

# Dental caries in schoolchildren: influence of inattention, hyperactivity and executive functions

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**Abstract:** Attention-deficit/hyperactivity disorder (ADHD) is characterized by inappropriate levels of hyperactivity, impulsivity, and/or inattention. Individuals with ADHD may present limitations with regard to executive functions and performing activities that involve planning and/or attention/concentration. The aim of the study was to investigate the association between dental caries and signs of ADHD in a representative sample of schoolchildren. A representative sample of 851 schoolchildren aged seven to 12 years was randomly selected from public and private schools. Data acquisition involved a clinical dental examination for cavitated permanent and deciduous teeth using the DMFT/dmft indices. Neuropsychological evaluations, including the assessment of intelligence (Raven's Colored Progressive Matrix Test) and executive functions (Corsi Tapping Blocks tests and Digit Span test) were also performed. Parents/caregivers and teachers answered the SNAP-IV Questionnaire for the investigation of signs of inattention and hyperactivity in the family and school environment. Parents/caregivers also answered questionnaires addressing socioeconomic and socio-demographic characteristics. Descriptive analysis of the variables and Poisson regression with robust variance were performed. Parental reports of signs of inattention (PR: 1.28;  $p < 0.05$ ) and hyperactivity (PR: 1.15;  $p < 0.05$ ) were associated with a greater occurrence of caries. A better performance on the backward order of the Corsi Tapping Blocks tests (PR: 0.94;  $p < 0.05$ ) and higher level of mother's schooling were associated with a lower frequency of caries. A better performance on executive function tasks was a protective factor against dental caries, whereas children considered inattentive and/or hyperactive by their parents had a higher prevalence rate of dental caries.

**Keywords:** Attention Deficit Disorder with Hyperactivity; Dental Caries; Executive Function.

## Introduction

Attention-deficit hyperactivity disorder (ADHD) is a common neuropsychiatric disorder characterized by a persistent, developmentally inappropriate pattern of inattention, hyperactivity, and/or impulsivity.<sup>1</sup> Studies report prevalence rates of ADHD ranging from 2.0% to 18.0%.<sup>2,3,4</sup> This relatively wide range is due to the different diagnostic criteria adopted

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in different studies as well as the characteristics of the analyzed population.<sup>5</sup>

Individuals affected by ADHD may experience problems with activities of daily living, family stress, poor academic performance, and low self-esteem.<sup>6,7</sup> Such individuals also tend to have some degree of impairment with regard to executive functions, which limits the performance of activities that involve organization, planning, concentration, monitoring one's own behavior, and cognitive flexibility.<sup>4,8</sup>

As the number of children diagnosed with ADHD increases every year<sup>9</sup>, dentists often encounter patients with this disorder. There is evidence that children with ADHD have greater difficulty in maintaining adequate oral hygiene and may present more oral problems.<sup>10,11</sup> However, the scientific literature remains inconclusive regarding the dental implications of ADHD and associated factors.<sup>12</sup> Although some studies report an association between ADHD and a higher occurrence of dental caries<sup>5,10,11,13</sup>, others have not found such an association.<sup>14,15</sup> Moreover, a large portion of investigations have been conducted with non-representative samples and the specific influence of signs of inattention/hyperactivity and executive functions on the occurrence of dental caries has not been investigated in a representative sample of schoolchildren.<sup>4,10,11,13</sup> Thus, the aim of the present study was to evaluate the association between the occurrence of dental caries and ADHD (signs reported by parents/caregivers and teachers and an assessment of cognitive functioning) in a representative sample of schoolchildren.

## Methodology

### Sample

A representative, cross-sectional study was conducted with children aged seven to twelve years attending public and private schools in the city of Diamantina, Brazil. The participants were randomly selected based on the population distribution of children in schools: municipal public schools (70%), state public schools (20%), and private schools (10%). The exclusion criteria were the use of an orthodontic appliance, intellectual disability (children scoring at or below the 5<sup>th</sup> percentile of Raven's Colored

Progressive Matrices test) or neurological disease (based on parental report).

