The prevalence of malocclusion is higher in schoolchildren with signs of hyperactivity

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Introduction: Attention deficit-hyperactivity disorder is a behavioral disorder characterized by a lack of focus, impulsive behavior, and or excessive activity. This research aimed to evaluate the association between signs of attention deficit-hyperactivity disorder and malocclusion in schoolchildren. **Methods:** A cross-sectional study was conducted with a representative sample of 633 children aged 7-12 years. The children were clinically examined for malocclusion using the Dental Aesthetic Index. The predominant breathing pattern was also determined. Parents answered a questionnaire addressing socioeconomic characteristics and the presence of nonnutritive sucking habits. The Swanson, Nolan, and Pelham Scale–IV was filled out by both parents and teachers to compare behavioral patterns. The children were submitted to a neuropsychological evaluation using the Raven's Colored Progressive Matrix Test. Data analysis involved the chi-square test and Poisson regression analysis. **Results:** The prevalence of malocclusion was 42% higher among children with signs of hyperactivity reported by both parents and teachers (prevalence ratio [PR], 1.42; 95% confidence interval [CI], 1.11-1.81; $P = 0.004$). In the final Poisson regression model, the prevalence of malocclusion was lower among schoolchildren aged 11 and 12 years (PR, 0.62; 95% CI. 0.52-0.73; $P < 0.001$) and higher among those who used a pacifier for at least 4 years (PR, 1.25; 95% CI, 1.02-1.54; $P = 0.029$) as well as those classified as mouth breathers (PR, 1.28; 95% CI, 1.09-1.51; $P = 0.003$). **Conclusions:** The prevalence of malocclusion was higher among children with signs of hyperactivity independently of age, pacifier use, and mouth breathing. (Am J Orthod Dentofacial Orthop 2021;159:653-9)

Attention deficit-hyperactivity disorder (ADHD) is a behavioral disorder characterized by a lack of focus, impulsive behavior, and or excessive activity.[1] ADHD can lead to the impairment of executive functions, compromising activities that require planning and concentration.[2,3] Some of the signs are a lack of attention to details, difficulty concentrating on tasks at school or during games, a lack of attention when addressed directly, failure to follow instructions, and difficulty organizing and completing tasks. Moreover, patients with ADHD avoid, dislike, or are reluctant to engage in activities that require sustained mental effort and are easily distracted. Children with signs of hyperactivity and impulsiveness often move about the classroom, run and climb on things when this type of activity is inappropriate, have difficulty playing quietly, tend to talk excessively, often answer questions in an abrupt manner, have difficulty waiting their turn, and often interrupt others.[1]

The criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition[1] include 9 signs and symptoms of inattention and 9 of hyperactivity and impulsivity. The diagnosis requires the occurrence of 6 or more signs and symptoms of at least 1 of these categories. It is also necessary for the symptoms to be present frequently for at least 6 months, be more pronounced than expected for the child's level of development, occur in at least 2 different settings (eg, home and school), emerge before the age of 12 years (at least some symptoms), and exert a negative impact on functioning at

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
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Submitted, June 2019; revised and accepted, November 2019.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2019.11.027

home, school or work. Moreover, the symptoms cannot be better explained by another mental disorder (eg, mood, anxiety, dissociative, or personality disorder).[1] The global prevalence of ADHD among school-age children ranges from 5% to 7%,[4,5] and this condition is reported to be more frequent in males.[6,7]

Studies have shown that some comorbidities, such as autism spectrum disorders, depression, and anxiety, may be associated with ADHD.[8] Children with ADHD are also more likely to have a shorter exclusive breastfeeding period[9] and respiratory disorders involving upper airway obstruction,[10,11] sleep-disordered breathing, and obstructive sleep apnea.[10-12] Respiratory disorders[13] and a short period of exclusive breastfeeding[14] are also associated with the occurrence of malocclusion, and studies have indicated a higher frequency of malocclusion and craniofacial changes in children with signs of ADHD.[9,12,15] However, few studies have investigated the possible causal network, and it remains unclear how these variables are related.

