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Habitual snoring in adolescents and its relationship to inhibitory control and attention

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ABSTRACT

Introduction. Sleep-disordered breathing (RBD), from habitual snoring to obstructive sleep apnea syndrome (OSAS), can influence brain functioning by affecting executive functions such as attention and inhibitory control.

Objective. To analyze the association between snoring and executive functions, specifically attention, impulsivity/inhibitory control in Argentine adolescents.

Population and methods. In 2018, a cross-sectional study was conducted on 831 adolescents attending public and private schools in La Pampa. Sleep duration, snoring, and the risk of OSAS were assessed using the pediatric sleep questionnaire (PSQ) and executive functions (attention and inhibitory control) using the Go/No-Go test. The association between SRT and executive functions was performed using a robust regression model adjusted for body mass index, hours of sleep, and physical activity.

Results. About 10% of the participants were habitual snorers, and about 7% were at risk of OSA (positive PSQ), with no significant differences between sexes. Errors of commission (No-Go errors) (β= 2.06; -3.20, -0.92) and errors of omission (Go errors) (β= -0.66; -1.31, -0.01) were significantly higher in snorers vs. non-snorers. In addition, individuals at risk for OSAS showed significantly more commission errors (No-Go errors) than those without OSAS risk (β= -1.98; -3.31, -0.66).

Conclusions. The associations between snoring and inattention and impulsivity, and between the risk of sleep apnea and lower inhibitory control found in the present study suggest alterations in executive functions due to sleep disorders.

Keywords: *sleep-disordered breathing; obstructive sleep apnea; executive function; psychological inhibition; adolescent.*

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INTRODUCTION

Sleep-disordered breathing (SDB) describes a syndrome characterized by variable upper airway obstruction. It includes a spectrum of clinical entities, from habitual snoring to obstructive sleep apnea syndrome (OSAS). Some studies indicate that between 1% and 4% of the general pediatric population and 4% to 11% of adolescents have SDB.[1,2] Sleep disruption and hypoxic episodes associated with SDB in the pediatric population have been suggested to affect the functioning of the prefrontal cortex. The cognitive domain most closely linked to this brain region is executive function.[3] Growing evidence suggests that children with SDB are at increased risk for difficulties in attention, concentration, and vigilance, as well as intellectual deficits and other executive function impairments, leading to lower school performance.[4-7] These difficulties in brain function have been demonstrated not only for children with OSAS but also for primary or habitual snoring.[5,8]

The degree of compromise is more significant in those with moderate to severe OSAS and with obesity as a comorbidity.[5] These findings have been described in school-age children, in whom tonsil and adenoid hypertrophy is the leading risk factor for OSAS;[5,8] an improvement in cognitive difficulties is observed after adenotonsillectomy.[2,9] However, there are fewer studies on adolescents, in whom overweight or obesity could play a preponderant role.[10,11]

Adolescence is characterized by developing higher-order skills and functions that control goal-directed behaviors, processes, and cognitive performances.[12] Impairment of such executive functions can lead to maladaptive daily behaviors, difficulties in mentally manipulating information, maintaining attention and motivation, and deficiencies in planning, judgment, and decision-making.[13]

The present study aims to evaluate the association between habitual snoring and the risk of OSAS as part of sleep-disordered breathing and executive functions such as attention and impulsivity/inhibitory control.

POPULATION AND METHODS

In an initiative agreed with the Undersecretariat of Sports and the Ministry of Sports and Education of the province of La Pampa, a cross-sectional observational study was conducted in a convenience sample of adolescents born in 2005. The study, conducted between August and October 2018, included 30 public and private management educational institutions from the 15 most numerous localities of the province, selected from a random sampling. All clinically healthy students (without a history of chronic disease or diagnosed or manifest anomalies) who gave their assent, added to the informed consent of their parents or guardians, were included. Students with a history of neurologic injury, diagnosed or manifest craniofacial anomalies, or diagnosed neurodevelopmental disorders or other conditions that could affect the results were excluded. Finally, those who did not correctly complete the forms were excluded.

