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SCIENTIFIC INVESTIGATIONS

Socioeconomic inequalities in pediatric obstructive sleep apnea

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Study Objectives: To examine the association between multiple measures of socioeconomic status (SES) and objectively measured obstructive sleep apnea (OSA) in a Canadian pediatric population.

Methods: This was a cross-sectional study of 188 children (4–17 years, mean age 9.3 ± 3.5 years) prospectively recruited from two hospital sleep clinics in Canada, using multivariable-adjusted linear and logistic regression of five measures of SES including parental education, income, social class, geographic location, and perceived SES based on the MacArthur Scale of Subjective Social Status, assessed in relation to four polysomnographic OSA variables including apnea-hypopnea index, apnea index, mean oxygen saturation level, and oxygen desaturation index.

Results: Overall, low household-level SES appeared to be associated with both frequency (apnea index ≥ 1 events/h) and severity (apnea-hypopnea index ≥ 5 events/h) of OSA in children, with maternal education showing the most consistent and significant associations. Specifically, children with mothers reporting less than high school education had nearly three times the odds of having OSA after controlling factors including body mass index (odds ratio 2.96 [95% confidence interval, 1.05–8.37]), compared to university-educated participants. Consistent associations were also observed for geographic location with less frequency and severity of OSA among nonurban children. Perceived SES was minimally inversely associated with our outcomes.

Conclusions: This cross-sectional, multicenter study demonstrated that SES factors are linked to the occurrence and severity of OSA in children. Results indicated the need to incorporate the screening of SES in the diagnostic process of pediatric OSA to provide more targeted intervention and patient-centered care.

Keywords: pediatric, obstructive sleep apnea, socioeconomic status, polysomnography

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Socioeconomic status influences the occurrence and characteristics of obstructive sleep apnea (OSA) in children. Although socioeconomic status is a powerful determinant of health disparities, previous research on pediatric OSA and socioeconomic status includes mostly retrospective studies that have the potential of bias and the diagnosis of OSA is typically obtained from self-reporting of parents and medical history records.

Study Impact: The results of this study using polysomnography showed that maternal education and geographic location had strong and consistent relationships with the occurrence of pediatric OSA. Results indicated the need to incorporate screening of socioeconomic status in the diagnostic process of pediatric OSA to provide targeted intervention and patient-centered care to reduce disease burden and prevent the progression of OSA in children.

INTRODUCTION

Obstructive sleep apnea (OSA) is caused by repeated obstruction of the upper airway that results in partial or complete cessation of airflow during sleep, which leads to intermittent hypoxemia and sleep fragmentation. These two aspects are closely related to adverse systemic health outcomes such as behavioral and cardiovascular problems and delayed growth and development in afflicted children.[1] The prevalence of OSA is known to be 1%–6% in children and is showing a significant increase, along with the marked increase in rates of obesity over the last 20 years.[2,3] Pediatric OSA is most often associated with adenotonsillar hypertrophy; however, various risk factors have been sought out including sex/gender, obesity, craniofacial morphology, and several neurologic and genetic conditions.[4]

In addition to such well-known risk factors, previous studies have shown that socioeconomic status (SES) may influence the occurrence and characteristics of OSA in children. SES has been found to be a powerful determinant of health disparities since it influences exposure to unhealthy living conditions and shapes

vulnerability to adverse exposures.[5] Even though the relationship between SES and health has been examined for many medical conditions as the social gradient in health, the association between OSA and SES has seldom been explored. Some studies based on adult OSA populations suggested that SES could be involved in the occurrence and severity of OSA; however, the results are variable mainly due to inconsistencies in the criteria and methodology involved in the diagnosis of OSA and to variations in SES measures that are not interchangeable across studies.[6,7] Furthermore, the mechanisms underlying the role of SES in OSA pathophysiology are yet to be fully elucidated, while reverse causality, accessibility to medical care, and environmental factors have been proposed as possible explanations.[8] Previous research on pediatric OSA and SES indicates that ethnicity, neighborhood socioeconomic variables (eg, poverty rate, population densities, and distance to major roads) and household-level SES factors (eg, family income, family structure, parental occupation, and education levels) are closely associated with the risk of OSA and its severity.[8–12]