To clarify the causal network of malocclusion in children with signs of ADHD, it is necessary to incorporate variables into a model on the basis of a conceptual framework. Thus, the present study hypothesized that children with signs of ADHD have higher frequencies of nonnutritive sucking habits and mouth breathing, with a consequently higher frequency of malocclusion. This study aimed to evaluate the possible association between signs of ADHD and malocclusion in schoolchildren aged 7-12 years and investigate the possible pathways for this association using a hierarchical approach.

MATERIAL AND METHODS

The present study was approved by the Human Research Ethics Committee of *Universidade Federal dos Vales do Jequitinhonha e Mucuri* (certificate no. 045/2011). Parents and guardians received clarifications regarding the objectives and signed a statement of informed consent. This study was conducted in accordance with the principles for medical research involving human subjects stipulated in the Declaration of Helsinki. All data remained anonymous and confidential.

A cross-sectional study was conducted with a representative sample of children aged 7-12 years attending public and private schools in the city of Diamantina, Brazil. A list of the number of students enrolled in public and private schools in the city was obtained from the Municipal Department of Education. Children were randomly selected proportionately to the distribution among municipal public schools (70%), state-run public schools (20%), and private schools (10%). Children with a past or current history of orthodontic treatment, those with intellectual disability (score at or below the fifth percentile of Raven's Colored Progressive Matrices test), and those with neurologic diseases (based on parental reports) were excluded from the study.

The sample size was calculated considering a 40.1% prevalence rate of malocclusion,[16] 95% confidence interval (CI), and 4% acceptable estimate error. As 2-stage sampling was performed (schools and classes), a design effect of 1.1 was also considered, leading to a minimum sample of 635 participants. To compensate for possible dropouts, we increased this number by 64 patients, leading to a total of 699 children.

Data collection took place in private rooms at the schools, with the child sitting in a chair in front of the examiner. Disposable mouth mirrors (PRISMA, São Paulo, São Paulo, Brazil), a periodontal probe (Trinity, Campo Mourão, PA, Brazil), headlamp (PETZL, Tikka XP, Crolles, France), and gauze were used for the clinical dental examination.

Dental examinations were performed by 2 dentists (I.M.V.; M.A.H.) and 2 assistants (L.D.R.; L.E.P.C.). The examiners participated in theoretical and practical training as well as calibration exercises for the diagnosis of malocclusion. Interexaminer and intraexaminer kappa values were higher than 0.82. Neuropsychological tests were performed by another team composed of 2 examiners. The results of the neuropsychological tests were analyzed and interpreted by a psychologist (F.O.F).

The Dental Aesthetic Index (DAI) was used for the investigation of malocclusion. The results were interpreted as follows: DAI $\leq$25 = normal, no need or slight need for treatment; 26$\leq$ DAI $\leq$30 = definite malocclusion, treatment elective; 31 $\leq$ DAI $\leq$ 35 = severe malocclusion, treatment highly desirable; and DAI $\geq$36 = very severe malocclusion, treatment mandatory.[17] Malocclusion was dichotomized as absent (DAI $\leq$25) or present (DAI $\geq$26).

The intellectual evaluation involved the use of the Raven's Colored Progressive Matrices test, which has been validated for children aged from 5 to 12 years in Brazil.[18] The test consists of a book with 36 drawings. Each drawing has 1 missing piece and 6 options to complete the drawing. The result is interpreted on the basis of the percentile, with percentiles equal to or less than 5 indicating intellectual disability.

The Swanson, Nolan, and Pelham Scale–IV is used to analyze child behavioral patterns through subscales for the identification of inattention, hyperactivity and/or impulsivity, and oppositional and/or defiant behavior. Considering the objectives of the present study, we used only the subscales for signs of inattention and hyperactivity and/or impulsivity. The Swanson, Nolan, and

