A more recent article also provided similar evidence that non-sleepy OSAS adults were exposed to increased cardiovascular risk.[23] In our study, when the necessity of symptoms was not included in the definition, the overall prevalence ranged from 7.4% to 40.3% depending on the OAHI/OAI cutoff one uses. Even adopting a rather conservative threshold of OAHI of 5 or greater, the prevalence of OSAS in boys and girls remains at 9.1% and 5.7%, respectively. Could this high rate of asymptomatic subjects with significant OAHI levels be due to sampling and design error? The relatively large proportion of subjects reported to have symptoms of allergic rhinitis might explain the high rate of OSAS in this group of children. However, the multivariate logistic regression results revealed that the presence of allergic rhinitis was not associated with the presence of OSAS as defined by OAHI of 5 or greater or ICSD-II criteria. In fact, the strength of our current study lay in the inclusion of subjects at low risk of OSAS, who were supposed to be free of any significant OSAS symptoms. In other words, most of the epidemiological studies that were based on reported symptoms,[24–26] or polysomnographic confirmation in selected subjects[11 27 28] would grossly underestimate the true OSAS prevalence by excluding asymptomatic subjects. Indeed, as demonstrated in our study, snoring that has been labelled as the cardinal symptom of OSAS[1] was reported at most by approximately 80% of the subjects.

Our calculated prevalence for childhood OSAS was higher than the commonly reported figure of between 1% and 3%. The use of different diagnostic criteria in defining OSAS can explain this discrepancy and thus it is necessary to standardise the diagnostic cutoff to allow for more meaningful interracial comparison. One previous study examined the prevalence of OSAS among Chinese children with a mean age of 6.2 years.[29] The study recruited hospital attendants, which greatly limited its application to the general population. In addition, it had a small sample size of 200 subjects and only 55% of suitable children, those reported to have habitual snoring, underwent overnight polysomnography. The study reported a prevalence rate of 0.1%, but this is likely to be an inaccurate estimation as a result of its unsatisfactory study design.

Previous studies reported that there were no gender differences in the prevalence of childhood OSAS.[28 30] In contrast, our study consistently demonstrated that boys outnumbered girls in the prevalence of OSAS across all diagnostic criteria. Male gender was found to be an independent factor associated with OSAS in multiple regression analysis. A higher prevalence of atopy and especially allergic rhinitis among the boys may explain this gender difference. There is robust evidence to suggest allergic rhinitis increases the risk of OSAS in children, and treatment of allergic rhinitis could possibly prevent the onset of OSAS and reduce the severity of existing OSAS.[31] Obesity is another important factor to account for the gender difference in OSAS prevalence. Boys are heavier than their female counterparts at all ages between 6 and 18 years.[32]

There are certain limitations in our study. First, we only achieved a 70% response rate to our questionnaire survey. This was compensated for by the large number of subjects (70% of high risk of OSAS subjects and a large sample of subjects at low risk of OSAS) undergoing overnight polysomnography to ascertain their OSAS status. Furthermore, this was a population-based study, therefore minimising any potential biases inherent in hospital-based subjects. Second, the ability of a single-night polysomnographic study to represent usual sleep has been questioned.[33 34] The first night effect would influence sleep patterns and architecture and thus the reliability of a single night recording. Our previous research work, however, has demonstrated that a single night polysomnographic study could detect obstructive sleep apnoea in children in nearly 85% of cases.[14] Third, our OSAS questionnaire had a sensitivity of approximately 80%, thus a proportion of genuine OSAS cases would have been missed in the initial screening phase. This deficit was partly overcome by including a reasonably large sample of subjects screened to be at low risk of OSAS to undergo polysomnography, thus allowing a weighted prevalence to be calculated. Despite our intensive effort and careful design, there is no doubt that a self-selected bias existed in the second phase. This could not have been completely prevented as parents were more likely to agree to take part in this study if they thought their child had a sleep problem, although the symptoms were mild and infrequent (thus had low scores). Nonetheless, we tried to rectify this bias by further weighting of the prevalence rates.

In conclusion, the present study estimated the prevalence of OSAS in Chinese children and the rates vary according to the diagnostic criteria used. Further research is needed to determine the level of apnoea hypopnoea index that is clinically significant as the prevalence of OSAS hinges on this important cutoff.

Acknowledgements The authors would like to thank all the staff of the Sleep Assessment Unit of Shatin Hospital for logistic support, and the schools, children and their parents for their cooperation and participation.

Funding This study was funded by grant CUHK4161/02M from the Research Grants Council of the Hong Kong SAR, China.

Competing interests None.