The Ministry of Social Welfare and Education authorities evaluated and approved the study's ethical and methodological aspects. The Patagonian Independent Ethics Committee (CEIP, by its Spanish acronym) approved the protocol, and it is registered in the National Health Research Registry (IS002673).

The sociodemographic data of the participants were obtained from the provincial educational system database. Five team members performed anthropometric measurements in the schools following standardized protocols.[14] Weight (kg) was recorded with a Tanita BF-350® digital scale (Tanita Corp., Tokyo, Japan), and height (cm) was measured with a SECA® stadiometer (S-213, Hamburg, Germany). Body mass index (BMI = weight(kg)/height[m^2]) was calculated, and adolescents were classified into two groups: not overweight (underweight and normal weight) and overweight (including obesity) according to the cut-off points of the International Obesity Task Force (IOTF) reference.[15] Physical activity was assessed using a specific module of the Argentine Social Debt Survey (EDSA, by its Spanish acronym), validated by Laíño et al.,[16] that estimates the average daily physical activity. Students with values ≥60 min/day were considered as physically active (PA), according to the recommendations of the World Health Organization.[17]

Pediatric Sleep Questionnaire

Together with the consent form, the parents or guardians received a questionnaire for evaluating the hours of sleep, one of which is the PSQ (Pediatric Sleep Questionnaire), validated in Spanish.[18]

The hours of sleep were estimated by evaluating the time parents reported that their children went to bed, went to sleep, and got up in the morning. Sleep for a short duration was considered sleep for less than 8 hours. The PSQ is composed of 22 items divided into three main domains: snoring (9 items), sleepiness (7 items), and behavior (6 items), with three response options (Yes, No, and Don't know). A positive snorer was defined as a subject who answered at least one of the following two questions of the PSQ: A1 Does he snore more than half the time? and A2: Does he always snore? A subject at increased risk of OSA is defined as a positive response for more than one-third of the items (8 or more positive questions) on the PSQ questionnaire.

Go/No-Go test

Before the anthropometric assessment, all adolescents were given the Go/No-Go test (session 1:128 Go/32 No-Go stimuli; session 2:32 Go/128 No-Go stimuli). This test requires participants to respond to a target stimulus (e.g., a letter, in our case, P or R). The response is motor and consists of pressing a button (mouse click) before the Go stimulus, not doing so before a No-Go stimulus, and having to do it as fast as possible.[19] Errors of commission (No-Go errors) are motor responses that occur when they are not required, and it is assumed that a lower hit rate before No-Go stimuli implies a lack of inhibitory control or impulsivity. Errors of omission (Go errors) occur due to a lack of motor response when required; a lower hit rate to Go stimuli is assumed to reflect inattention. The total duration of the test is 8 minutes.

Data analysis

The Kolmogorov-Smirnov goodness-of-fit test was applied to establish the variables' distribution type. A robust linear regression model was used on the raw data to analyze the association between snoring and positive PSQ with executive functions and adjusted for sex, physical activity, overweight/obesity (OW/OB), and sleep duration. We considered a *p*-value <0.05 was considered statistically significant. Data were analyzed with R 3.4.3™ (Foundation for Statistical Computing, Vienna, Austria) and SPSS 25.0™ for Windows (SPSS Inc., Chicago, IL).

RESULTS

A total of 831 subjects were included from 1017 who were initially invited to participate in the study, of which 5 were excluded because they did not show up on the appointment day or did not complete the questionnaire correctly. Finally, 377 males (45.6%) and 449 females (54.4%) were evaluated, with a mean age of 13.1±0.4 years. Standardized BMI values were close to one deviation above the median of the IOTF reference. Overweight (including obesity) exceeded 30%. Of this percentage, 12.7% of the males and 11.8% of the females were obese. Median nightly sleep was 8 hours; slightly more than one-third of the adolescents slept less than 8 hours. At least 60% of the subjects complied with 60 minutes of daily physical activity; males were significantly more active than females. Between 9% and 10% of the respondents were snorers, and between 5% and 8% were at risk of OSAS (positive PSQ), with no significant differences between sexes. All variables showed asymmetric distributions (*Table 1*).