Pelham Scale–IV was answered by the parents or caregivers and teachers of each participant as a way of comparing behavioral patterns in the family and school settings, as this is part of the criteria for the diagnosis of ADHD. Thus, signs of ADHD were identified on the basis of the reports of both the parents or caregivers and teachers. Each subscale has 9 items scored with the following options: 0 = *not at all*, 1 = *just a little*, 2 = *quite a bit*, and 3 = *very much*. The total is calculated by the sum of the item scores of each subscale divided by the total number of items on the subscale. Signs of ADHD were considered present when the mean score on the inattention subscale was >1.78 according to parents and caregivers and >2.56 according to teachers and when the score on the hyperactivity subscale was >1.44 according to parents and caregivers and >1.78 according to teachers.[19]

The parents and caregivers answered a questionnaire addressing socioeconomic and/or demographic data and nonnutritive sucking habits. Information was collected on the child's age and sex, parent's or caregiver's schooling, and family income. Age was dichotomized by the median. Parent's or caregiver's schooling was dichotomized as ≤8 or >8 years of study (cutoff point corresponding to a complete elementary school education). Family income was categorized on the basis of the Brazilian monthly minimum wage (approximately $270). Information was collected on the history and duration of pacifier use, finger and/or thumb sucking, and bottle feeding. Sucking habits were dichotomized as <48 or ≥48 months, on the basis of the findings of a previous study.[20]

The following are the most striking characteristics of mouth breathing: tongue with the dorsum raised and tip lowered; tongue on the floor of the mouth or interposed anteriorly between the arches; thick, everted lower lip; over-functioning of the mentalis muscle; flaccidity of the lips, tongue, and cheeks; atypical swallowing; facial asymmetry; noisy respiration; an increased height of the face; maxillary atresia; malocclusion; and a narrow, high palate.[21] These characteristics were observed as complementary factors to establish the diagnosis of the breathing pattern. The examiner also kept the children seated comfortably for 5 minutes for observation and evaluation of the predominant breathing type. If a child spent a larger portion of the time with his or her mouth open, mouth breathing was recorded. In this investigation, a child was considered to be a mouth breather when presenting predominantly oral breathing during the examiner's observation and at least 1 of the clinical characteristics described above.[21]

Statistical analysis

The data were analyzed using SPSS Statistics for Windows (version 22.0; IBM, Armonk, NY). A conceptual proposal was structured to explain the possible pathways of associations between the explanatory variables and malocclusion (Fig). Socioeconomic and/or demographic variables, nonnutritive sucking habits, and mouth

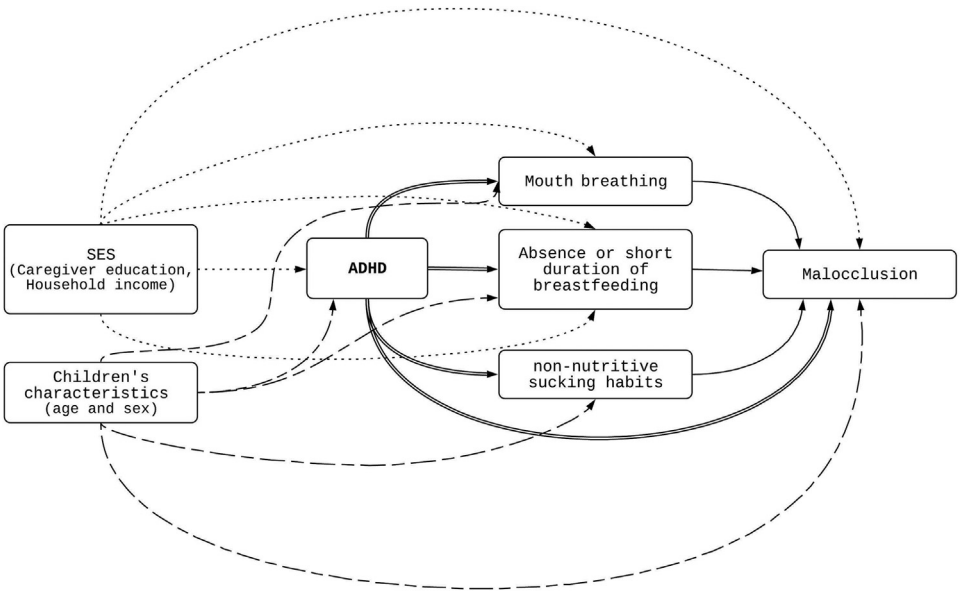

Fig. Summary chart for relations between explanatory variables, ADHD, and malocclusion. *SES*, socioeconomic status.

