Associations of Sleep-Related Outcomes with Behavioral and Emotional Functioning in Children with Overweight/Obesity

Lucia V. Torres-Lopez, MSc[1], Cristina Cadenas-Sanchez, PhD[1,2], Jairo H. Migueles, PhD[1,3], Pontus Henriksson, PhD[4], Marie Löf, Prof[3,4], and Francisco B. Ortega, Prof[1,3,5]

Objective To evaluate the associations of parent-reported sleep-disordered breathing (SDB) and device-assessed sleep behaviors with behavioral and emotional functioning in pediatric patients with overweight/obesity.

Study design A total of 109 children with overweight/obesity (mean age, 10.0 ± 1.1 years) were included in this cross-sectional study. We used the Spanish version of the Pediatric Sleep Questionnaire (PSQ) to assess SDB and its subscales (ie, snoring, daytime sleepiness, and inattention/hyperactivity). Device-assessed sleep behaviors (ie, wake time, sleep onset time, total time in bed, total sleep time, and waking after sleep onset) were estimated using wrist-worn accelerometers. We used the Behavior Assessment System for Children, second edition to assess behavioral and emotional functioning (ie, clinical scale: aggressiveness, hyperactivity, behavior problems, attention problems, atypicality, depression, anxiety, retreat, and somatization; adaptive scale: adaptability, social skills, and leadership).

Results SDB was positively associated with all clinical scale variables (all $\beta > 0.197$, $P \leq .041$) and with lower adaptability and leadership (all $\beta < -0.226$, $P < .021$). Specifically, the PSQ subscale relating to daytime sleepiness was associated with higher attention problems, depression, anxiety, and retreat (all $\beta > 0.196$, $P \leq .045$) and lower adaptability ($\beta = -0.246$, $P = .011$). The inattention/hyperactivity subscale was significantly associated with the entire clinical and adaptive scales (all $\beta > |0.192|$, $P \leq .046$) except for somatization. The snoring subscale and device-assessed sleep behaviors were not related to any behavioral or emotional functioning variables.

Conclusions Our study suggests that SDB symptoms, but not device-assessed sleep behaviors, are associated with behavioral and emotional functioning in children with overweight/obesity. Specifically, daytime sleepiness, a potential SDB symptom, was related to higher attention problems, depression, anxiety, and retreat and lower adaptability. *(J Pediatr 2022;246:170-8)*.

Healthy sleep is essential for school-age children's health, including adequate duration and continuity, consistent sleep onset and wakeup timing, and the absence of sleep disorders.[1] One-third of the pediatric population experience sleep problems, however.[2] Obstructive sleep-disordered breathing (SDB) affects 4%-11% of children worldwide, with a range of severity from primary snoring to obstructive sleep apnea (OSA).[3] Pediatric obesity is closely linked to sleep problems[4] and increases the risk of SDB compared with children of normal weight (20.8% vs 6.3%).[5] Furthermore, children with overweight/obesity often have suboptimal sleeping times, insufficient sleep efficiency,

ADHD	Attention-deficit/hyperactivity disorder
BASC-2	Behavior Assessment System for Children, second edition
BSI	Behavioral Symptoms Index
OSA	Obstructive sleep apnea
PHV	Peak height velocity
PSQ	Pediatric Sleep Questionnaire
SDB	Sleep-disordered breathing
SMD	Standardized mean difference
SRBD	Sleep-Related Breathing Disorders
WASO	Wake after sleep onset

From the [1]PROFITH (PROmoting FITness and Health through physical activity) research group, Sport and Health University Research Institute, Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, Granada, Spain; [2]Institute for Innovation and Sustainable Development in the Food Chain, Public University of Navarra, Pamplona, Spain; [3]Department of Biosciences and Nutrition, Karolinska Institutet, Huddinge, Sweden; [4]Department of Health, Medicine, and Caring Sciences, Linköping University, Linköping, Sweden; and [5]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

This work is part of a PhD thesis conducted in the Official Doctoral Programme in Biomedicine of the University of Granada, Spain. The ActiveBrains project was funded by the Spanish Ministry of Economy and Competitiveness and the Fondo Europeo de Desarrollo Regional (DEP2013-47540, DEP2016-79512-R, DEP2017-91544-EXP, and RYC-2011-09011). L.V.T.-L. is supported by a grant from the Spanish Ministry of Science, Innovation and Universities (FPU17/04802). C.C.-S. is supported by the Spanish Ministry of Science and Innovation (FJC2018-037925-I). J.H.M. is supported by a grant from the Spanish Ministry of Education, Culture, and Sport (FPU15/02645). Additional support was provided by the University of Granada, Plan Propio de Investigación 2016, Excellence actions: Units of Excellence, Scientific Excellence Unit on Exercise and Health, by the Junta de Andalucía, Consejería de Conocimiento, Investigación y Universidades, and European Regional Development Fund (SOMM17/6107/UGR). Funding was also provided by the SAMID III network, RETICS, funded by the PNI + D + I 2017–2021 (Spain), ISCIII Sub-Directorate General for Research Assessment and Promotion, the European Regional Development Fund (RD16/0022), the EXERNET Research Network on Exercise and Health (DEP2005-00046/ACTI; 09/UPB/19; 45/UPB/20; 27/UPB/21), the European Union's 2020 Research and Innovation Program under Grant Agreement 667302, and the HL-PIVOT network Healthy Living for Pandemic Event Protection. Additional funding was obtained from the Andalusian Operational Programme supported with European Regional Development Fund (project B-CTS-355-UGR18). The authors declare no conflicts of interest.

https://doi.org/10.1016/j.jpeds.2022.03.006

and short sleep duration.[6-10] The study of the associations between sleep disorders and behavioral and emotional functioning is particularly relevant in the context of childhood obesity.

A cross-sectional study in children with overweight showed that SDB was related to parent-reported attention problems, anxiety, aggressiveness, and depression.[11] Another study found that children and adolescents with comorbid overweight/obesity and SDB had an increased risk for externalizing behaviors, such as aggressiveness.[12] Moreover, children and adolescents with SDB are more likely to exhibit signs of attention-deficit/hyperactivity disorder (ADHD), such as hyperactivity and inattention.[13]

Device-assessed sleep duration has shown inconsistent associations with behavioral problems in children.[14-17] For example, longer sleep duration was associated with a lower risk of internalizing problem but not of externalizing problems in 8-year-old children.[17] In the present study, we investigated the associations of parent-reported SDB and device-estimated sleep behaviors with behavioral and emotional functioning in children with overweight/obesity.