However, the current literature is mostly based on retrospective study designs that have the potential of bias and a diagnosis of OSA that is typically obtained from self-reporting of parents and by medical history records rather than the gold standard, polysomnography (PSG). Furthermore, the clinical assessment of pediatric OSA is limited to certain PSG variables such as the apnea-hypopnea index (AHI) and fails to provide insight into the oxygenation level of pediatric OSA patients, which may be more directly related to poor health outcome prognoses.[13]

This observational study therefore aimed to determine whether SES and objectively measured indices of OSA are associated in a pediatric patient population. We hypothesized that low SES would be associated with the increased occurrence and severity of OSA in children after controlling for well-established risk factors.

METHODS

Participants

This study recruited 218 patients aged 4–17 years with the complaint of snoring and respiratory problems during sleep, referred to the BC Children's Hospital or to the CHU Sainte-Justine for the diagnosis and treatment of OSA from January 2015 to September 2017. Participants' guardians (mostly mothers) completed questionnaires on sociodemographics and all participants underwent level-1 PSG evaluations for OSA diagnosis and clinical examinations for the verification of oral health status. Previous adenotonsillar surgery was recorded. The presence of syndromes involving craniofacial abnormalities, muscle dystrophy, endocrinological disorders, cerebral palsy, psychological disorders, respiratory disorders, genetic disorders, connective tissue disorders, and developmental disorders was also verified. Participants were excluded if they did not agree to complete the SES questionnaire or were not proficient in English or French. Those lacking relevant PSG data were excluded from the analysis. Complete information on all SES and PSG variables was available for 103 participants. Final analysis was done on a dataset of 188 participants after multiple imputation was used to handle missing data.

This study was conducted in accordance with the amended Declaration of Helsinki. Approval for the study was obtained from the UBC Clinical Research Ethics Board (#H12-03285) and the Research Ethics Board at CHU Sainte-Justine/UMontreal (#3639). Written informed consent and assent forms were obtained from all participants prior to recruitment.

Objective assessment of OSA

Attended standardized PSG was performed for all participants at the BC Children's Hospital and the CHU Sainte-Justine sleep clinics and scored according to the American Academy of Sleep Medicine criteria.[14] All scorers participate regularly in intra- and interlaboratory scoring concordance activities. Electroencephalogram, electrooculography, electrocardiogram, airflow using nasal pressure, oxygen saturation, leg and chin electromyography, chest and abdominal movement, and snoring were measured.

As respiratory variables, an apnea was identified by a ≥ 90% amplitude decrease from baseline of the oronasal thermal sensor signal lasting a minimum duration of 2 breaths. Hypopneas were scored if there was a ≥30% decrease from baseline of the nasal pressure signal and was associated with either an oxygen desaturation ≥3% or an arousal, and the event duration was a minimum duration of 2 breaths. The AHI and apnea index (AI) of the respiratory events were evaluated. OSA severity was defined as normal (AHI < 2 events/h), mild (2 ≤ AHI < 5 events/h), moderate (5 ≤ AHI <10 events/h), or severe (AHI ≥10 events/h).[15] Subjects were also grouped as normal (AI <1 event/h) and OSA (AI ≥ 1 event/h) based on AI. To evaluate the hypoxic burden, the mean oxygen saturation levels were recorded during total sleep. Oxygen desaturation index was calculated as the number of times the blood's oxygen level dropped by ≥ 3% during 1 hour of sleep.

On the night of the PSG, the accompanying parent or legal guardian was invited to fill in questionnaires with items related to medical history, medications, and sleep symptoms. Among those, the question "Does your child struggle to breathe while asleep?" was used to predict the presence of OSA before PSG.[16] Weight and height were measured and body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