To calculate the sample size, an unknown prevalence rate of 50% was considered, since no data were found on the prevalence of caries in this age group in the city of Diamantina and this rate gives the largest sample size. Using a 95% confidence interval, 4% acceptable estimate error and a design effect of 1.2, as two-stage sampling was performed (schools, followed by classes), the minimum sample size was determined to be 720 participants. To compensate for possible dropouts, the sample was increased by 194 individuals, totaling 914 children.

### Data collection

Before the clinical examination, the child was instructed to perform tooth brushing. During the examination, the child remained seated in a chair in front of the examiner in a private room at the school. A head lamp (PETZL, Tikka XP, Crolles, France), disposable mouth mirror (PRISMA, São Paulo, SP, Brazil), periodontal probe (Trinity, Campo Mourão, PA, Brazil) and gauze were used and all procedures complied with bio-safety norms. The criteria of the World Health Organization<sup>16</sup> were used for the evaluation of cavitated permanent and deciduous teeth considering only the decayed component of the decayed, missing and filled teeth (DMFT/dmft) indices. The absence of untreated cavitated teeth was recorded when  $D + d = 0$  and the presence of untreated cavitated teeth was recorded when  $D + d \geq 1$ .

### Training and calibration of examiners

A team consisting of five dentists and five assistants was responsible for conducting the dental examinations. The examiners had undergone both theoretical and practical exercises for the diagnosis of dental caries. Weighted Kappa coefficients were calculated for the determination of inter-examiner and intra-examiner agreement. All Kappa values were higher than 0.7. Another team composed of four examiners was also responsible for conducting the neuropsychological tests. The analysis and interpretation of neuropsychological tests were performed by a psychologist (FOF).

## Neuropsychological evaluation

The neuropsychological evaluation involved the assessment of intellectual function (Raven's Colored Progressive Matrices test) and executive functions (Corsi Block Tapping test and the Digit Span test).

### Intellectual function

Raven's Colored Progressive Matrices test is the gold standard for intellectual assessments. It consists of a set of reasoning tasks for the evaluation of fluid intelligence and is therefore less affected by contextual variables. The test consists of three sets of 12 items (total: 36 items). Each item is a drawing of a pattern with one piece missing and six options offered to complete the pattern. One point is awarded for each correct response. The test has been normalized for children from five to 12 years of age and validated for use on the Brazilian population.<sup>17</sup> The result is scored as a percentile compared to norms. Percentiles equal to or less than five indicate that the child's abstract reasoning is lower than 95% of the population of children of the same age and therefore suggests intellectual disability. In the present study, children scoring at or below the 5th percentile were excluded to avoid a confounding factor.

### Executive functions

The Digit Span test is used to evaluate short-term memory and working memory storage capacity. In the forward order portion of the test, the participant is asked to repeat a set of random numbers given orally by the examiner; a new digit is added to the sequence with each correct repetition. In the backward order, the participant must repeat the set of numbers in the reverse (backward) sequence dictated by the examiner for the evaluation of the executive component of short-term memory. The total score is computed by the maximum number of digits the participant can repeat correctly in each step.<sup>18</sup>

The Corsi Block Tapping test is used to evaluate the reach of short-term memory by employing visuospatial memory. The participant is instructed to repeat a sequence of movements performed by the examiner by touching blocks on a board. As in the Digit Span test, the participant repeats the sequence in the forward order during the first step of the test and the

backward order in the second step. The total score is determined by the maximum number of sequences (span) the participant can reproduce.<sup>19</sup>

### Assessment of signs of inattention and hyperactivity

The Swanson, Nolan, and Pelham Scale (SNAP - IV) is used for the evaluation of child behavior through subscales that address inattention, hyperactivity/impulsivity, and defiant/oppositional behavior. In the present study, only the subscales for the evaluation of inattention and hyperactivity/impulsivity (nine items each subscale) were used. SNAP IV was answered by parents/caregivers and teachers to compare the behavioral patterns reported in the family and school environment, which is part of the diagnostic criteria for ADHD. Each item is scored from 0 to 3 (not at all = 0; "just a little" = 1, "quite a bit" = 2, and "very much" = 3). SNAP-IV scores are calculated by summing the item scores in the specific subset (e.g., inattention, hyperactivity) and dividing by the number of items in the subset (Table 1). The score of any subset is reported as the average rating per item. Five percent cutoff scores are provided for teachers and parents. If the results are higher than the cutoffs, significant inattention and/or hyperactivity is considered. There are different cutoffs for teachers and parents. For inattention, the cutoff is 2.56 for teachers and 1.78 for parents. For hyperactivity, the cutoff is 1.78 for teachers and 1.44 for parents. In the present study, data analysis was conducted separately for the scores attributed by the teachers and parents to assess child behavior in both environment (family and school).<sup>20</sup>