Methods

We used baseline data from the ActiveBrains project, a randomized controlled trial investigating the effects of an exercise program on brain structure and function and cognition in children with overweight/obesity. Data were collected from November 2014 to February 2016 in a total of 110 overweight/obese children from Granada, Spain. One child was excluded for difficulties shown in Spanish reading comprehension; thus, a total of 109 children (mean age, 10.04 ± 1.12 years; 45 girls) were included in this cross-sectional study. A detailed description of the trial protocol, aims, and methods has been published elsewhere.[18]

All participants met the following inclusion criteria: (1) overweight or obese, based on the sex- and age-specific international body mass index cutoff points proposed by the World Obesity Federation,[19,20] (2) age 8.0-11.9 years, (3) no physical disabilities or neurologic disorders that affect physical performance, (4) no ADHD, and (5) no menarche at baseline for girls.

Parents/legal guardians of the participants were informed of the purpose of the study, and their written informed consent was obtained. The study was conducted according to the principles outlined in the Declaration of Helsinki. The study protocol was approved by the Ethics Committee on Human Research of the University of Granada, and the study was registered at ClinicalTrials.gov (identifier NCT02295072).

SDB was evaluated via the Spanish version of the Pediatric Sleep Questionnaire (PSQ), which has shown high reliability and internal consistency[21] as well as validity for identifying SDB.[22,23] This questionnaire was completed by legal guardians, who rated each item according to their child's usual sleep patterns. The Sleep-Related Breathing Disorders (SRBD) scale (range, 0-1) was used to quantify the SDB diagnosis, with higher scores indicating greater severity. This scale consists of 22 closed-response question items from the reduced version of the PSQ and includes 3 subscales[22,23]: snoring (4 items), sleepiness (4 items), and inattention/hyperactivity (6 items). These subscales have been considered valid and reliable instruments for use in research on SDB in children.[24] The answer options for each item include "yes," "no," and "I don't know." In the last domain of the questionnaire (inattention/hyperactive subscale), the response options are "never," "sometimes," "often," and "almost always." To be consistent with these answer options throughout the questionnaire, one of the sections was recategorized as follows: "never" and "sometimes" answers were categorized as "no," and "often" and "almost always" answers were categorized as "yes." The overall scale was calculated as the sum of the affirmative answers divided by the total number of items (ie, 22). Occasional missing answers or "I do not know" responses were eliminated from the denominator when calculating the scores. An SRBD score >0.33 was considered to indicate high risk for diagnosis of SDB.[22,23] A meta-analysis indicated that the SRBD scale has suitable accuracy in detecting children with OSA, with a sensitivity of 0.73 and specificity of 0.59.[25]

Participants were instructed to wear an accelerometer (GT3X+; ActiGraph) on their nondominant wrist for 7 consecutive days, 24 hours a day, and to record information on sleep onset and wakeup times each day in a sleep diary. The accelerometers were initialized to record accelerations at 100 Hz. Raw accelerations were downloaded in ActiLife version 6.13.3 (ActiGraph) and processed in the R package GGIR version 1.5.12 (https://www.cran.r-project.org/).[26] Detailed information on accelerometer data processing for sleep analysis can be found elsewhere.[27] Sleep onset and wake times were detected using an algorithm guided by the participants' reported times.[28] First, the algorithm examined potential sleep occurrences throughout the 24 hours. Then the first and last epochs, classified as sleep before and after the reported times, were considered the definitive sleep wake and onset times. An algorithm developed by Sadeh et al[29] was applied within the total time in bed to classify each minute as "sleep" or "wake" time. Device-assessed sleep behavior included indicators of sleep timing (ie, wake and sleep onset times), sleep duration (ie, total time in bed and total sleep time), and sleep pattern (ie, wake after sleep onset [WASO] time). The total time in bed is the difference between wake and sleep onset times. Total sleep time represents the sum of all minutes classified as sleep within the total time in bed. The total amount of time classified as WASO time each night was also derived.

The Behavior Assessment System for Children, second edition (BASC-2) was used to assess behavioral and emotional functioning. The assessment was completed by parents to evaluate negative behaviors and positive

attributes of children aged 6-12 years.[30] The BASC-2 is divided into 2 scales: the clinical scale (ie, aggressiveness, hyperactivity, behavior problems, attention problems, atypicality, depression, anxiety, retreat, and somatization) and the adaptive scale (ie, adaptability, social skills, and leadership). Responses are clustered into 4 global dimensions: external problems, including aggressiveness, hyperactivity, and behavioral problems; internal problems, including anxiety, depression, and somatization; adaptability skills, including adaptability, social skills, and leadership; and a Behavioral Symptoms Index (BSI), including aggressiveness, hyperactivity, attention problems, atypical behaviors, anxiety, and depression. For each indicator, standard *t*-scores with an average of 50 points and SD of 10 points were used in the analyses. For external and internal problems and BSI, *t*-scores >70 were considered clinically significant and those of 60-70 were considered at risk. For adaptive skills, *t*-scores <30 were considered clinically significant and those of 30-40 were considered at risk.[30]

Age, sex, parental education level, wave of participation (ie, ActiveBrains was conducted in 3 waves for logistical reasons), and peak height velocity (PHV) were considered potential confounders. Parental education level was obtained through a self-reported questionnaire. Parents' responses were categorized as none, one, or both had a university-level education. The wave of participation (1, 2, or 3) was categorized into 2 dichotomous dummy variables for inclusion in the models. PHV, an indicator of biological maturity during childhood and adolescence, was calculated from anthropometric variables (standing and seated height) and participant age using Moore equations.[31]

Descriptive characteristics of the study participants are presented as mean and SD for continuous variables and as frequency and percentage for categorical variables. Before analyses, the extreme values (ie, outliers) were winsorized to limit their influence on the results. In brief, we visually inspected histograms and quantile-quantile plots of the variables included and identified extreme values. This was done by replacing raw scores <1st percentile of the cohort-wide distribution with the value of the 1st percentile and replacing scores >99th percentile with the value of the 99th percentile.[32] Furthermore, all variables were checked for normality. After checking for normal distribution, the SRBD scale was normalized using the Blom formula[33] because it showed a skewed distribution. Bivariate Pearson correlation tests were performed as exploratory analyses and to test the correlations between behavioral and emotional functioning variables. Sensitivity analyses were performed using the data before winsorization and normalization, and the findings remained unchanged.