breathing may act as confounding variables interfering in the association between signs of ADHD and malocclusion. These variables can also act as mediators between the main independent variable (signs of ADHD) and malocclusion. Descriptive statistics (absolute and relative frequencies) were performed. The chi-square test was used to investigate associations between the categorical variables and the occurrence of malocclusion. Independent variables with a $P < 0.25$ in the bivariate analysis and those with theoretical justification were incorporated into the multivariate model. The Poisson regression model followed a hierarchical approach from distal to proximal determinants[22] in the following order: socioeconomic and/or demographic factors, characteristics of the child, signs of ADHD, and oral habits. On each level, Poisson regression with robust variance was performed to determine associations between the independent variables and malocclusion (absent or present). Prevalence ratios (PR) and 95% CIs were calculated. The level of significance was set at 5% ($P < 0.05$).

RESULTS

A total of 633 (90.55%) schoolchildren participated through to the end of the study. The main reason for losses was incomplete questionnaires. The majority of the participants (57.1%) had malocclusion. The mean age of the overall sample was 9.42 ± 1.58 years, and the female sex accounted for 59.0% (n = 374). Significant differences between groups (with and without malocclusion) were found regarding age, pacifier use, finger and/or thumb sucking, mouth breathing, and reports of signs of hyperactivity by parents or guardians and teachers. No significant associations were found between malocclusion and child's sex, caregiver's schooling, household income, or inattention (reported in both contexts) (Table I).

In the unadjusted model, child's age (PR, 0.64; 95% CI, 0.55-0.76; $P < 0.001$), pacifier use (PR, 1.31; 95% CI, 1.07-1.60; $P = 0.009$), finger and/or thumb sucking (PR, 1.22; 95% CI, 1.02-1.44; $P = 0.023$) and mouth breathing (PR, 1.21; 95% CI, 1.03-1.43; $P = 0.017$) were associated with a greater frequency of malocclusion. Children considered to be hyperactive by parents or caregivers and teachers were also more likely to have malocclusion (PR, 1.39; 95% CI, 1.09-1.78; $P = 0.007$) (Table II).

The multivariate Poisson regression model demonstrated that the prevalence of malocclusion was lower among schoolchildren aged between 11 and 12 years (PR, 0.62; 95% CI, 0.52-0.73; $P < 0.001$). The prevalence of malocclusion was higher among children who used a pacifier for 4 years or more (PR, 1.25; 95% CI, 1.02-1.54; $P = 0.029$) and those classified as mouth breathers (PR, 1.28; 95% CI, 1.09-1.51; $P = 0.003$). Moreover, the prevalence of malocclusion was 42% higher among children with signs of hyperactivity reported by both parents and teachers (PR, 1.42; 95% CI, 1.11-1.81; $P = 0.004$). The child's sex, caregiver's schooling, and finger and/or thumb sucking were incorporated into the adjusted model but were not associated with malocclusion (Table II).

DISCUSSION

In the present study, the prevalence of malocclusion was higher among schoolchildren with signs of ADHD reported by parents and teachers independently of other factors. Previous studies have reported significant differences in craniofacial morphology[15] and palate width[12] in patients with ADHD compared with those without

Table I. Socioeconomic and neuropsychological variables according to occurrence of malocclusion