Assessment of SES

On the night of the PSG, the accompanying parent or legal guardian was also invited to complete a 3-page SES questionnaire. Both objective and subjective SES were assessed using conventional measures, with the highest SES being the reference group. Educational attainment of the mother was divided into four groups: less than high school, high school/college, bachelor degree, and above bachelor. Maternal education was moderately correlated with paternal education (Cramer's V = .41) and is a more consistent social determinant of child oral health.[17] Household income was based on the self-reported employment income of the father during the last 12 months since 22% of mothers had no income due to not working or homemaking/caregiving (vs 6% of fathers not working or caregiving) and categorized into three income groups ($30,000 or less, $31,000–$50,000, and $51,000 and above) based on the distribution of the data. Social class was based on five hierarchical

categories of the father's occupation(s) according to job titles: upper class (I), upper-middle class (II), lower-middle class (III), working class (IV), or underclass/poor (V).[18,19] Where two job titles were reported for the father's occupation (eg, manual labor and business owner), we used the job type/title that had the highest social class (eg, business owner) to assign participants to a relevant social class category. Due to low numbers, we analyzed occupational social class as three groups (upper [classes I and II], middle [class III], and low [classes IV and V]), which were moderately correlated with paternal education (Cramer's V = .32). Postal codes were used to identify participants living in urban, periurban, rural, or remote locations in the provinces of British Columbia or Quebec. We first mapped each postal code using city websites and matched to the relevant type of location. Additionally, the MacArthur Scale of Subjective Social Status was used to assess perceived SES with the single-item measure of respondents ranking themselves on a ladder (0–10) relative to others in their community.[20,21]

Covariates

Sociodemographic variables included child's age (years), child's sex (female/male), and *z* score of objectively measured BMI (zBMI). Additional variables for sensitivity analysis included ethnic background (White/non-White) based on parental country of origin according to Canada's census region[22] and craniofacial syndrome (binary).

Statistical analysis

Descriptive statistics (means, standard deviations, and frequencies) are summarized for sociodemographic and health characteristics, described by sex and by age group (younger [4–8 years] and older [9–17 years]). Means were compared across sex and age groups using a two-sample *t* test and proportions were compared using a chi-squared test. Cramer's V was used to assess the interrelationship of the five categorical exposure variables, with strong effect sizes found only for the association between maternal and paternal education and between maternal and paternal social class. A series of multivariable linear and logistic regression models was used to assess the cross-sectional associations between each SES variable and each continuous outcome (AHI score and number of sleep apnea events) or each binary outcome (moderate/severe sleep apnea and one or more apnea events). We checked for nonlinearity in the associations across age using models with and without age-squared included, but models with age only performed better based on the *R*-squared statistic. Parsimonious models therefore adjusted for age, sex, and zBMI. Additional confounding from ethnocultural differences and from syndromic status were tested in the sensitivity analysis. All statistical analyses were performed using RStudio version 1.3.959 (R version 3.5.1) software and results are reported as regression coefficients or odds ratios (ORs) and 95% confidence intervals.

RESULTS

Table 1 summarizes the sample's characteristics. Our sample consisted of 42% female pediatric patients who averaged 9.3 years (standard deviation 3.5), were predominantly of non-White ethnic backgrounds (59%), mostly resided in urban settings (61%), and came from middle-class families (49%). Bivariate analyses showed a significant difference by sex for paternal income ($P = .032$) and adenotonsillar surgery history ($P = .048$) only. The overall severity of OSA was within the moderate category with a mean AHI score of 7.1 events/h (11.9 events/h). Boys and older patients showed a higher AHI and oxygen desaturation index and more of the boys and older patients showed severe OSA, although the difference was not statistically significant. Children who presented a syndromic condition were evaluated separately and were only included as a confounder for sensitivity analysis.

Associations between SES variables and occurrence of OSA

Multivariable adjusted models showed that the lowest level of household-level SES was associated with 0.5 to 2 additional sleep apnea events per night compared to the highest SES group (**Table 2**). Moreover, associations for maternal education and occupation-based social class appeared monotonic. Results for geographic location suggested that children living in nonurban settings have fewer total sleep apnea events compared to urban-dwelling children in the sample. Perceived SES was minimally positively associated with total number of sleep apnea events per night.

Both maternal education and social class were also associated with higher odds of AI ≥ 1 event/h in multivariable-adjusted models (**Table 3**). Less than high school maternal education was significantly linked to nearly three times higher odds of AI ≥ 1 event/h (OR 2.96 [95% confidence interval, 1.05–8.37]). Again, children living in nonurban locations had a lower likelihood of AI ≥1 event/h, while perceived SES was minimally inversely associated.

