

# CHILDREN WITH ADHD SHOWN DIFFERENT ALPHA, BETA AND SMR EEG BANDS DURING HABIL MOTOR TASKS WITH HIGH ATTENTION DEMAND



ORIGINAL ARTICLE  
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CRIANÇAS COM TDAH EXIBEM DIFERENTE PERFIL NO EEG DURANTE TAREFAS MOTORAS QUE DEMANDAM ATENÇÃO

NIÑOS CON TDAH EXIBEN DIFERENTE PERFIL DE EEG DURANTE TAREAS MOTORAS QUE DEMANDAN ATENCIÓN

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## ABSTRACT

**Introduction:** ADHD probably affects more than 50% of schoolchildren, yet although characteristics such as inattention and/or hyperactivity and impulsiveness are clear, electrophysiological brain behavior during motor activity is not fully understood. **Objective:** To investigate alpha, beta, and SMR band patterns on the EEG in children with Attention Deficit Hyperactivity Disorder (ADHD) during attention-demanding motor skills tasks. **Methods:** Fourteen children with a mean age of  $9.64 \pm 1.74$  years divided into diagnosed and undiagnosed with ADHD underwent an EEG at rest and during task performance with attentional demand. Alpha, SMR and beta waves were observed on the EEG. Data were evaluated using the Shapiro-Wilk test in order to determine data normality. ONE WAY ANOVA and Tukey's post hoc tests were used to determine intragroup and intergroup differences, and the Pearson (r) and Spearman (p) correlations were used to determine correlations. All treatments had a significance of 5%. **Results:** The ADHD and N-ADHD groups showed no difference in cortical alpha, beta and SMR bands at rest, but there were differences in cortical behavior during activity. The cortical activity correlation coefficient (0.30) differed from undiagnosed children (0.70). **Conclusions:** The ADHD group had a low correlation coefficient between rest and activity, contrary to the N-ADHD group. In the intergroup comparison, ADHD had higher alpha, beta and SMR band output power during the same high attentional task when compared with N-ADHD. **Level of Evidence III.**

**Keywords:** Electroencephalography; Attention Deficit-Hyperactivity Disorder; Attention.

## RESUMO

**Introdução:** O TDAH afeta, provavelmente, mais de 50% crianças em idade escolar, porém, embora características como falta de atenção e/ou hiperatividade e impulsividade sejam claras, o comportamento eletrofisiológico do cérebro durante atividades motoras não é bem entendido. **Objetivo:** Investigar o padrão das bandas Alfa, Beta e SMR no EEG de crianças com transtorno do déficit de atenção com hiperatividade (TDAH), durante tarefas motrizes com alta demanda de atenção. **Métodos:** Catorze crianças com média de idade de  $9,64 \pm 1,74$  anos, divididas nos grupos diagnosticadas e não diagnosticadas com TDAH, realizaram EEG em repouso e durante o desempenho de tarefa com demanda de atenção. As ondas Alfa, SMR e Beta foram observadas no EEG. Os dados foram avaliados pelo teste de Shapiro-Wilk para determinar a normalidade dos dados. Os teste ANOVA one-way e post hoc de Tukey foram usados para determinar as diferenças intragrupo e intergrupo, e a correlação de Pearson (r) e Spearman (p) foram usadas para determinar as correlações. Todos os tratamentos tiveram significância de 5%. **Resultados:** Os grupos TDAH e N-TDAH não apresentaram diferença na banda cortical Alfa, Beta e SMR em repouso, porém, durante a atividade, constataram-se diferenças do comportamento cortical. O índice de correlação da atividade cortical (0,30) foi diferente nas crianças não diagnosticadas (0,70). **Conclusões:** O grupo TDAH apresentou baixo índice de correlação entre repouso e atividade, diferentemente do grupo N-TDAH. Na comparação intergrupos, o TDAH apresentou maior potência de saída da banda Alfa, Beta e SMR durante a mesma tarefa de alta atenção em comparação com o N-TDAH. **Nível de Evidência III.**