Hierarchical linear regression analyses were performed to examine the associations of sleep-related outcomes (ie, overall SDB and by subscale, along with device-assessed sleep behaviors) with behavioral and emotional functioning. The stepwise method was used to investigate the influence of potential confounders in the models in step 1 (ie, age, sex, paternal education level, wave of participation, and PHV). Next, hierarchical regressions were carried out, entering the SRBD scale, snoring subscale, daytime sleepiness subscale, inattention-hyperactivity subscale, or each device-assessed sleep behavior variable (ie, wake time, sleep onset time, total time in bed, total sleep time, and WASO time) separately as a predictor into step 2 and also entering each behavioral and emotional functioning variable as an outcome in separate regression analyses after the inclusion of confounders previously defined in step 1. It should be noted that the PSQ inattention/hyperactivity subscale can overlap BASC-2 hyperactivity and attention problems, and thus SDB could be affected by the strong relationship among these components.

Additionally, the participants were classified into high risk (scores >0.33; score range, 0-1) and low risk (scores <0.33; score range, 0-1) of SDB diagnosis.[22,23] We used one-way ANCOVA to explore standardized mean differences (SMDs) between the high-risk and low-risk of SDB groups for behavioral and emotional functioning variables, adjusting for the different confounders previously identified as significantly associated with the outcomes in the hierarchical linear regression.

The Benjamini–Hochberg procedure was applied to account for the random effects in multiple comparisons for each independent domain—SRBD scale, snoring subscale, sleepiness subscale, inattention/hyperactive subscale, wake time, sleep onset time, total time in bed, total sleep time, and WASO time—with $q = 0.1$.[34] All analyses were performed using SPSS for Windows version 22.0 (IBM). The level of significance was set at $P < .05$.

Results

Descriptive characteristics for all participants and stratified by sex are presented in **Table I**. Only 41 of 105 participants (39%) met the recommendation of sufficient sleep duration for their age (ie, 9-11 hours per night). Regarding external and internal problems, 3 of 109 participants (2.8%) and 14 of 109 (12.8%) had clinically important levels, respectively, and 9 of 109 (8.3%) and 19 of 109 (17.4%) were at risk. Regarding the BSI, 5 of 109 participants (4.6%) had clinically important levels, and 16 of 109 (14.7%) were at risk. Regarding adaptive skills, 5 of 109 (4.6%) participants had clinically important levels, and 16 of 109 (14.7%) were at risk. Hierarchical linear regression analyses for the association of overall SRBD scale and the snoring, sleepiness, and inattention/hyperactivity subscales with behavioral and emotional functioning variables are presented in **Table II**. **Table III** (available at www.jpeds.com) shows the bivariate correlations between behavioral and emotional functioning variables. Hierarchical linear regression analyses for the association of device-assessed sleep behaviors (ie, wake time, sleep onset

Table I. Descriptive characteristics of the participants

Characteristics	Total		Boys		Girls	
	N	Value	N	Value	N	Value
Age, y, mean ± SD	109	10.04 ± 1.12	64	10.16 ± 1.15	45	9.88 ± 1.08
Weight, kg, mean ± SD	109	56.21 ± 11.23	64	57.11 ± 11.2	45	54.94 ± 11.28
Height, cm, mean ± SD	109	144.22 ± 8.41	64	144.98 ± 7.97	45	143.13 ± 8.99
Body mass index category, n (%)						
Overweight		28 (25.7)		16 (25)		12 (26.7)
Obesity type I		47 (43.1)		30 (46.9)		17 (37.8)
Obesity type II		34 (31.2)		18 (28.1)		16 (35.6)
Behavioral and emotional functioning*						
Clinical scale, mean ± SD						
Aggressiveness	109	48.85 ± 9.86	64	49.53 ± 10.02	45	47.89 ± 9.64
Hyperactivity	108	45.67 ± 8.52	64	45.42 ± 8.93	44	46.02 ± 7.97
Behavior problems	109	51.73 ± 9.05	64	52.2 ± 9.00	45	51.07 ± 9.18
Attention problems	109	50.48 ± 10.31	64	50.05 ± 9.50	45	51.09 ± 11.45
Atypicality	109	50.62 ± 10.74	64	49.19 ± 10.93	45	52.67 ± 10.25
Depression	108	54.45 ± 15.53	64	55.05 ± 17.20	44	53.64 ± 12.86
Anxiety	109	53.61 ± 11.06	64	53.17 ± 12.18	45	54.24 ± 9.32
Retreat	108	51.14 ± 13.21	64	50.78 ± 14.24	44	51.66 ± 11.70
Somatization	108	51.81 ± 14.37	64	48.7 ± 11.68	44	56.34 ± 16.69
Adaptive scale, mean ± SD						
Adaptability	109	49.56 ± 10.76	64	48.94 ± 11.12	45	50.44 ± 10.30
Social skills	108	51.4 ± 10.95	64	50.45 ± 10.67	44	52.77 ± 11.33
Leadership	109	47.93 ± 10.53	64	48.03 ± 9.89	45	47.78 ± 11.48
Global dimensions†						
External problems	108	49.04 ± 8.71	64	49.12 ± 9.04	44	48.91 ± 8.31
Internal problems	108	54.42 ± 13.92	64	52.97 ± 13.84	44	56.52 ± 13.92
Adaptability skills	108	49.5 ± 11.18	64	49.02 ± 10.80	44	50.2 ± 11.80
BSI punctuation	108	50.89 ± 11.06	64	50.7 ± 11.66	44	51.16 ± 10.25
SDB breathing (range, 0 to 1)						
SRBD scale, mean ± SD	109	0.19 ± 0.13	64	0.19 ± 0.13	45	0.18 ± 0.13
Snoring subscale, mean ± SD	109	0.21 ± 0.30	64	0.19 ± 0.27	45	0.25 ± 0.33
Daytime sleepiness subscale, mean ± SD	107	0.17 ± 0.22	64	0.15 ± 0.22	43	0.20 ± 0.22
Inattention/hyperactivity subscale, mean ± SD	109	0.13 ± 0.20	64	0.15 ± 0.22	45	0.10 ± 0.17
SDB presence, n (%)		17 (16)		10 (16)		7 (16)
Device-assessed sleep behaviors						
Wake time, h:min	105	8:08 (0:34)	62	8:05 (0:33)	43	8:11 (0:35)
Sleep onset time, h:min	105	23:00 (00:40)	62	23:00 (00:40)	43	23:00 (00:39)
Total time in bed, min/day	105	529.37 ± 31.76	62	527.52 ± 33.09	43	532.03 ± 29.90
Total sleep time, min/day	105	460.89 ± 35.84	62	456.51 ± 32.10	43	467.20 ± 40.18
WASO time, min/day	105	76.58 ± 23.64	62	79.80 ± 20.55	43	71.95 ± 27.07