Sensitivity analyses for total number of apnea events and for odds of AI ≥ 1 event/h showed that results were minimally altered, and occasionally strengthened, by the additional adjustment for ethnic background and the presence of a syndromic condition (**Table S1** and **Table S2** in the supplemental material). Both ethnic background and syndrome status were statistically significant in sensitivity models.

Associations between SES variables and severity of OSA

Multivariable adjusted models showed a monotonic association of maternal education and father's income with OSA severity, while the lowest level of social class was minimally positively associated with the AHI score (**Table 4**). Similar to frequency of sleep apnea, nonurban-dwelling children showed lower levels of OSA severity than urban dwellers. Notably, greater perceived SES was linked to less severity.

Similarly, we found higher odds of moderate/severe apnea (AHI ≥ 5 events/h) associated with lower levels of maternal education and father's income, after adjusting for known confounders (**Table 5**). By contrast, lower social class was associated with lower odds of moderate/severe apnea. Results for geographic location appeared stronger for odds of AI ≥ 1 event/h and again showed protective effects of periurban and rural

Table 1—Sample characteristics.

Characteristic	All Patients	Girls	Boys	*P*	Younger (4–8 y)	Older (9–17 y)	*P*
n	188	78	110		99	89	
Female, n (%)	78 (42)				35 (35)	43 (48)	.098
Age (y), mean (SD)	9.3 (3.5)	8.8 (3.6)	9.7 (3.3)	.075	6.3 (4)	12.0 (8)	
Ethnicity (binary), n (%)							
White	78 (41)	36 (19)	42 (22)	.346	41 (22)	37 (20)	.289
Non-White	110 (59)	42 (22)	68 (36)		48 (26)	62 (33)	
Maternal education, n (%)							
Less than high school	40 (21)	16 (8.5)	24 (13)	.131	21 (11)	19 (10)	.176
High school/college	66 (35)	30 (16)	36 (19)		32 (17)	34 (18)	
Bachelor's degree	49 (26)	24 (13)	25 (13)		26 (14)	23 (12)	
Above bachelor	33 (18)	8 (4.3)	25 (13)		10 (5)	23 (12)	
Household income, n (%)							
T1 ($30,000 or less)	55 (29)	15 (19)	40 (36)	.032	21 (21)	34 (38)	.252
T2 ($31,000–$50,000)	49 (26)	25 (32)	24 (22)		24 (24)	25 (28)	
T3 ($51,000 and above)	84 (45)	38 (49)	46 (42)		44 (44)	40 (45)	
Household social class, n (%)							
Upper (classes I and II)	61 (32)	27 (14)	34 (18)	.204	28 (15)	33 (18)	.699
Middle (III)	92 (49)	41 (22)	51 (27)		47 (25)	45 (24)	
Low (IV and V)	35 (19)	10 (5)	25 (13)		14 (7)	21 (11)	
Geographic location, n (%)							
Urban	115 (61)	46 (24)	65 (35)	.437	53 (28)	62 (33)	.655
Periurban	40 (21)	20 (11)	20 (11)		18 (10)	22 (12)	
Rural/remote	33 (18)	12 (6)	21 (11)		18 (10)	15 (8)	
Perceived SES (social ladder), mean (SD)	6.45 (1.65)	6.5 (1.53)	6.4 (1.73)	.407	6.5 (1.5)	6.4 (1.8)	.475
Body mass index *z* score, mean (SD)	1.23 (2.22)	1.26 (2.26)	1.22 (2.20)	.903	.93 (2.58)	1.51 (1.80)	.077
Craniofacial syndrome, n (%)	30 (16)	14 (18)	15 (14)	.670	13 (7)	17 (9)	.779
T&A history, n (%)	21 (11)	4 (2)	17 (9)	.048	7 (4)	14 (7)	.258
AHI score, mean (SD)	7.1 (11.9)	5.5 (8.9)	8.2 (13.6)	.093	6.2 (12.4)	7.9 (11.5)	.334
Sleep apnea severity, n (%)							
Normal (AHI < 2 events/h)	71 (37)	35 (19)	36 (19)	.388	30 (16)	41 (22)	.058
Mild (2 ≤ AHI <5 events/h)	57 (30)	22 (12)	35 (19)		33 (18)	24 (13)	
Moderate (5 ≤ AHI <10 events/h)	26 (14)	9 (5)	17 (9)		15 (8)	11 (6)	
Severe (AHI ≥10 events/h)	34 (18)	12 (6)	22 (12)		11 (6)	23 (12)	
Apnea index, mean (SD)	1.8 (4.7)	1.2 (1.6)	2.3 (6.0)	.074	2.0 (6.0)	1.6 (3.0)	.552
Apnea index (1+), n (%) (binary)	74 (40)	28 (15)	46 (24)	.281	41 (22)	33 (18)	.551
Mean O_2 saturation, mean (SD)	95.8 (6.5)	96.3 (1.4)	95.5 (8.4)	.315	95.5 (9.3)	96.2 (1.5)	.504
ODI, mean (SD)	6.3 (15.5)	5.1 (13.2)	7.1 (16.9)	.369	5.3 (15.0)	7.2 (15.9)	.383