Robust linear regression models were applied to analyze individuals with habitual snoring and risk of OSAS and executive functions. The first model corresponded to the crude model. Then the adjusted models were tested for the different independent variables –expressed as quantitative or categorical variables– physical activity, BMI (Z_IMC) or OW/OB, and sleep duration (or sleep <8 hours). In all cases, the results of the adjustments were similar, whether quantitative or categorical variables were used.

Snoring indicated significant regression coefficients for hit rate against No-Go stimuli in snoring vs. non-snoring students, both in the crude model (β= -2.06; -3.20, -0.92) and in the model adjusted for sex, physical activity, OW/OB, and sleep duration (β= -2.15; -3.34, -0.95). Significantly lower coefficients of hit rate against Go stimuli were also found in snoring vs. non-snoring subjects in both the crude model (β = -0.66; -1.31, -0.01) and adjusted (β = -0.74; -1.44, -0.04) (*Table 2*).

Concerning the risk of OSAS, significant regression coefficients were obtained for the hit rate to No-Go stimuli in students with positive PSQ vs. students without risk of OSAS, both in the crude model (β = -1.98; -3.31, -0.66) and in the adjusted model (β = -1.99; -3.33, -0.64) (*Table 3*).

There were no significant differences in the mean reaction time for snoring and the risk of OSAS.

DISCUSSION

There is no universally accepted definition for snoring. In practice, human perception by parents is the gold standard for diagnosis.[20] In studies

Table 1. Descriptive parameters of the sample1

	Males	Females	*p*-value
N (%)	377 (45.6)	449 (54.4)	
Age (years)	13.1 (0.4)	13.1 (0.4)	0.362
BMI (z-score)	0.83 (1.6)	0.92 (1.5)	0.294
Overweight/obesity (%)	32.1	37.9	0.084
Sleep (hours)	8.0 (1.5)	8.0 (2.0)	0.779
Short sleep (%)	30.8	33.0	0.509
PA (%)	71.9	64.1	0.018
Snoring (%)	10.4	9.1	0.540
PSQ + (%)	5.8	8.0	0.221

[1]Except for age, quantitative variables correspond to the median and interquartile range.
N: number; BMI: body mass index; PA: physically active; PSQ: Pediatric Sleep Questionnaire.

that asked whether snoring always occurs, the prevalence is 1.5% to 6.2%; in studies that ask whether snoring occurs frequently, it is from 3.2% to 14.8%.[20,21] The prevalence of snoring in this sample was 9.7%, within the ranges described in the literature.[20,21] Numerous studies have examined the specific association between executive functions and SDB, although with mixed results.[5,7,8,12,22-25]

Our study found statistically significant differences between habitual adolescent snorers and non-snorers in both commission and omission errors. Errors of commission are associated with a lack of inhibitory control or impulsivity, while errors of omission are associated with inattention.[19] Therefore, in our sample, patients with habitual snoring had greater difficulties in attention and in achieving inhibitory control than those who did not snore. Habitual snoring is a parameter to consider in patients with difficulties in academic achievement, independently of OSAS,[7,8] since it is one of the factors that compromise executive

Table 2. Regression coefficients between snoring and executive functions

Variable	Executive function	Raw model			Adjusted model[1]		
		B	CI		B	CI	
Session 1 Accuracy P*100	Go errors (omission)	-0.66*	-1.31	-0.01	-0.74*	-1.44	-0.04
Session 1 Accuracy R*100		-4.87	-10.20	0.43	-3.81	-9.33	1.71
Reaction time P		15.05	-8.28	38.4	11.3	-11.3	33.9
Session 2 Accuracy P*100	No-Go errors (commission)	-2.06*	-3.20	-0.92	-2.15*	-3.34	-0.95
Session 2 Accuracy R*100		-0.12	-1.47	1.23	-1.07	-2.61	0.46
Reaction time R		11.12	-9.10	31.4	7.24	-14.90	29.4

*[1] Adjusted for sex, physical activity, overweight/obesity and sleep duration. * p <0,05.*
B: b coefficient; CI: confidence interval.