### Socioeconomic/socio-demographic characteristics

Parents/caregivers filled out a socio-demographic questionnaire addressing the sex and age of the child, parents' marital status, parental education level, and household income (total monthly earning of all members of the household measured in Brazilian currency (R\$) and categorized based on the Brazilian monthly minimum wage - approximately US\$ 300), and number of individuals living on the same income.

**Table 1.** Description of SNAP IV scale items.

For each item, select the box that best describes this child. Put only one check per item.	
<b>Inattention</b>	
1	Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities
2	Often has difficulty sustaining attention in tasks or play activities
3	Often does not seem to listen when spoken to directly
4	Often does not follow through on instructions and fails to finish schoolwork, chores, or duties
5	Often has difficulty organizing tasks and activities
6	Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (e.g., schoolwork or homework)
7	Often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)
8	Often is distracted by extraneous stimuli
9	Often is forgetful in daily activities
<b>Hyperactivity</b>	
10	Often fidgets with hands or feet or squirms in seat
11	Often leaves seat in classroom or in other situations in which remaining seated is expected
12	Often runs about or climbs excessively in situations in which it is inappropriate
13	Often has difficulty playing or engaging in leisure activities quietly
14	Often is "on the go" or often acts as if "driven by a motor"
15	Often talks excessively
16	Often blurts out answers before questions have been completed
17	Often has difficulty awaiting turn
18	Often interrupts or intrudes on others (e.g., butts into conversations/games)

## Data analysis

Data analysis was conducted using the Statistical Package for Social Sciences (SPSS for Windows, version 20.0; SPSS Inc., Chicago, USA). Descriptive statistics (absolute and relative frequencies) were first performed. The Kolmogorov-Smirnov test was used to determine the normality of the data. The chi-square test was used to investigate associations between categorical variables and the occurrence of dental caries. The Mann-Whitney U-test was employed to investigate associations between quantitative variables (neuropsychological data) and the occurrence of caries. Poisson regression models with robust variance were created to determine which variables significantly explained the occurrence of caries. Independent variables that achieved a p-value < 0.20 in the bivariate analysis and those with a theoretical justification were incorporated into the univariate analysis. The Poisson regression model followed a hierarchical approach from distal to proximal determinants<sup>21</sup>: a) characteristics of the child; b) socio-demographic factors; and c) psychological factors. For each level, Poisson regression with robust variance was performed to determine associations between the independent variables and dental caries (presence/absence). Explanatory variables with a p-value < 0.05 after

adjustment for other variables on the same level and previous level were selected for the multivariate model. Prevalence ratios (PR) and 95% confidence intervals (CI) were calculated. The level of significance was set at 5%.

## Ethical aspects

This study was conducted in compliance with international statutes and national legislation on ethics in research involving human subjects and received approval from the Human Research Ethics Committee of *Universidade Federal dos Vales do Jequitinhonha e Mucuri* (Brazil) under process number 045/2011. All parents/guardians signed a statement of informed consent. This investigation was conducted in full accordance with ethical principles, including those stipulated in the Declaration of Helsinki by the World Medical Association.

## Results

Among the 914 participants selected, 63 were excluded due to intellectual deficit (25 children), refusal to allow dental examination (7 children), and undergoing orthodontic treatment (31 children). Thus, the final sample consisted of 851 children (Figure 1). The mean age of the children was 9.39 years (SD = 1.68) and 54.8%

were female. More than half had a household income of up to two times the Brazilian monthly minimum wage and 74.60% of the families had four or more individuals who depended on this income.