AHI = apnea-hypopnea index, ODI = oxygen desaturation index, SD = standard deviation, SES = socioeconomic status, T&A = tonsillectomy and adenoidectomy.

locations. Perceived SES was minimally inversely associated with odds of moderate/severe apnea.

Sensitivity analyses adjusting for ethnic background attenuated the results for level and odds of severity across all SES variables except maternal education, which stayed consistent, and social class, which became more strongly inversely associated (**Table S3** and **Table S4**). Additional adjustment for syndrome status further attenuated all results, including maternal education, and excluding periurban location, which became significantly negatively linked to level of apnea (**Table S3** and **Table S4**).

DISCUSSION

The results of this study showed that household-level SES was associated with both the occurrence and severity of OSA in

Table 2—Association between socioeconomic status and total number of sleep apnea events per night in children in Canada.

	Model A (Age and Sex)		Model B: Model A + zBMI	
	Coefficient	95% CI	Coefficient	95% CI
Maternal education				
Above bachelor	Reference		Reference	
Bachelor's degree/ undergraduate	0.80	−1.31 to 2.90	0.83	−1.28 to 2.94
High school/college	0.70	−1.30 to 2.69	0.78	−1.24 to 2.79
Less than high school	1.97	−0.21 to 4.16	2.08	−0.13 to 4.30
Father's income				
T3 ($51,000 and above)	Reference		Reference	
T2 ($31,000–$50,000)	−0.20	−1.87 to 1.47	−0.15	−1.84 to 1.54
T1 ($30,000 or less)	0.67	−0.96 to 2.30	0.75	−0.92–2.41
Social class (father's occupation)				
Upper (class I and II)	Reference		Reference	
Middle (III)	0.24	−1.28 to 1.76	0.24	−1.28 to 1.77
Low (IV and V)	1.63	−0.34 to 3.59	1.64	−0.34 to 3.61
Geographic location				
Urban	Reference		Reference	
Periurban	−1.10	−2.81 to 0.60	−1.11	−2.81 to 0.60
Rural	−0.79	−2.61 to 1.04	−0.81	−2.64 to 1.02
Perceived SES (social ladder rank)	0.16	−0.25 to 0.57	0.15	−0.26 to 0.57

CI = confidence interval, SES = socioeconomic status, zBMI = body mass index *z* score.

children, with lower maternal education levels showing the strongest associations with increased odds of pediatric OSA. This relationship persisted even after adjusting for well-known confounders of OSA including age, sex/gender, and zBMI. There is ample literature on the influence of SES in adult OSA populations but much less research on pediatric OSA. In pediatric OSA studies, the diagnosis of OSA is often based on various methods including indirect approaches and the majority were of a retrospective design from a single center. Moreover, previous investigations of SES are often limited to 2–3 variables. By contrast, all OSA pediatric patients in this study were diagnosed based on level-1 sleep studies and 5 measures of SES were evaluated, including objective and subjective SES, to provide a comprehensive understanding of the role of SES parameters on characteristics of pediatric OSA. The results of this study add to the body of evidence showing that low SES may be inversely associated with children's health and also underlie the need to further assess the role of household SES as a factor that may influence the prevalence and characteristics of OSA in children.