Table 3. Regression coefficients between positive Pediatric Sleep Questionnaire and executive functions

Variable	Executive function	Raw model			Adjusted model[1]		
		B	CI		B	CI	
Session 1 Accuracy P*100	Go errors (omission)	-0.16	-0.94	0.62	-0.21	-1.03	0.60
Session 1 Accuracy R*100		-3.13	-9.23	2.97	-2.90	-9.21	3.40
Reaction time P		-3.43	31.37	24.52	-10.64	38.97	17.69
Session 2 Accuracy P*100	No-Go errors (commission)	-1.98*	-3.31	-0.66	-1.99*	-3.33	-0.64
Session 2 Accuracy R*100		-0.32	-1.82	1.18	-0.90	-2.82	1.02
Reaction time R		2.68	-20.84	26.21	-3.05	-28.95	22.86

*[1] Adjusted for sex, physical activity, overweight/obesity and sleep duration. * p <0,05.*
B: b coefficient; CI: confidence interval.

functions to a greater extent, according to some published studies.[5,7,23] The explanation for this association is not well established since some studies show that the combination of intermittent hypoxia associated with fragmented sleep contributes to cognitive deficit and alteration in cognitive functions.[3,4,25,26]

This could explain the association of executive function deficits in OSAS but does not include habitual snoring. In addition, other studies have found no direct association between cognitive deficits and intermittent hypoxia or fragmented sleep.[12,22,27] This suggests that there must be other mechanisms involved beyond sleep fragmentation/disruption.[28]

This study identified that 5.8% to 8% of adolescents were at risk for OSA (PSQ positive). This result exceeds the prevalence of up to 6% described in the literature in children[29,30] and suggests that at least some of the increased prevalence of OSAS may begin in adolescence.

Our study also found a significant association between adolescents at risk of OSAS and commission errors in the Go/No-Go test compared to those without risk of OSAS. This result suggests a lack of inhibitory control or impulsivity in those at risk for OSAS that could influence the executive functions necessary for learning.[22]

In this study, it was only possible to infer a higher risk of OSAS through positive PSQ, which is its main limitation, given that the gold standard for the evaluation of OSAS is polysomnography, a method with high economic costs due to the highly trained personnel, the technology involved, as well as the facilities required for this practice outside the clinical setting. In this sense, PSQ is a reliable, validated screening method for detecting OSAS, especially useful in settings with less complex resources. This work provides evidence on the association between habitual snoring and risk of OSAS, as part of sleep disorders and compromise in executive functions, from a model adjusted for confounding variables that may affect sleep disorders in adolescents, a less studied age group and where tonsil and adenoid hypertrophy would not be the leading cause of SDB, as it is in the preschool age group. Future lines of research could benefit from incorporating complementary standardized assessment tools, such as the d2 selective attention test or the BRIEF-2, which would provide a broader perspective on attentional difficulties in adolescents with habitual snoring. These tools should guide the development of effective interventions to improve sleep quality and affect adolescents' academic and social performance.

CONCLUSIONS

In this study, habitual snorers have lower inhibitory control or greater impulsivity, as well as inattention, compared with non-snoring adolescents. Those adolescents at risk for OSAS also have lower inhibitory control than those who are not in the risk group. This association suggests considering sleep breathing disorders, including habitual snoring, as factors influencing executive functions and their potential reversibility with adequate and timely treatment. ■

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