Regarding the signs of ADHD, inattention was reported more by teachers (9.50%) than parents/caregivers (5.90%) and hyperactivity was reported more by parents/caregivers (15.30%) than teachers (9.90%). Considering the presence of symptoms in the two contexts, the prevalence of inattention and hyperactivity was estimated at 2.40% and 3.80%, respectively. Table 2 displays the distribution of the socioeconomic and neuropsychological variables.

The prevalence of untreated cavitated deciduous and permanent teeth was 53.2%. An association was found between the presence of caries and reports of inattention by parents/caregivers, reports of hyperactivity by parents/caregivers, household income, and mother's schooling

(Table 3). In the comparison between groups (without cavitated teeth and with cavitated teeth), significant differences were found for the Corsi Block Tapping test (backward order) and Raven's Colored Progressive Matrices (Table 4), as children without cavitated teeth had significantly higher performances on these tasks.

In the univariate Poisson regression analysis, household income and mother's schooling (socioeconomic variables) were associated with the occurrence of caries. Among the neuropsychological variables, the occurrence of dental caries was significantly associated with parental report of inattention, agreement between parents/caregivers and teachers regarding inattention, parental report of hyperactivity, and performance on the forward Digit Span test, Corsi Block Tapping test, and Raven's Colored Progressive Matrices test (Table 5).

After the univariate analysis, the occurrence of multicollinearity was analyzed before incorporating the

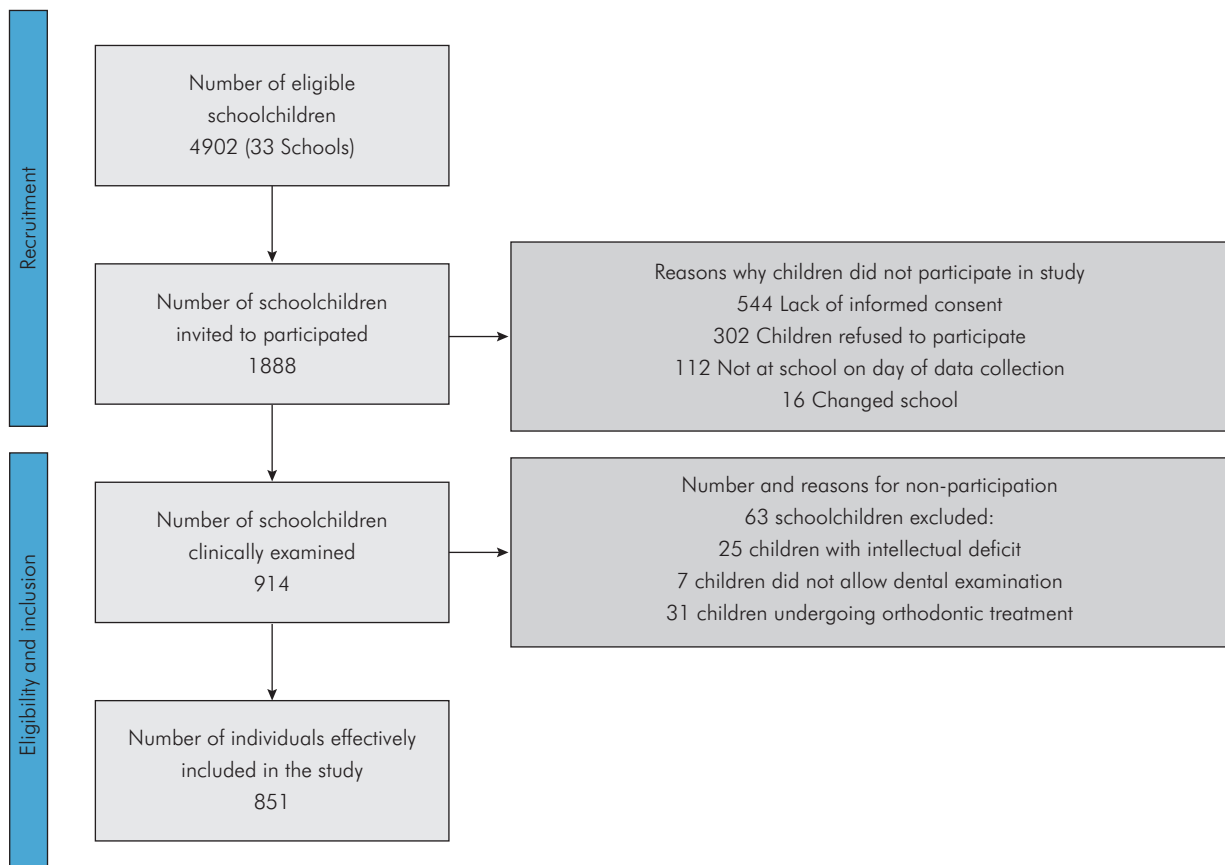


Figure 1. Flowchart of participant selection process.