*Values based on standard *t*-scores with an average of 50 ± 10 points.
†External problems include aggressiveness, hyperactivity, and behavior problems; internal problems include depression, anxiety, and somatization; adaptability skills include adaptability, social skills, and leadership; and BSI includes aggressiveness, hyperactivity, attention problems, atypicality, depression, and anxiety.[37] Detailed descriptions of these indicators are provided in **Table V** (available at www.jpeds.com).

time, total time in bed, total sleep time, and WASO time) with behavioral and emotional functioning variables are presented in **Table IV**. Age, sex, parental education level, wave, and PHV were included as potential confounders in hierarchical linear regressions. Anxiety and internal problems were adjusted for age, somatization was adjusted for sex, and leadership was adjusted for parental education level because these were the unique covariates selected in the hierarchical regression (step 1).

The SDB and inattention/hyperactivity subscale were associated with all the global dimensions studied (ie, worse external and internal problems, adaptability skills, and BSI punctuation; all $\beta > |0.258|$, $P \leq .007$). The snoring subscale was not associated with any of the global dimensions (all $\beta < |0.167|$ and $P \geq .078$). The daytime sleepiness subscale was associated with higher internal problems ($\beta = 0.231$, $P = .015$), higher BSI ($\beta = 0.257$, $P = .008$), and lower adaptability skills ($\beta = -0.207$, $P = .033$). All the associations reported surpassed the correction for multiple comparisons test.

SDB was positively associated with all the variables in the clinical scale (all $\beta > 0.197$, $P \leq .041$). The snoring subscale was significantly associated with higher attention problems ($\beta = 0.204$, $P = .037$), yet this association was disregarded by the multiple comparisons correction test. The daytime sleepiness subscale was associated with higher attention problems, depression, anxiety, and retreat (all $\beta > 0.196$, $P \leq .045$), and the inattention/hyperactivity subscale was positively associated with all the clinical scale variables (all $\beta > 0.192$, $P \leq .046$) except somatization. All the associations reported were corrected for multiple comparisons.

Regarding the adaptive scale, SDB was associated with worse adaptability ($\beta = -0.271$, $P = .004$) and leadership

Table II. Hierarchical linear regression for the associations of overall SRBD scale and subscales (snoring, sleepiness, and inattention/hyperactivity) with behavioral and emotional functioning variables

	Overall SRBD scale		Snoring subscale		Daytime sleepiness subscale		Inattention/ hyperactivity subscale	
Variables	*β*	***P***	*β*	***P***	*β*	***P***	*β*	***P***
Clinical scale								
Aggressiveness	0.197	**.040**	0.109	.261	0.073	.453	0.305	**.001**
Hyperactivity	0.197	**.041**	0.049	.612	0.115	.242	0.424	**<.001**
Behavior problems	0.231	**.016**	0.126	.193	0.074	.447	0.345	**<.001**
Attention problems	0.422	**<.001**	0.204	.034	0.333	**<.001**	0.478	**<.001**
Atypicality	0.279	**.003**	0.087	.371	0.172	.077	0.394	**<.001**
Depression	0.336	**<.001**	0.116	.232	0.210	**.030**	0.322	**.001**
Anxiety*	0.321	**<.001**	0.097	.288	0.206	**.024**	0.375	**<.001**
Retreat	0.250	**.009**	0.179	.064	0.196	**.045**	0.192	**.046**
Somatization†	0.303	**.001**	0.113	.233	0.087	.364	0.164	.082
Adaptive scale‡								
Adaptability	−0.271	**.004**	−0.083	.392	−0.246	**.011**	−0.271	**.004**
Social skills	−0.177	.066	−0.104	.283	−0.118	.228	−0.230	**.017**
Leadership§	−0.226	**.021**	−0.099	.299	−0.154	.110	−0.275	**.004**
Global dimensions¶								
External problems	0.258	**.007**	0.129	.183	0.092	.347	0.446	**<.001**
Internal problems*	0.412	**<.001**	0.167	.078	0.231	**.015**	0.335	**<.001**
Adaptability skills‡	−0.278	**.004**	−0.118	.225	−0.207	**.033**	−0.317	**.001**
BSI punctuation	0.412	**<.001**	0.152	.117	0.257	**.008**	0.524	**<.001**

Each association (ie, pair main exposure-outcome) was introduced in separate hierarchical regression models. Potential confounders (ie, age, sex, parental education level, wave, and PHV) were included in step 1 of the stepwise regression to test their association to the outcomes, so that for each outcome, only the relevant confounders were retained in the final models. In step 2, the exposure variable of interest (eg, overall SRBD scale, snoring or sleepiness, or inactive/hyperactivity subscale) was entered using the method ENTER to force it in the model. *β* values are standardized coefficients. Bold type indicates that the specific association surpassed the Benjamini–Hochberg correction for multiple-comparisons test.

*Adjusted by age.

†Adjusted by sex.

‡Lower values indicate better results (ie, poorer adaptive skills). Detailed descriptions of the indicators are provided in Table V.

§Adjusted by parental education level.