Our finding of the strong and significant association with maternal education levels aligns with a previous study of 34,933 children which also found a significant increase in the odds of sleep-disordered breathing for maternal educational attainment: OR 1.21 for compulsory school or less (≤ 9 years of education) and OR 1.35 for vocational or some regular high school (10–11 years) compared to those with ≥ 12 years. Another recent study showed that attainment of high school or less education was associated with a 26% increase in poor sleep health reports, although the results were not specific to OSA.[23] The OR of 2.96 from our study indicated a much higher magnitude of association between lowest maternal education and OSA among children in Canada, compared to university as highest. Such discrepancy may have arisen from bias due to measurement error in the diagnosis of OSA in the comparable literature, which has been based on census data used as proxy codes for sleep-disordered breathing and subjective reports based on a pediatric sleep questionnaire.[23] Thus, our study based on objective PSG diagnosis of OSA suggests that maternal education level has a stronger relationship with the occurrence of childhood OSA than previously established. This result is particularly notable when considering the fact that parental education level lower than vocational or college was shown to have a long-lasting influence on the occurrence of OSA even into early adulthood and higher mortality rates.[24]

Nevertheless, another PSG-based study on OSA in children reported that mother's age when giving birth and living in suburban areas were significantly associated with pediatric OSA but the association with maternal education was nonsignificant.[25] The likely reason for this different finding is the specific diagnostic criteria applied for pediatric OSA. The aforementioned study applied a criterion of AHI ≥ 1 event/h plus at least one other OSA-related symptom to define pediatric OSA, whereas AI ≥ 1 event/h was considered a sufficient sign of pathology in our study, creating a difference in the severity of OSA of the study group. The diagnostic criteria for childhood OSA are not fully agreed upon and the numeric

Table 3—Association between socioeconomic status and odds of AI ≥ 1 event/h in children in Canada.

	Model A (Age and Sex)		Model B: Model A + zBMI	
	OR	95% CI	OR	95% CI
Maternal education				
Above bachelor	Reference		Reference	
Bachelor's degree/ undergraduate	2.32	0.85–6.30	2.34	0.86–6.38
High school/college	2.25	0.87–5.84	2.30	0.88–6.02
Less than high school	2.88	1.04–8.03	2.96	1.05–8.37
Father's income				
T3 ($51,000 and above)	Reference		Reference	
T2 ($31,000–$50,000)	0.77	0.37–1.59	0.76	0.36–1.58
T1 ($30,000 or less)	0.67	0.32–1.37	0.65	0.31–1.36
Social class (father's occupation)				
Upper (class I and II)	Reference		Reference	
Middle (III)	1.76	0.89–3.49	1.76	0.89–3.49
Low (IV and V)	1.47	0.61–3.54	1.47	0.61–3.54
Geographic location				
Urban	Reference		Reference	
Periurban	0.89	0.42–1.88	0.89	0.42–1.88
Rural	0.82	0.36–1.83	0.81	0.36–1.83
Perceived SES (social ladder rank)	0.98	0.82–1.18	0.98	0.82–1.18

AI = apnea index, CI = confidence interval, OR = odds ratio, SES = socioeconomic status, zBMI = body mass index *z* score.

cutoff remains a subjective decision of a sleep specialist.[15,26] Obstructive apneic events are rare in healthy children and most pediatric sleep specialists consider an AI of more than 1 indicative of abnormality, hence the more inclusive value of AI ≥ 1 event/h was employed in our study as in other studies on pediatric OSA.[27] Moreover, investigations on the relationship between education level and the risk of OSA in adult populations show results consistent with our study.[24] A large Korean population-based study reported a significant educational gradient for adults at a high risk of OSA, with those reporting elementary education only having 28% higher odds of high-risk OSA.[28] Another cross-sectional study showed an inverse association between education and frequency of OSA in a Persian population.[29]

The connection between maternal education level and OSA could establish a long-lasting relationship in the child which is likely bidirectional with feedback loops. Lower education level is directly associated with well-known risk factors of OSA such as obesity[30] and poor sleep hygiene,[31] while OSA symptoms such as excessive daytime sleepiness result in poor academic performance[24] that can limit access to higher education.