**Table 2.** Frequency of socioeconomic and neuropsychological variables.

Variables	n	%
Child's sex		
Male	385	45.20
Female	466	54.80
Marital status of mother or guardian		
Not married	183	21.70
Married	458	54.30
Divorced	81	9.50
Other	122	14.50
Household income		
Less than BMMW	108	12.80
One to less than two times BMMW	387	45.80
Two to less than five times BMMW	252	29.80
Five BMMW or more	98	11.50
Number of individuals living on income		
Two or three	213	25.40
Four or five	478	57.00
Six or seven	110	13.10
Eight or nine	25	3.00
Ten or more	13	1.50
Mother's schooling		
Incomplete primary school	209	24.70
Complete primary education	88	10.40
Incomplete high school	51	6.00
Complete high school	288	34.00
Higher education	210	24.80
SNAP-IV		
Inattention		
Reported by parents	50	5.90
Reported by teachers	81	9.50
Reported in both contexts (agreement)	20	2.40
Hyperactivity		
Reported by parents	130	15.30
Reported by teachers	84	9.90
Reported in both contexts (agreement)	32	3.80

\* BMMW: Brazilian monthly minimum wage

variables into the multivariate model. The chi-square test demonstrated that household income and mother's schooling were significantly associated ( $p < 0.001$ ). Thus, to avoid the occurrence of multicollinearity, only mother's schooling was chosen for the model as this variable is considered a precise socioeconomic indicator and was more significantly associated with the outcome. Moreover, mother's schooling has often been used as one of the best predictors of children's health, especially in developing countries.<sup>22</sup>

In the analysis of the multicollinearity among the psychological variables, the SNAP-IV items parental

**Table 3.** Association between variables and occurrence of cavitated teeth

Variables	Without cavitated teeth		With cavitated teeth		p*
	n	%	n	%	
Inattention					
Reported by parents	14	3.50	36	8.00	0.006
Reported by teachers	35	8.80	46	10.20	0.481
Reported in both contexts	5	1.30	15	3.30	0.470
Hyperactivity					
Reported by parents	45	11.40	130	15.30	0.003
Reported by teachers	35	8.80	49	10.90	0.32
Reported in both contexts	12	3.00	20	4.40	0.285
Household income					
> 0.001					
Less than BMMW	41	10.40	67	14.90	
One to less than two times BMMW	146	37.00	241	53.60	
Two to less than five times BMMW	137	34.70	115	25.60	
Five BMMW or more	71	18.00	27	6.00	
Mother's schooling					
> 0.001					
Incomplete primary school	66	16.70	143	31.70	
Complete primary school	31	7.80	57	12.60	
Incomplete high school	18	4.60	33	7.30	
Complete high school	132	33.40	156	34.60	
Higher education	148	37.50	62	13.70	

BMMW: Brazilian monthly minimum wage; \* chi-square test

report of inattention, agreement between parents/caregivers and teachers regarding inattention, and parental report of hyperactivity were significantly associated with each other ( $p < 0.0001$ ). It was also found that the Digit Span test (forward order) was significantly associated with SNAP-IV ( $p < 0.001$ ). Thus, only parental report of inattention was selected, since it was more strongly associated with the occurrence of caries.