¶External problems include aggressiveness, hyperactivity, and behavior problems; internal problems include depression, anxiety, and somatization; adaptability skills include adaptability, social skills, and leadership; behavioral symptoms index include aggressiveness, hyperactivity, attention problems, atypicality, depression, and anxiety.[37]

Table IV. Hierarchical linear regression for the associations of sleep with behavioral and emotional functioning variables

	Wake time		Sleep onset time		Total time in bed		Total sleep time		WASO time	
Variables	**B**	***P***	*β*	***P***	*β*	***P***	*β*	***P***	*β*	***P***
Clinical scale										
Aggressiveness	−0.116	.237	−0.144	.142	0.046	.640	0.049	.620	−0.022	.827
Hyperactivity	0.094	.344	0.022	.823	0.119	.229	0.048	.631	−0.018	.856
Behavior problems	0.002	.983	0.075	.447	−0.145	.140	0.054	.586	−0.204	.037
Attention problems	0.186	.058	0.174	.075	−0.105	.288	0.045	.645	−0.134	.174
Atypicality	0.181	.065	0.111	.259	0.039	.691	0.033	.736	−0.056	.568
Depression	−0.117	.238	−0.076	.442	−0.046	.642	−0.019	.849	−0.023	.815
Anxiety*	−0.050	.588	−0.076	.411	0.001	.996	0.108	.244	−0.140	.128
Retreat	0.068	.495	0.155	.117	−0.154	.117	−0.018	.859	−0.163	.099
Somatization†	−0.024	.807	−0.066	.493	0.017	.860	0.059	.543	−0.047	.632
Adaptive scale										
Adaptability	−0.035	.727	−0.063	.521	0.128	.192	−0.005	.963	0.185	.060
Social skills	0.032	.750	−0.056	.572	0.193	.050	0.147	.136	0.036	.713
Leadership	0.096	.332	0.021	.831	0.193	.049	0.157	.110	0.066	.506
Global dimensions‡										
External problems	−0.008	.932	−0.020	.843	0.001	.989	0.058	.558	−0.099	.319
Internal problems*	−0.084	.383	−0.092	.338	−0.028	.776	0.059	.542	−0.099	.301
Adaptability skills	0.034	.734	−0.045	.648	0.212	.031	0.119	.228	0.118	.232
BSI punctuation*	0.019	.844	0.007	.941	−0.028	.773	0.028	.774	−0.079	.415

Each association (ie, pair main exposure-outcome) was introduced in separate hierarchical regression models. Potential confounders (ie, age, sex, parental education level, wave, and PHV) were included in step 1 of the stepwise regression to test their association to the outcomes, so that for each outcome only the relevant confounders were retained in the final models. In step 2, the exposure variable of interest, wake time/sleep onset time/total time in bed/total sleep time/WASO time was entered using the method ENTER to force to be in the model. *β* values are standardized coefficients. Bold type indicates that the specific association surpassed the Benjamini–Hochberg correction for multiple comparisons test.

*Adjusted by age.

†Adjusted by sex.

‡External problems include aggressiveness, hyperactivity, and behavior problems; internal problems include depression, anxiety, and somatization; adaptability skills include adaptability, social skills, and leadership; behavioral symptoms index include aggressiveness, hyperactivity, attention problems, atypicality, depression, and anxiety.[37] Detailed descriptions of each indicator are provided in Table V.

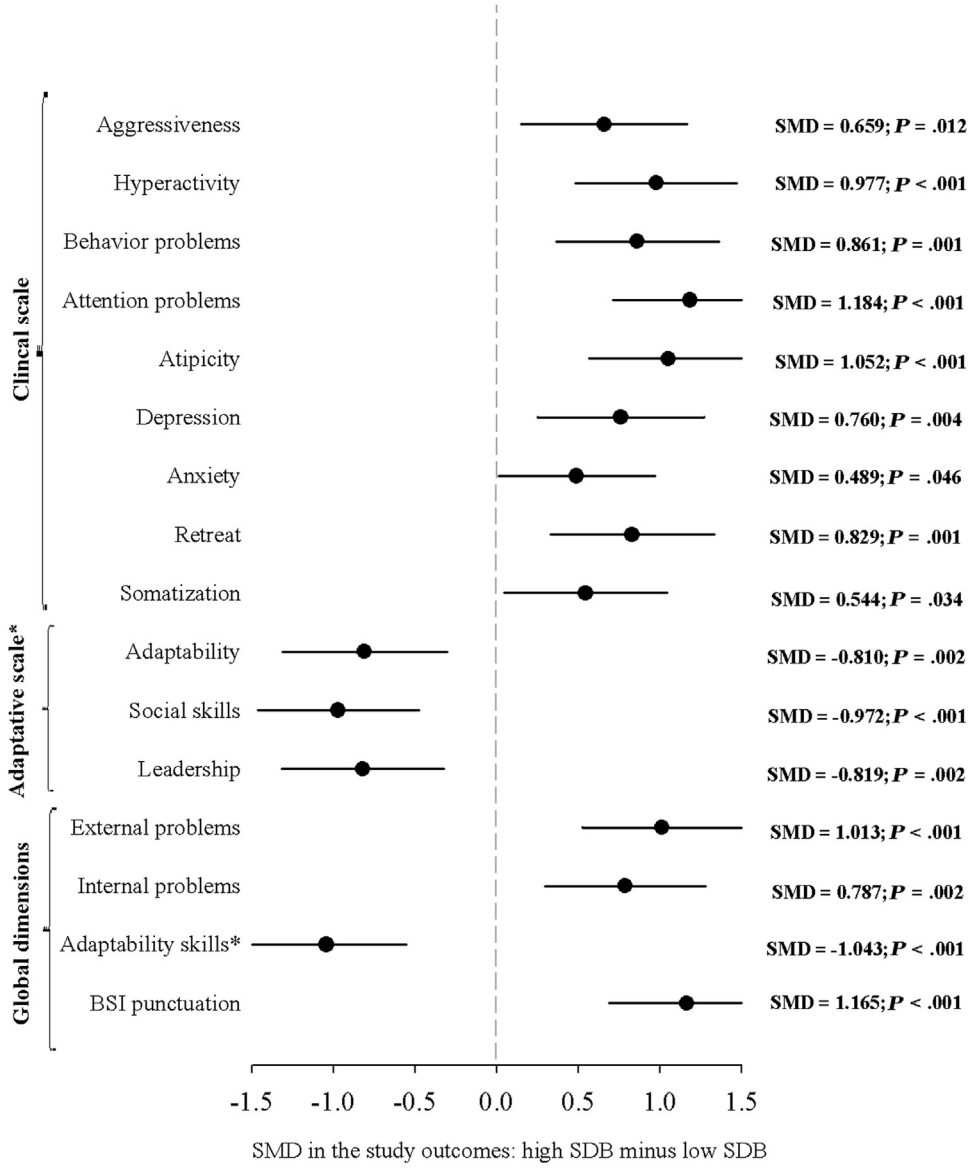

Figure. Mean differences between the SDB groups (higher risk of SDB vs lower risk of SDB) on behavioral and emotional functioning outcomes. Dots represent *z*-score values, and bars represent 95% CIs. Bold type indicates that the specific association surpassed the Benjamini–Hochberg correction for the multiple comparisons test. Scores were adjusted by the different confounders previously found to be significantly associated with the outcomes in hierarchical linear regression. A SRBD scale was calculated from the 22 items on the questionnaire. Scores >0.33 were considered suggestive of high risk for a pediatric SDB.[22,23] *Lower values indicate better results (ie, poorer adaptive skills).