Maternal education has also been associated with other sleep-related outcomes. The frequency of nightmares was significantly different according to maternal education level[32] and low maternal education was associated with lower sleep scores based on sleep duration.[33] Lower maternal education levels have been consistently associated with lesser time in bed[34] and decreased regular bedtime routines,[35] all factors that are both directly and indirectly related to an increased risk of pediatric OSA.[31,36] Also, while childhood obesity, a main etiologic factor of OSA, is also inversely associated with maternal education,[37] it did not appear to be part of the mechanism linking maternal education and pediatric OSA as our models adjusted for zBMI and the association remained significant. Our findings suggest the need for improved sleep counseling and informational support among mothers with less than high school education to increase the rate of early diagnosis and timely treatment.[38]

Geographic location was another SES variable related to childhood OSA in this study, as reported elsewhere. Our results showed that periurban dwelling was inversely associated with the level of apnea and ORs became significant after adjustment of syndrome status. Children living in nonurban settings had fewer sleep apnea events during total sleep time compared to urban-dwelling children. Analysis of our sample showed that periurban respondents were of the two highest SES categories of all variables, whereas urban respondents had mixed SES including both very wealthy and very poor categories. The high SES composition of our study's periurban respondents likely explains the inverse association with OSA outcomes, which contrasts with a previous study reporting that mothers who lived in suburban areas showed greater levels of OSA in their children compared to urban-dwelling mothers.[25] Measurement error and location-specific SES composition of urban residents may explain this contradiction in findings. Moreover, the level of ease of medical access could be another factor influencing outcomes, as living in close proximity to medical facilities was linked with a lower prevalence of pediatric OSA following treatment.[39]

Table 4—Association between socioeconomic status and severity of sleep apnea in children in Canada.

	Model A (Age and Sex)		Model B: Model A + zBMI	
	Coefficient	95% CI	Coefficient	95% CI
Maternal education				
Above bachelor	Reference		Reference	
Bachelor's degree/ undergraduate	0.46	−4.86 to 5.79	0.23	−5.07 to 5.53
High school/college	1.98	−3.06 to 7.02	1.38	−3.67 to 6.44
Less than high school	2.86	−2.67 to 8.39	2.07	−3.49 to 7.64
Father's income				
T3 ($51,000 and above)	Reference		Reference	
T2 ($31,000–$50,000)	1.51	−2.67 to 5.69	1.02	−3.18 to 5.22
T1 ($30,000 or less)	3.12	−0.97 to 7.21	2.43	−1.71 to 6.58
Social class (father's occupation)				
Upper (class I and II)	Reference		Reference	
Middle (III)	−0.84	−4.70 to 3.02	−0.90	−4.73 to 2.93
Low (IV and V)	0.24	−4.74 to 5.23	0.11	−4.84 to 5.05
Geographic location				
Urban	Reference		Reference	
Periurban	−3.71	−7.97 to 0.54	−3.66	−7.88 to 0.56
Rural/remote	−3.64	−8.20 to 0.92	−3.37	−7.91 to 1.17
Perceived SES (social ladder rank)	−0.36	−1.40 to 0.67	−0.22	−1.26 to 0.82

CI = confidence interval, SES = socioeconomic status, zBMI = body mass index *z* score.

Other research on residential area and childhood OSA reveals strong correlations between the odds of pediatric OSA and residential areas. Lower household income[8] or living in a low-SES neighborhood after adjusting for factors known to influence the prevalence of OSA including ethnicity was associated with higher odds.[10] Another reason for our finding that nonurban areas showed lower odds of OSA in children may be due to the level of air pollution. Air pollution is a well-known risk factor of respiratory disease, and a recent review reported evidence to support its positive relationship with OSA.[40] Montreal, Quebec, which was a data collection site for this study, has one of the highest air pollution levels of Canadian cities.[41] Urban ozone pollution was shown to cause nasal inflammatory changes which could increase the incidence of OSA.[42] Another factor could be the increased level of light pollution at night in the urban area that impacts the human circadian rhythm, which could in turn increase the risk of OSA by impairing the function of the cardiopulmonary system.[43,44]

Lowest household income and social class based on paternal occupation were associated with more sleep apnea events during sleep in children. A previous study reported significantly increased odds for pediatric sleep-disordered breathing with certain paternal occupations including drivers, mechanics, metalware workers, welders, chemical process workers, and food manufacture workers, which are often characterized by lower income and education levels.[12] Early life stressors related to low SES could harm the biological system of a child, which consequently has a detrimental effect on overall sleep and associated disorders.[45] The underlying mechanism through which low SES manifests as sleep problems is yet to be fully elucidated. Low income and low social class could directly lead to increased psychological stress[46] and barriers to health care access.[47] Future research evaluating the social gradients in pediatric OSA treatment rates and responses is also warranted.