The multivariate Poisson regression model revealed that three variables remained significant for explaining the occurrence of caries: mother's schooling, parental report of inattention, and span (maximum sequence)

**Table 4.** Association between neuropsychological variables and occurrence of cavitated teeth.

Variable	Without cavitated teeth		With cavitated teeth		p*
	Mean (SD)	Median (q1-q3)	Mean (SD)	Median (q1-q3)	
Digit Span test (forward order)	4.95 (1.07)	5 (4-5)	4.79 (1.00)	5 (4-5)	0.066
Digit Span test (backward order)	3.05 (0.84)	3 (3-3)	3.11(2.13)	3 (3-3)	0.779
Corsi Block Tapping test (forward order)	4.72 (1.00)	5 (4-5)	4.64 (0.98)	5 (4-5)	0.314
Corsi Block Tapping test (backward order)	4.42 (1.07)	5 (4-5)	4.17 (1.22)	4 (4-5)	0.008
Raven (percentile)	56.72 (24.04)	60 (40-75)	53.01 (25.07)	50 (30-70)	0.028

\*Mann-Whitney test.

**Table 5.** Univariate and multivariate Poisson regression considering occurrence of cavitated teeth as dependent variable and socio-demographic characteristics, SNAP questionnaire, and executive functions as independent variables.

Poisson	Univariate analysis				Multivariate			
	95% CI			p	95% CI			p
	PR	Lower	Upper		PR	Lower	Upper	
Sex								
Female	1	-	-	-	-	-	-	-
Male	1.044	0.920	1.185	0.507	-	-	-	-
Age (years)	0.965	0.929	1.001	0.059	-	-	-	-
Household income								
Five BMMW or more	1	-	-	-	-	-	-	-
2 to less than 5 times BMMW	1.649	1.163	2.336	0.005	-	-	-	-
1 to less than 2 times BMMW	2.266	1.628	3.153	≤ 0.0001	-	-	-	-
Less than BMMW	2.264	1.587	3.229	≤ 0.0001	-	-	-	-
Number of individuals living on income	1.074	0.996	1.158	0.064	-	-	-	-
Mother's schooling								
Higher education	1	-	-	-	1	-	-	-
Complete high school	1.830	1.447	2.315	≤ 0.0001	1.798	1.422	2.273	≤ 0.0001
Incomplete high school	2.212	1.652	2.962	≤ 0.0001	2.111	1.578	2.823	≤ 0.0001
Complete primary school	2.245	1.735	2.905	≤ 0.0001	2.139	1.648	2.777	≤ 0.0001
Incomplete primary school	2.309	1.836	2.905	≤ 0.0001	2.234	1.773	2.814	≤ 0.0001
Father's schooling								
Higher education	1	-	-	-	-	-	-	-
Complete high school	1.136	0.857	1.506	0.375	-	-	-	-
Incomplete high school	1.423	0.997	2.032	0.052	-	-	-	-
Complete primary school	1.604	1.213	2.123	0.001	-	-	-	-
Incomplete primary school	1.608	1.250	2.069	≤ 0.0001	-	-	-	-
Not inattentive - Parental report	1	-	-	-	1	-	-	-
Inattentive - Parental report	1.384	1.150	1.666	0.001	1.285	1.070	1.543	0.007
Not inattentive - Teachers' reports	1	-	-	-	-	-	-	-
Inattentive - Teachers' reports	1.075	0.879	1.315	0.481	-	-	-	-
Not inattentive - Parent/teacher agreement	1	-	-	-	-	-	-	-
Inattentive - Parent/teacher agreement	1.424	1.097	1.849	0.008	-	-	-	-
Not hyperactive - Parental report	1	-	-	-	-	-	-	-
Hyperactive - Parental report	1.282	1.110	1.482	0.001	-	-	-	-
Not hyperactive - Teachers' reports	1	-	-	-	-	-	-	-
Hyperactive - Teachers' reports	1.108	0.914	1.344	0.297	-	-	-	-
Not hyperactive - Parent/teacher agreement	1	-	-	-	-	-	-	-
Hyperactive - Parent/teacher agreement	1.183	0.897	1.559	0.233	-	-	-	-
Digit Span test (forward order)	0.923	0.866	0.984	0.014	-	-	-	-
Digit Span test (Backward order)	1.007	0.985	1.030	0.548	-	-	-	-
Corsi Block Tapping test (Forward order)	0.945	0.886	1.008	0.084	-	-	-	-
Corsi (Backward order)	0.907	0.862	0.955	≤ 0.0001	0.940	0.896	0.987	0.013
Raven (Percentile)	0.997	0.995	1.000	0.047	1.000	0.998	1.003	0.844

**Table 6.** Multivariate Poisson regression considering occurrence of cavitated teeth as dependent variable and socio-demographic characteristics, parental reports of hyperactivity, and executive functions as independent variables.