($\beta = -0.226$, $P = .021$). The snoring subscale was not associated with any of the adaptive scale variables (all $\beta > -0.104$, $P \geq .283$). The daytime sleepiness subscale was only inversely associated with worse adaptability ($\beta = -0.246$, $P = .011$), whereas the inattention/hyperactivity subscale was inversely associated with all the adaptive scale variables (all $\beta < -0.230$, $P \leq .017$). All the associations were corrected for multiple comparisons.

The **Figure** represents the behavioral and emotional functioning differences (and 95% CIs) between the high-risk (>0.33) and low-risk (<0.33) SDB groups. For the global dimensions, the high-risk group had greater external and internal problems and BSI punctuation (all SMDs >0.787, $P \leq .002$) and lower adaptability skills (SMD $= -1.043$, $P < .001$) compared with the low-risk group. Children at high risk of SDB had significantly higher aggressiveness, hyperactivity, behavior problems, atypicality, depression, anxiety, retreat, and somatization (all SMD > 0.489, $P \leq .046$) and lower adaptability, social skills, and leadership (all SMD ≥ -0.810, $P \leq .002$).

For the global dimensions, only the total time in bed was associated with better adaptability skills (β = 0.212, P = .031). However, after applying the multiple comparisons test, this association was not significant. Neither of the device-assessed sleep behaviors was associated with the clinical scale variables after controlling for multiple comparisons (all $P \geq .037$). Only the total time in bed was associated with better social skills (β = 0.193, P = .050) and leadership (β = 0.193, P = .049), yet these associations did not surpass the multiple comparisons correction. Neither of the remaining device-assessed sleep behavior variables was associated with the adaptive scale.

Discussion

The main findings of this study support that SDB symptoms are related to worse behavioral and emotional functioning (ie, higher external and internal problems and lower adaptability skills) in children with overweight/obesity. These associations might be explained in part by the shared symptoms between ADHD and SDB, which may result in overlap between the PSQ and BASC-2 items. Moreover, our findings also support the idea that daytime sleepiness can be related to attention problems, depression, anxiety, retreat. and worse adaptability. We did not observe any associations between device-assessed sleep behaviors and behavioral and emotional functioning.

Our findings are consonant with a previous study in which polysomnography-determined OSA was associated with worse behavioral functioning outcomes (ie, aggressiveness, hyperactivity, attention problems, anxiety, and depression) but not with social skills, as assessed by the BASC in children with overweight.[11] In contrast, that study did not find any association with atypicality and leadership. Discrepancies between the aforementioned findings in children aged 10-17 years and our findings in children aged 8-12 years could be partially explained by differences in participant age, sample size, and method of measuring OSA (polysomnography vs questionnaire). Using the PSQ, Lande et al showed that higher scores in the SRBD scale of the PSQ were significantly associated with worse scores on behavior problems and mood, specifically in externalizing and internalizing behavior and depression, in children with hypertension (~60% with obesity).[35] A similar association was found in children with obesity, in which those allocated in the OSA group had poorer ratings of parent-reported internalizing and externalizing behaviors, adaptive skills, and overall behavior compared with their peers without OSA.[36] However, our results are not in line with that study's finding of no significant differences between polysomnography-determined OSA and controls in parent-reported internalizing and externalizing problems, adaptive skills, and BSI.[36] The differences between the studies might be explained by the age of the sample (10-18 years), as well as the severity of SDB. Nevertheless, previous studies in normal-weight children are in line with our findings, showing that parent-reported SDB and daytime sleepiness were positively associated with emotional problems.[37] Our findings are supported by Perfect et al, who also observed higher hyperactivity, attention problems, and aggressiveness and lower adaptive skills in children with SDB compared with their peers.[38]

Regarding sleep behavior, unlike in our study, a systematic review posited that shorter self-reported sleep duration was consistently associated with adverse mental health outcomes.[39] Despite the limited evidence on device-assessed sleep behavior, several previous studies observed that device-estimated sleep duration was related to behavioral functioning in children.[15-17,40] However, our findings are in agreement with those from Hammam et al supporting that total sleep duration is not a predictor of behavior problems in preschool children.[14] In agreement, Guerlich et al found that longer device-assessed sleep duration was not associated with externalizing problems in 8-year-old children.[17] The variability of the methodological procedures and data processing used in previous studies, as well as characteristics of the study sample, could explain the inconsistencies found. Moreover, even though device-assessed sleep duration might not be related to behavioral and emotional functioning, daytime sleepiness seems to be. A possible explanation for this relationship is that both daytime sleepiness and behavioral and emotional functioning are parents' perceptions, which might be more relevant than the device-assessed sleep duration for characterizing behavioral and emotional functioning in children with overweight/obesity.

Some limitations of this study must be acknowledged. First, this was a cross-sectional study and thus does not allow for causal inference of any of the studied associations. Second, our data were obtained from parental questionnaires instead of polysomnography, and caution is advised when interpreting these findings regarding younger age when other factors may be major determinants of SDB (eg, adenotonsillar disease). Third, the accelerometer-based estimates of sleep were based on movement patterns, not purely on sleep behavior. Fourth, we did not ask parents to report their child's medical history of sleep symptoms and sleepiness. Interestingly, the SRBD scale includes as part of its score items related to attention and hyperactivity because they are known to be strongly related.[22] This might be controversial, given that the behavioral and emotional functioning scale also includes attention problems as an indicator, and, in turn, the SBD could be affected by the strong relationship among these components. For that reason, we further evaluated the SDB by subscales. Therefore, our findings should be considered with caution when the inattention/hyperactivity subscale is included.