The current study has several limitations. The results showed wide confidence intervals, which may be due to the study being underpowered to detect statistical differences in multivariable models using a relatively sparse dataset. However, a significant relationship between maternal education and pediatric OSA was still observed. Given the wide confidence intervals, we performed a posthoc power calculation to estimate the linear regression model of SES and severity of sleep apnea, or total number of events. It showed that best performance would be with a data size exceeding 956 observations. Another methodological concern is that SES was self-reported and, like all self-reported data, may be subject to social desirability bias. For example, individuals may be more inclined to report higher levels of SES due to social desirability favoring better education and/or occupations. Additionally, measurement error in categorizing income groups or social class may have led to nondifferential misclassification which would bias results toward the null (underestimate associations). The study's population focused on pediatric patients and thus results cannot be generalized to children without any symptoms of OSA. Finally, the cross-sectional nature of this study precludes causal inference and results may also be subject to residual confounding from unmeasured confounders. Nevertheless, key strengths of this study include the use of multiple SES indicators and the diagnosis of OSA based on

Table 5—Association between socioeconomic status and odds of moderate or severe sleep apnea in children in Canada.

	Model A (Age and Sex)		Model B: Model A + zBMI	
	OR	95% CI	OR	95% CI
Maternal education				
Above bachelor	Reference		Reference	
Bachelor's degree/ undergraduate	1.03	0.39–2.77	0.99	0.37–2.66
High school/college	1.30	0.52–3.25	1.17	0.46–2.97
Less than high school	1.38	0.51–3.74	1.20	0.43–3.33
Father's income				
T3 ($51,000 and above)	Reference		Reference	
T2 ($31,000–$50,000)	1.51	0.70–3.26	1.40	0.64–3.05
T1 ($30,000 or less)	1.60	0.76–3.35	1.44	0.67–3.06
Social class (father's occupation)				
Upper (class I and II)	Reference		Reference	
Middle (III)	0.89	0.45–1.78	0.88	0.44–1.77
Low (IV and V)	0.70	0.28–1.75	.69	0.27–1.73
Geographic location				
Urban	Reference		Reference	
Periurban	0.68	0.31–1.52	0.68	0.31–1.53
Rural	0.46	0.18–1.15	0.48	0.19–1.20
Perceived SES (social ladder rank)	0.93	0.77–1.12	0.95	0.78–1.15

CI = confidence interval, OR = odds ratio, SES = socioeconomic status, zBMI = body mass index *z* score.

objective PSG measurements conducted in 2 specialist centers in Canada with regular intra- and interlaboratory scoring concordance activities; more objective measurements in this study could more accurately reflect the relationship between SES and pediatric OSA than previous studies. Additionally, availability of universal access to health care in Canada helped reduce selection bias in terms of which children were referred for PSG assessment and diagnosis, irrespective of their socioeconomic status.

The findings from this study support the need for future studies of a longitudinal design based on a larger sample with a comprehensive analysis of multiple factors related to SES and OSA simultaneously. This cross-sectional, multicenter study demonstrated that SES factors are linked to the occurrence and severity of OSA in children. Specifically, maternal education and geographic location showed the strongest and most consistent relationships. Results indicated the need to incorporate the screening of SES in the diagnostic process of pediatric OSA to provide more targeted intervention and patient-centered care.

ABBREVIATIONS

AHI, apnea-hypopnea index
AI, apnea index
BMI, body mass index
OR, odds ratio
OSA, obstructive sleep apnea
PSG, polysomnography
SES, socioeconomic status
zBMI, body mass index z score

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DISCLOSURE STATEMENT

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