Poisson	Multivariate (95% CI)			p
	PR	Lower	Upper	
Mother's schooling				
Higher education	1	--	--	--
Complete high school	1.792	1.416	2.268	≤ 0.0001
Incomplete high school	2.120	1.584	2.835	≤ 0.0001
Complete primary school	2.152	1.660	2.790	≤ 0.0001
Incomplete primary school	2.212	1.754	2.790	≤ 0.0001
Not hyperactive - Parental report	1	--	--	--
Hyperactive - Parental report	1.152	1.002	1.325	0.047
Corsi Block Tapping test (backward order)	0.941	0.897	0.987	0.013
Raven (Percentile)	1.000	0.997	1.002	0.922

on the Corsi Block Tapping test (backward order) (Table 5). The results of the multivariate analysis indicate that the prevalence rate of dental caries was twice as high in children whose mothers had lower levels of schooling. However, the prevalence ratio was reduced by 6% for every one-point increase on the Corsi Block Tapping test (backward order). Regarding inattention, children reported as inattentive by parents/caregivers had a 28% higher prevalence of cavitated teeth compared to children not reported as inattentive by parents/caregivers.

To test the influence of parental report of hyperactivity, this variable was incorporated into a multivariate model replacing the report of inattention (Table 6). Schooling remained significant, indicating that children whose mothers had a lower level of education were about twice as likely to have cavitated teeth ( $p < 0.05$ ). A better performance on the Corsi Block Tapping test (backward order) was a protective factor against the occurrence of cavitated teeth, as children with better performance had a 5.9% reduction in the prevalence of cavitated teeth. The performance on the Raven's Colored Progressive Matrices test was not a significant explanatory variable for the occurrence of caries. A parental report of hyperactivity was significantly associated with the occurrence of cavitated teeth, as children considered hyperactive by their parents/caregivers had a 15% higher prevalence rate of cavitated teeth.

## Discussion

The present study evaluated the influence of signs of hyperactivity/inattention and executive functions on

the occurrence of dental caries in children aged seven to 12 years in the city of Diamantina, Minas Gerais, Brazil. The prevalence of caries was 53.2%, which is similar to the rate reported in the most recent national oral health survey<sup>23</sup>, which found a 56.5% prevalence rate of dental caries among 12-year-old children.

Regarding signs of ADHD, inattention was reported more by teachers (9.50%) than parents/caregivers (5.90%), whereas hyperactivity was reported more by parents/caregivers (15.30%) than teachers (9.90%). Considering the criterion of symptoms in both settings (family and school), the prevalence of inattention and hyperactivity was 2.40% and 3.80%, respectively. These results contrast with the findings of another study also involving schoolchildren<sup>24</sup>, in which the prevalence of inattention and hyperactivity reported by teachers was higher than that reported by parents/caregivers.

When considering the fact that teachers reported a higher occurrence of attention deficit than did parents, it should be noted that the levels of parental education and household income were low. Previous studies report that parents with a low level of schooling tend to underestimate attention deficit in their children.<sup>24,25</sup> Moreover, it is possible that a low socioeconomic status and lack of access to information on ADHD may have reduced the score in the parental reports of signs.<sup>24</sup> It is also possible that attention deficit is more evident to teachers because they are especially focused on academic performance. Thus, the classification of inattention may have been influenced by the child's performance at school.



A study investigating the influence of cognitive impairment on the prevalence of dental caries in individuals with cerebral palsy showed that individuals with a poorer performance on Raven's Colored Progressive Matrices were more likely to have caries.<sup>26</sup> In the present study, the performance on Raven's test was a significant predictor for the occurrence of caries when considered alone in the univariate regression analysis, but lost its statistical significance when considered in conjunction with other variables (mother's schooling, reports of inattention, reports of hyperactivity, and executive functions) in the multivariate model. This indicates that, when controlling for mother's schooling, executive functions have greater explanatory power with regard to caries than intellectual performance.