	Malocclusion		
Variables	*No*	*Yes*	P*
Child's sex			0.198
Male	103 (38.0)	156 (43.1)	
Female	168 (62.0)	206 (56.9)	
Age, y			<0.001
7-10	124 (45.8)	236 (65.2)	
11-12	137 (50.6)	102 (28.2)	
Caregiver's schooling, y			0.143
>8	177 (65.6)	255 (71.0)	
≤8	93 (34.4)	104 (29.0)	
Household income			0.377
≥2 × BMMW	103 (38.3)	150 (41.8)	
<2 × BMMW	166 (61.7)	209 (58.2)	
Pacifier use, mo			0.034
<48	261 (96.3)	334 (92.3)	
≥48	10 (3.7)	28 (7.7)	
Finger and/or thumb sucking, mo			0.044
<48	247 (91.1)	311 (85.9)	
≥48	24 (8.9)	51 (14.1)	
Mouth breathing			0.031
No	239 (88.8)	296 (82.7)	
Yes	30 (11.2)	62 (17.3)	
Inattention (reported in both contexts)			0.717
No	261 (97.0)	351 (97.5)	
Yes	8 (3.0)	9 (2.5)	
Hyperactivity (reported in both contexts)			0.051
No	266 (98.5)	345 (95.8)	
Yes	4 (1.5)	15 (4.2)	

Note. Values are n (%).
BMMW, Brazilian monthly minimum wage.
*Chi-square test.

Table II. Univariate and multivariate Poisson regression considering the occurrence of malocclusion as a dependent variable and sociodemographic characteristics and SNAP questionnaire as independent variables

Variables	*Univariate analysis*	P*	*Multivariate analysis*	P†
Child's sex				
Male	1.000	0.194	1.000	0.262
Female	0.194 (0.799-1.046)		0.927 (0.812-1.058)	
Child's age, y				
7-10	1.00	>0.001	1.00	>0.001
11-12	0.649 (0.551-0.764)		0.619 (0.524-0.730)	
Caregiver's schooling, y				
≥8	1.00	0.154	1.00	0.252
<8	0.894 (0.767-1.043)		0.909 (0.773-1.070)	
Household income				
≥2 × BMMW	1.00	0.374		
<2 × BMMW	0.940 (0.820-1.077)			
Pacifier use, mo				
<48	1.00	0.009	1.00	0.029
≥48	1.313 (1.072-1.608)		1.258 (1.023-1.545)	
Finger and/or thumb sucking, mo				
<48	1.00	0.023	1.00	0.154
≥48	1.220 (1.027-1.449)		1.139 (0.956-1.362)	
Mouth breathing				
No	1.00	0.017	1.00	0.003
Yes	1.218 (1.037-1.431)		1.287 (1.093-1.515)	
Inattention (reported in both contexts)				
Not inattentive	1.00	0.729		
Inattentive	0.923 (0.587-1.453)			
Hyperactivity (reported in both contexts)				
No	1.00	0.007	1.00	0.004
Yes	1.398 (1.097-1,782)		1.424 (1.117-1.816)	

Note. Values are PR (95% CI).
SNAP, Swanson, Nolan, and Pelham Scale; *BMMW*, Brazilian monthly minimum wage.
*P <0.25; †P <0.05.

ADHD. Another study found that the prevalence of parafunctional habits and orthodontic treatment needs reported by parents was higher among children with ADHD.[9] However, it is possible that the use of parents' perceptions regarding the need for orthodontic treatment has limitations. Although studies point to an association between ADHD and malocclusion, the explanations for this association were not demonstrated statistically. Moreover, inattention and hyperactivity were not assessed separately. Thus, it is important to investigate the pathways of this association to enable the establishment of strategies for preventing malocclusion in patients with ADHD.

In the present investigation, no collinearity was found among the socioeconomic variables, characteristics of the child (sex and age), pacifier use, mouth breathing, and signs of hyperactivity. However, collinearity was identified between finger and/or thumb sucking and hyperactivity (chi-square test, P <0.05). These results were confirmed in the adjusted analysis, in which signs of hyperactivity remained associated with malocclusion independently of socioeconomic status, child's characteristics, reports of prolonged nonnutritive sucking habits, and mouth breathing. Only finger and/or thumb sucking lost its association with malocclusion after the inclusion of signs of hyperactivity, suggesting a way to explain the main association found in the present study. Patients with signs of hyperactivity had a higher frequency of finger and/or thumb-sucking habits after the age of 48 months. As finger and/or thumb sucking is associated with the occurrence of malocclusion, it is possible that this habit contributes to the greater prevalence of malocclusion in children with signs of hyperactivity.