**Descritores:** Eletroencefalografia; Transtorno do déficit de atenção com hiperatividade; Atenção.

## RESUMEN

**Introducción:** El TDAH afecta probablemente a más del 50% de los escolares, pero aunque las características como la falta de atención y/o la hiperactividad e impulsividad sean entendidas como comportamiento electrofisiológico del cerebro durante las actividades motoras, esto no es bien entendido. **Objetivo:** investigar el patrón de las franjas de Alfa, Beta y SMR en el EEG en niños con trastorno de déficit de atención y de Hiperactividad (TDAH), durante tareas motrizes con altas demandas de atención. **Métodos:** catorce niños con promedio de edad de  $9,64 \pm 1,74$  años, divididos en diagnosticados y no diagnosticados con TDAH, realizaron EEG durante el reposo y desempeño de la tarea motriz con alta demanda de atención. Las ondas Alfa, SMR y Beta se observaron en el EEG. Los datos fueron evaluados por el test de Shapiro-Wilk para determinar la



normalidad. ANOVA ONE WAY y el test de Tukey fueron utilizados para determinar las diferencias intragrupo e intergrupo, así como también la correlación de Pearson (*r*) y Spearman (*p*) fueron usadas para determinar las correlaciones. Todos los tratamientos tuvieron un nivel de significancia del 5%. Resultados: El TDAH y el N-TDAH no presentaron diferencias en la Franja Cortical Alfa, Beta y SMR durante el reposo, no obstante, al estar en actividad, el comportamiento cortical presentó diferencias. El índice de correlación de la actividad cortical (0,30) fue diferente de niños no diagnosticados (0,70). Conclusiones: El TDAH presentó un bajo índice de correlación entre reposo y actividad, a diferencia del N-TDAH. En la comparación intergrupos, el TDAH presentó mayor potencia de salida de la franja Alfa, Beta y SMR durante la misma tarea de alta atención, en comparación con el N-TDAH. **Nivel de Evidencia III.**

**Descriptor:** Electroencefalografía; Trastorno por Déficit de Atención con Hiperactividad; Atención.

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## INTRODUCTION

A wide variety of cortical areas and subcortical structures are required during neural processing in events involving attention.<sup>1</sup> Thus, the neural mechanism of attention, although still in need of further investigation, seems to be related to the parietal cortex's participation in the localization of objects in space.<sup>2</sup> As a result, the imbalance of attention is increasingly being treated as a disorder that requires treatment<sup>3</sup> due to the strict relationship of these processes with learning, especially in the school environment and with the involvement of associated disorders such as Attention Deficit Hyperactivity Disorder.

A large number of children are affected by this disorder, although it may have invisible nature. Although the Diagnostic and Statistical Manual of Mental Disorders (DSM) affirm that statistically, 7.2% of the school children has ADHD, but, this data could be sub estimated due the undiagnosed attention problems not perceived in the behavior.<sup>4</sup> According to the Swedish Council on Health Technology Assessment of Stockholm in 2013<sup>3</sup> close to 10% of children at scholar age may have ADHD, and the number depends upon the diagnosis method.

Childrens affected by ADHD constantly struggle against a persistent pattern of inattention and/or characteristic hyperactivity-impulsiveness,<sup>5</sup> a fact that directly affects behavior, providing academic and relational deficits for those with ADHD, and has a severe impact on the lives of close relatives and friends.<sup>6,7</sup>

However, even with all the characteristic impairments in children with ADHD and people close to them because of the abundant number of behavioral signs and, especially the absence of physical symptoms, their diagnosis is complex and still imprecise. However, Rohde<sup>5</sup> state that such classification systems do not define the term "frequently", and thus, depending on where the person responsible for the diagnosis inserts the cut-off point to determine frequency, there may be more or fewer children classified with a positive diagnosis, due, therefore, to the subjectivity of methods.