The socioeconomic status of the study population was low, as 58.60% of families declared earning an income of up to two times the Brazilian monthly minimum wage. Significant associations were found between the occurrence of dental caries and both mother's schooling and household income using the chi-square test. However, only mother's schooling was incorporated into the multivariate Poisson regression to avoid the possible occurrence of multicollinearity. In the univariate Poisson regression analysis, an association was found between household income and the occurrence of dental caries, with a lower prevalence rate of caries among higher income families. Despite trends of a significant reduction in epidemiological indicators, dental caries remains highly prevalent among children from families with a low socioeconomic status.<sup>27,28</sup>

The prevalence of dental caries was lower among children whose mothers had a higher level of schooling. Scientific evidence has indicated that low parental education, especially among mothers, is a predisposing factor for dental caries in children.<sup>29,30,31</sup> Moreover, a study on the determinants of dental caries reports that children whose mothers are less educated visit the dentist less frequently.<sup>32</sup> A higher educational level often translates to better working conditions, a higher household income<sup>33</sup>, and better access to goods and services as well as the adoption of healthier habits.<sup>28</sup> Moreover, studies indicate that individuals with a low level of schooling often have

little knowledge with regard to health status and tend not to recognize the need for treatment.<sup>34,35,36,37,38</sup>

Children reported as inattentive by their parents/caregivers had an increased prevalence of dental caries. This association was likely due to the negative influence that attention deficit exerts on activities of daily living carried out by the child in the home environment, with the possible adoption of inadequate oral hygiene habits. Similarly, children reported as hyperactive by parents/caregivers were more likely to have dental caries. One explanation for these findings is that children with ADHD have difficulty staying focused, which may result in a decrease in the effectiveness of brushing.<sup>13</sup>

A better performance on the Corsi Block Tapping test (backward order) was associated with a lower occurrence of dental caries. The backward order of this test is used to evaluate executive functions that involve planning, attention, working memory, and behavioral control based on motor coordination and visual-spatial memory. A previous study found that children with ADHD had poorer motor skills<sup>39</sup>, which could be one of the explanatory factors for a worse performance on the Corsi Block Tapping test (backward order). Thus, it is possible that children with ADHD have poor oral health due to problems with regard to motor coordination, which is fundamental to effective tooth brushing.

A recent study with a representative sample found no association between ADHD and oral health.<sup>40</sup> The absence of an association may be due to the failure to investigate the different signs of ADHD. In the present study, the signs were analyzed separately and both inattention and hyperactivity were associated with the occurrence of caries. It should be noted that the prevalence ratio was higher for inattention, indicating that this sign is more strongly associated with the occurrence of caries in comparison to hyperactivity.

As caries is a multifactor disease, some important factors should also be taken into consideration, such as dietary habits and sugar intake.<sup>41</sup> There is evidence that ADHD children consume carbohydrates and sweets more than children without this disorder.<sup>13</sup> Some studies have also found a significant association between ADHD and obesity/overweight.<sup>42,43</sup> As

ADHD is a disorder characterized by inattention and impulsivity, changes in dietary habits may be related to these behavioral characteristics. Moreover, some parents faced with these characteristics may be more permissive, making dietary concessions that could facilitate the unregulated consumption of cariogenic foods.<sup>10</sup>

This study provides new evidence on what aspects related to ADHD are associated with dental caries. The fact that inattention and hyperactivity were associated with the outcome may assist in the planning of oral health programs for children with ADHD as well as the prioritization of resources for the implementation of prevention and health promotion policies for these children. However, the cross-sectional study design does not enable the establishment of causality and the associations should therefore be interpreted with caution. Longitudinal studies and case-control studies controlling for confounding factors such as dietary practices and oral hygiene habits are needed to allow a better understanding of factors associated with the higher occurrence of caries in individuals with signs of ADHD.

## Conclusion

In conclusion, parental reports of attention deficit/hyperactivity and executive functions evaluated using the Corsi Block Tapping test (backward order) were explanatory factors for the occurrence of dental caries after controlling for the influence of intelligence and mother's schooling. A better performance with regard to executive functions was associated with a lower prevalence rate of dental caries, whereas children considered inattentive and/or hyperactive by their parents/caregivers had a higher prevalence rate of dental caries.

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