The severity of SDB was mild in our participants (only 16% scored >0.33 on the SRBD scale), and thus we might have not been able to detect some associations that could be present in more severely affected children. Our exclusion of children with ADHD may explain the mild severity of SDB in our sample. Further studies in children with more severe SDB symptoms (eg, children with ADHD) are warranted to further explore these associations. Public health implications from this study include the need to support sleep hygiene in children with overweight/obesity. ■

Submitted for publication Nov 4, 2021; last revision received Mar 2, 2022; accepted Mar 4, 2022.

Reprint requests: Lucia V. Torres-Lopez, MSc, Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, 18011 Granada, Spain. E-mail: luciatl@ugr.es

References

1. Buysse DJ. Sleep health: can we define it? Does it matter? Sleep 2014;37:9-17.
2. Owens JA, Spirito A, McGuinn M, Nobile C. Sleep habits and sleep disturbance in elementary school-aged children. J Dev Behav Pediatr 2000;21:27-36.
3. Lumeng JC, Chervin RD. Epidemiology of pediatric obstructive sleep apnea. Proc Am Thorac Soc 2008;5:242-52.
4. Skjåkødegård HF, Danielsen YS, Frisk B, Hystad SW, Roelants M, Pallesen S, et al. Beyond sleep duration: sleep timing as a risk factor for childhood obesity. Pediatr Obes 2021;16:e12698.
5. Abazi Y, Cenko F, Cardella M, Tafa G, Laganà G. Sleep disordered breathing: an epidemiological study among Albanian children and adolescents. Int J Environ Res Public Health 2020;17:8586.
6. Miller AL, Lumeng JC, LeBourgeois MK. Sleep patterns and obesity in childhood. Curr Opin Endocrinol Diabetes Obes 2015;22:41-7.
7. Morrissey B, Taveras E, Allender S, Strugnell C. Sleep and obesity among children: a systematic review of multiple sleep dimensions. Pediatr Obes 2020;15:e12619.
8. Kanellopoulou A, Notara V, Magriplis E, Antonogeorgos G, Rojas-Gil AP, Kornilaki EN, et al. Sleeping patterns and childhood obesity: an epidemiological study in 1,728 children in Greece. J Clin Sleep Med 2021;17:1093-101.
9. Sakamoto N, Gozal D, Smith DL, Yang L, Morimoto N, Wada H, et al. Sleep duration, snoring prevalence, obesity, and behavioral problems in a large cohort of primary school students in Japan. Sleep 2017;40:zsw082.
10. Wu Y, Gong Q, Zou Z, Li H, Zhang X. Short sleep duration and obesity among children: a systematic review and meta-analysis of prospective studies. Obes Res Clin Pract 2017;11:140-50.
11. Beebe DW, Ris MD, Kramer ME, Long E, Amin R. The association between sleep disordered breathing, academic grades, and cognitive and behavioral functioning among overweight subjects during middle to late childhood. Sleep 2010;33:1447-56.
12. Biggs SN, Tamanyan K, Walter LM, Weichard AJ, Davey MJ, Nixon GM, et al. Overweight and obesity add to behavioral problems in children with sleep-disordered breathing. Sleep Med 2017;39:62-9.
13. Sedky K, Bennett DS, Carvalho KS. Attention deficit hyperactivity disorder and sleep disordered breathing in pediatric populations: a meta-analysis. Sleep Med Rev 2014;18:349-56.
14. Hammam N, Sadeghi D, Carson V, Tamana SK, Ezeugwu VE, Chikuma J, et al. The relationship between machine-learning-derived sleep parameters and behavior problems in 3- and 5-year-old children: results from the CHILD Cohort study. Sleep 2020;43:zsaa117.
15. Carson V, Ezeugwu VE, Tamana SK, Chikuma J, Lefebvre DL, Azad MB, et al. Associations between meeting the Canadian 24-hour movement guidelines for the early years and behavioral and emotional problems among 3-year-olds. J Sci Med Sport 2019;22:797-802.
16. Pesonen AK, Räikkönen K, Paavonen EJ, Heinonen K, Komsi N, Lahti J, et al. Sleep duration and regularity are associated with behavioral problems in 8-year-old children. Int J Behav Med 2010;17:298-305.
17. Guerlich K, Gruszfeld D, Czech-Kowalska J, Ferré N, Closa-Monasterolo R, Martin F, et al. Sleep duration and problem behaviour in 8-year-old children in the Childhood Obesity Project. Eur Child Adolesc Psychiatry 2021. https://doi.org/10.1007/s00787-021-01731-8 [Epub ahead of print].
18. Cadenas-Sánchez C, Mora-González J, Migueles JH, Martín-Matillas M, Gómez-Vida J, Escolano-Margarit MV, et al. An exercise-based randomized controlled trial on brain, cognition, physical health and mental health in overweight/obese children (ActiveBrains project): rationale, design and methods. Contemp Clin Trials 2016;47:315-24.
19. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes 2012;7:284-94.
20. Bervoets L, Massa G. Defining morbid obesity in children based on BMI 40 at age 18 using the extended international (IOTF) cut-offs. Pediatr Obes 2014;9:e94-8.
21. Vila MT, Torres AM, Soto BB. Spanish version of the Pediatric Sleep Questionnaire (PSQ). A useful instrument in investigation of sleep disturbances in childhood. Reliability analysis. An Pediatr (Barc) 2007;66:121-8 (in Spanish).
22. Chervin RD, Weatherly RA, Garetz SL, Ruzicka DL, Giordani BJ, Hodges EK, et al. Pediatric sleep questionnaire. Prediction of sleep apnea and outcomes. Arch Otolaryngol Head Neck Surg 2007;133:216-22.
23. Chervin RD, Hedger K, Dillon JE, Pituch KJ. Pediatric sleep questionnaire (PSQ): validity and reliability of scales for sleep-disordered breathing, snoring, sleepiness, and behavioral problems. Sleep Med 2000;1:21-32.
24. Chervin RD, Dillon JE, Bassetti C, Ganoczy DA, Pituch KJ. Symptoms of sleep disorders, inattention, and hyperactivity in children. Sleep 1997;20:1185-92.
25. Michelet D, Julien-Marsollier F, Vacher T, Bellon M, Skhiri A, Bruneau B, et al. Accuracy of the sleep-related breathing disorder scale to diagnose obstructive sleep apnea in children: a meta-analysis. Sleep Med 2019;54:78-85.
26. Migueles JH, Rowlands AV, Huber F, Sabia S, van Hees VT. GGIR: A research community-driven open source R package for generating physical activity and sleep outcomes from multi-day raw accelerometer data. J Meas Phys Behav 2019;2:188-96.
27. Migueles JH, Cadenas-Sanchez C, Tudor-Locke C, Löf M, Esteban-Cornejo I, Molina-Garcia P, et al. Comparability of published cut-points for the assessment of physical activity: implications for data harmonization. Scand J Med Sci Sport 2019;29:566-74.
28. van Hees VT, Sabia S, Anderson KN, Denton SJ, Oliver J, Catt M, et al. A novel, open access method to assess sleep duration using a wrist-worn accelerometer. PLoS One 2015;10:e0142533.
29. Sadeh A, Sharkey KM, Carskadon MA. Activity-based sleep-wake identification: an empirical test of methodological issues. Sleep 1994;17:201-7.
30. Reynolds CR, Kamphaus RW. In: Behavior assessment system for children. 2nd ed. Circle Pines (MN): American Guidance Service; 2004.
31. Moore SA, McKay HA, Macdonald H, Nettlefold L, Baxter-Jones ADG, Cameron N, et al. Enhancing a somatic maturity prediction model. Med Sci Sports Exerc 2015;47:1755-64.
32. Sink KM, Espeland MA, Castro CM, Church T, Cohen R, Dodson JA, et al. Effect of a 24-month physical activity intervention vs health education on cognitive outcomes in sedentary older adults: the LIFE randomized trial. JAMA 2015;314:781-90.
33. Blom G. Statistical estimates and transformed beta variables. (New York, NY: Wiley; 1961). Stockholm, Sweden: Almquist and Wiksell; 1958.
34. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. J R Stat Soc Ser B 1995;57:289-300.