Ethics approval This study was conducted with the approval of the ethics committee of the Chinese University of Hong Kong.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **American Thoracic Society.** Standards and indications for cardiopulmonary sleep studies in children. *Am J Respir Crit Care Med* 1996;**153**:866–78.
2. **Tarasiuk A,** Greenberg-Dotan S, Simon-Tuval T, *et al*. Elevated morbidity and health care use in children with obstructive sleep apnea syndrome. *Am J Respir Crit Care Med* 2007;**175**:55–61.
3. **Li AM,** Chan DF, Fok TF, *et al*. Childhood obstructive sleep apnoea: an update. *Hong Kong Med J* 2004;**10**:406–13.
4. **Li AM,** Au CT, Sung RY, *et al*. Ambulatory blood pressure in children with obstructive sleep apnoea: a community based study. *Thorax* 2008;**63**:803–9.
5. **Chan JY,** Li AM, Au CT, *et al*. Cardiac remodeling and dysfunction in children with obstructive sleep apnea—a community based study. *Thorax* 2009;**64**:233–9.
6. **Kheirandish L,** Gozal D. Neurocognitive dysfunction in children with sleep disorders. *Dev Sci* 2006;**9**:388–99.
7. **Kwok KL,** Ng DK, Chan CH. Cardiovascular changes in children with snoring and obstructive sleep apnoea. *Ann Acad Med Singapore* 2008;**37**:715–21.
8. **Gozal D,** Kheirandish-Gozal L. Neurocognitive and behavioral morbidity in children with sleep disorders. *Curr Opin Pulmon Med* 2007;**13**:505–9.
9. **Lumeng JC,** Chervin RD. Epidemiology of pediatric obstructive sleep apnea. *Proc Am Thorac Soc* 2008;**5**:242–52.
10. **Redline S,** Tishler PV, Schluchter M, *et al*. Risk factors for sleep-disordered breathing in children. Associations with obesity, race, and respiratory problems. *Am J Resp Crit Care Med* 1999;**159**:1527–32.
11. **Stepanski E,** Zayyad A, Nigro C, *et al*. Sleep-disordered breathing in a predominantly African-American pediatric population. *J Sleep Res* 1999;**8**:65–70.
12. **Wing YK,** Hui SH, Pak WM, *et al*. A controlled study of sleep related disordered breathing in obese children. *Arch Dis Child* 2003;**88**:1043–7.
13. **Li AM,** Cheung A, Chan D, *et al*. Validation of a questionnaire instrument for prediction of obstructive sleep apnea in Hong Kong Chinese children. *Pediatr Pulmonol* 2006;**41**:1153–60.
14. **Li AM,** Wing YK, Cheung A, *et al*. Is a 2-night polysomnographic study necessary in childhood sleep-related disordered breathing? *Chest* 2004;**126**:1467–72.

15. **American Thoracic Society.** Cardiorespiratory sleep studies in children: establishment of normative data and polysomnographic predictors of morbidity. *Am J Respir Crit Care Med* 1999;**160**:1381—7.
16. **American Academy of Sleep Medicine.** *International Classification of Sleep Disorders, diagnostic and coding manual*. 2nd edn. Westchester, Illinois: American Academy of Sleep Medicine, 2005:56—9.
17. **Carroll JL.** Obstructive sleep-disordered breathing in children: new controversies, new directions. *Clin Chest Med* 2003;**24**:261—82.
18. **Leung SS,** Cole TJ, Tse LY, *et al*. Body mass index reference curves for Chinese children. *Ann Hum Biol* 1998;**25**:169—74.
19. **Marcus CL.** Childhood obstructive sleep apnea syndrome: unanswered questions. *Chest* 2008;**134**:1114—15.
20. **Bixler EO,** Vgontzas AN, Lin HM, *et al*. Blood pressure associated with sleep-disordered breathing in a population sample of children. *Hypertension* 2008;**52**:841—6.
21. **Young T,** Palta M, Dempsey J, *et al*. The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993;**328**:1230—5.
22. **Young T,** Finn L, Peppard PE, *et al*. Sleep disordered breathing and mortality: eighteen-year follow-up of the Wisconsin sleep cohort. *Sleep* 2008;**31**:1071—8.
23. **Kohler M,** Craig S, Nicoll D, *et al*. Endothelial function and arterial stiffness in minimally symptomatic obstructive sleep apnea. *Am J Respir Crit Care Med* 2008;**178**:984—8.
24. **Liu X,** Sun Z, Uchiyama M, *et al*. Prevalence and correlates of sleep problems in Chinese school children. *Sleep* 2000;**23**:1053—62.
25. **Ng DK,** Kwok KL, Cheung JM, *et al*. Prevalence of sleep problems in Hong Kong primary school children: a community-based telephone survey. *Chest* 2005;**128**:1315—23.
26. **Ersu R,** Arman AR, Save D, *et al*. Prevalence of snoring and symptoms of sleep-disordered breathing in primary school children in istanbul. *Chest* 2004;**126**:19—24.
27. **Brunetti L,** Rana S, Lospalluti ML, *et al*. Prevalence of obstructive sleep apnea syndrome in a cohort of 1,207 children of southern Italy. *Chest* 2001;**120**:1930—5.
28. **Sogut A,** Altin R, Uzun L, *et al*. Prevalence of obstructive sleep apnea syndrome and associated symptoms in 3—11-year-old Turkish children. *Pediatr Pulmonol* 2005;**39**:251—6.
29. **Ng DK,** Kwok KL, Poon G, *et al*. Habitual snoring and sleep bruxism in a paediatric outpatient population in Hong Kong. *Singapore Med J* 2002;**43**:554—6.
30. **Teculescu DB,** Caillier I, Perrin P, *et al*. Snoring in French preschool children. *Pediatr Pulmonol* 1992;**13**:239—44.
31. **Ng DK,** Chan CH, Hwang GY, *et al*. A review of the roles of allergic rhinitis in childhood obstructive sleep apnea syndrome. *Allergy Asthma Proc* 2006;**27**:240—2.
32. **So HK,** Nelson EA, Li AM, *et al*. Secular changes in height, weight and body mass index in Hong Kong children. *BMC Public Health* 2008;**8**:320.
33. **Bliwise DL,** Benkert RE, Ingham RH. Factors associated with nightly variability in sleep-disordered breathing in the elderly. *Chest* 1991;**100**:973—6.
34. **Stepnowsky CJ Jr,** Orr WC, Davidson TM. Nightly variability of sleep-disordered breathing measured over 3 nights. *Otolaryngol Head Neck Surg* 2004;**131**:837—43.