Some studies have shown that children with ADHD tend to have insufficient breastfeeding and, consequently, higher frequencies of parafunctional habits[9] and malocclusion.[12] Thus, 1 limitation of the present investigation was the failure to evaluate the type and duration of breastfeeding.

As malocclusion has a multifactor etiology, it is important to evaluate the influence of social determinants.[23] Less privileged children are more predisposed to environmental and behavioral factors associated

with malocclusion.[23-25] A representative study conducted in Brazil with children aged 7-10 years showed that the prevalence of malocclusion was higher among those with a low socioeconomic status.[23] Another social determinant associated with malocclusion is mother's or caregiver's schooling.[16,26] These factors may influence the duration of breastfeeding and adoption and/or maintenance of nonnutritive sucking habits. However, the present investigation found no association between socioeconomic factors and malocclusion in either the unadjusted or adjusted analysis.

The prevalence of malocclusion was lower among children in the highest age group (11-12 years). Occlusal changes and the growth and development of the jaws enable the self-correction of some types of malocclusion.[27-30] A longitudinal study showed that the prevalence of malocclusion was significantly reduced (70%-58%) from the deciduous dentition to the mixed dentition phase.[30] Similarly, the prevalence of anterior open bite decreased from 51% in the deciduous dentition to 4% in the mixed or permanent dentition because of self-correction.[27,29,30]

Previous epidemiologic studies have shown that nonnutritive sucking habits are important environmental risk factors for a malocclusion.[20,31-34] In the present investigation, the prevalence of malocclusion was 25% higher among children who used pacifiers in comparison with children who did not. However, finger and/or thumb sucking lost its association with malocclusion when signs of hyperactivity were included in the adjusted analysis.

A systematic review with a meta-analysis of 16 studies showed that children with ADHD had significantly more nocturnal awakenings, sleep-disordered breathing, and daytime sleepiness than the control group.[35,36] However, in the present study, signs of hyperactivity and breathing pattern did not work together, as both conditions remained associated with malocclusion in the adjusted analysis. It is possible that respiratory sleep disorders affect patients independently of mouth breathing.

Another limitation of the present study was the possibility of recall bias with regard to parents' or caregivers' reports of nonnutritive sucking habits, which is an inherent characteristic of the retrospective observational design. Longitudinal studies are needed to provide more consistent information and evaluate the long-term effects of the etiologic factors of malocclusion. Moreover, investigating the influence of breastfeeding on children with ADHD is important to understanding the role of these conditions in craniofacial development and changes in breathing, swallowing, chewing, and speaking.[37]

In developing countries, such as Brazil, access to dental services is restricted, and most children have never visited a dentist.[38] Therefore, the early identification of factors associated with the development of malocclusion in children is fundamental because it enables the implementation of prevention and health promotion policies before the establishment of craniofacial changes and malocclusion through interceptive and preventive orthodontics as well as educational actions addressing the occurrence of nonnutritive sucking habits and mouth breathing in children with ADHD. Particular attention should be paid to the dental care of children with ADHD. As the prevalence of this condition is constantly on the rise,[39] it is fundamental for dentists to identify the clinical implications of ADHD regarding oral health to outline specific prevention strategies for this group of patients.

CONCLUSIONS

The prevalence of malocclusion was higher among children with signs of hyperactivity independently of age, pacifier use, and mouth breathing.

AUTHOR CREDIT STATEMENT

I.M.V., R.V.S., and J.R.J. participated in the execution of the study and interpretation of the data. I.M.V., R.V.S., J.R.J., F.O.F., M.L.R.J., L.R.P.F., and S.M.P. participated in the concept of the study design and data analysis. All authors participated in the drafting of the manuscript.

ACKNOWLEDGMENTS

This study received funding from the Brazilian fostering agency *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES, Brazil [Coordination for the Advancement of Higher Education Personnel]). We are grateful for the help of M.A.H., L.D.R and L.E.P.C., who contributed to the data colletion. The authors declare that they have no commercial associations that might represent a conflict of interest in connection with the submitted manuscript.

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