35. Lande MB, Hooper SR, Batisky DL, Kupferman JC, Szilagyi PG, Samuels JA, et al. Sleep disordered breathing as measured by SRBD-PSQ and neurocognition in children with hypertension. Am J Hypertens 2015;28:552-8.
36. Tan E, Healey D, Schaughency E, Dawes P, Galland B. Neurobehavioural correlates in older children and adolescents with obesity and obstructive sleep apnoea. J Paediatr Child Health 2014;50:16-23.
37. Liu J, Liu X, Ji X, Wang Y, Zhou G, Chen X. Sleep disordered breathing symptoms and daytime sleepiness are associated with emotional problems and poor school performance in children. Psychiatry Res 2016;242:218-25.
38. Perfect MM, Archbold K, Goodwin JL, Levine-Donnerstein D, Quan SF. Risk of behavioral and adaptive functioning difficulties in youth with previous and current sleep disordered breathing. Sleep 2013;36:517-25.
39. Chaput JP, Gray CE, Poitras VJ, Carson V, Gruber R, Olds T, et al. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. Appl Physiol Nutr Metab 2016;41(6 Suppl 3):S266-82.
40. Paavonen EJ, Räikkönen K, Lahti J, Komsi N, Heinonen K, Pesonen AK, et al. Short sleep duration and behavioral symptoms of attention-deficit/hyperactivity disorder in healthy 7- to 8-year-old children. Pediatrics 2009;123:e857-64.

Table III. Bivariate correlation between behavioral and emotional functioning indicators

Indicators	Aggressiveness	Hyperactivity	Behavior problems	Attention problems	Atypicality	Depression	Anxiety	Retreat	Somatization	Adaptability	Social skills
Clinical scale											
Aggressiveness	-										
Hyperactivity	0.451*	-									
Behavior problems	0.582*	0.321*	-								
Attention problems	0.306*	0.355*	0.445*	-							
Atypicality	0.196†	0.470*	0.321*	0.423*	-						
Depression	0.532*	0.519*	0.379*	0.451*	0.481*	-					
Anxiety	0.336*	0.350*	0.206†	0.298*	0.323*	0.621*	-				
Retreat	0.276*	0.263*	0.208†	0.328*	0.340*	0.496*	0.494*	-			
Somatization	0.123	0.207†	0.111	0.188	0.375*	0.331*	0.201†	0.260*	-		
Adaptive scale											
Adaptability	−0.391*	−0.273*	−0.320*	−0.451*	−0.296*	−0.428*	−0.386*	−0.473*	−0.172	-	
Social skills	−0.435*	−0.303*	−0.425*	−0.457*	−0.255*	−0.325*	−0.131	−0.404*	−0.005	0.607*	-
Leadership	−0.158	−0.207*	−0.231†	−0.566*	−0.179	−0.310*	−0.253*	−0.331*	−0.045	0.424*	0.630*

*$P < .01$.
†$P < .05$.

Table V. Definition of behavioral and emotional functioning indicators in this study

Behavioral and emotional functioning indicators	Definition
Internalizing problems	
Depression	Feeling of unhappiness, sadness, and stress that may result in an inability to carry out everyday activities or may bring on thoughts of suicide
Anxiety	The tendency to be nervous, fearful, or worried about real or imagined problems
Somatization	The tendency to be overly sensitive to and complain about relatively minor physical problems and discomforts
Externalizing problems	
Aggressiveness	The tendency to act in a hostile manner (either physical or verbal) that is threatening to others
Hyperactivity	The tendency to be overly active, rush through work or activities, and act without thinking
Behavior problems	The tendency to engage in antisocial and rule-breaking behavior, including destroying property
Other problems	
Attention problems	The tendency to be easily distracted and unable to concentrate more that momentarily
Atypicality	The tendency to behave in ways that are considered odd or commonly associated with psychosis
Retreat or withdrawal	The tendency to evade others to avoid social contact
Adaptive skills	
Adaptability	The ability to adapt readily to changes in the environment
Social skills	The skills necessary for interacting successfully with peers and adults in home, school, and community settings
Leadership	The skills associated with accomplishing academic, social, or community goals, including the ability to work with others

Definitions were extracted from the BASC (Reynolds CR, Kamphaus RW. Behavior assessment system for children. Circle Pines (MN): American Guidance Service; 1992).