In this sense, an EEG proved to be effective in identifying the increase in Theta frequency in the left frontal region with the evaluation made with neuropsychological tests in children with ADHD.<sup>6,7</sup> Additionally, when analyzing the frequency bands visualized in the EEG, quantitative analyses may be performed that provide information about the temporal relations and the functional connectivity of the recording sites,<sup>8</sup> but in another hand, and the combination of standard clinical examination and EEG theta/beta power ratio increases in ADHD children.<sup>9</sup>

Thus, the objective of this investigating whether children diagnosed with ADHD show Alpha, Beta, and SMR bands in EEG and the possible correlation between the electroencephalographic record in moments of rest and the accomplishment of a skillful-motor task with demands of attention in children with and without a diagnosis of ADHD.

## METHODS

### Study type and ethical statement

This study is a cross sectional, ex-post-facto stud and all procedures here described are in accordance with resolution 196/96, approved by the PROCIMH ethics council, filed under No. 0026/2009. All participants signed the Free Informed Consent Form and the parents also gave their consent to the voluntary participation in the study.

### Volunteer Group

Children (N=14) with a mean age of 9.64±1.74 years, of both sexes, living in a poor community in the interior of the State of Rio de Janeiro made up the volunteer group in the present investigation. The subjects were separated into a group with no ADHD diagnosis, non ADHD diagnosis by a Specialist Physician. All children shared the same social situation.

### Data Collection Instrument

The instrument used for this procedure was Pocomp+ - Biofeedback System (USA) and Biograph Software, version 2.1. The placement of the electrodes for EEG collection was performed in the 10-20 system,<sup>10</sup> as recommended by the Brazilian Society of Clinical Neurophysiology. The points chosen were the Cz point of reference located strictly at the top of the skull, and the points A1 located in the left ear and A2 in the right ear in order to identify energy emission from each cortical hemisphere.

### Procedures

The data collection procedure occurred after written consent was given by the subjects' guardians. The individuals were taken to a properly prepared laboratory and then individually, were taken to a secluded room, with controlled noise and temperature, for electroencephalographic collection. The collection procedure began with the individual sitting with their eyes closed for 2 minutes. After that, without interruption, the skillful motor task began.

This task was characterized by a total of 5 trials in a simple reaction time test that used software specific to this function. The program displays three distinct points on the screen, one in the center, one on the left and one on the right. Initially, the program requires the assessed individual's to pay attention to a central point that lights up. Randomly, this luminous stimulus ceases, and immediately the luminous stimulus passes to one of the other points, the left or the right. When this occurs, the evaluator had to press the specific key for each point as quickly as possible; he or she may already have their index fingers touching these keys. The program records the time between the appearance of the light signal and the act of pressing the correct key. All performance measurements were disregarded.

It is worth mentioning that before the start of the EEG collection as well as during the first two attempts, the test procedure (motor skill

task) was explained to the children. The total time for the 5 skillful-motive task trials was 2 minutes and throughout the collection procedure the Alpha, SMR and Beta frequency bands were recorded.

### Statistical Analysis

The data were treated preliminarily using the Shapiro-Wilk test to verify the normality of the sample. Once the data were identified, the Pearson (r) was used in parametric data and Spearman (p) correlation coefficients was used to non-parametric data were selected to verify the existing correlations. The ANOVA ONE WAY with Tukey's posterior test was used to determine the difference. All tests had a 5% of significance. All statistical analysis was performed through the program GraphPad Prism 5.0.

### RESULTS

The alpha, beta and SMR cortical wave bands show differences between N-ADHA and ADHD children during high attentional motor task.

For the Alpha band, the ADHD obtained a mean of  $4.31 \pm 3.77$  at rest and  $12.48 \pm 12.35$  during the task, for the SMR band  $3.49 \pm 2.49$  at rest and  $8.87 \pm 7.50$  during the task, finally for the Beta band  $6.98 \pm 3.41$  at rest and  $12.26 \pm 5.68$  during the task. The N-ADHD in the Alpha band obtained  $3.90 \pm 5.09$  at rest and  $4.07 \pm 7.01$  during the task, for the SMR band  $3.34 \pm 4.86$  at rest and  $3.46 \pm 4.93$  during the task and for the Beta band  $7.73 \pm 4.86$  at rest and  $7.27 \pm 4.71$  during the task as showed in the Figure 1.

Subjects with no diagnosis of ADHD (n = 7) and subjects diagnosed with ADHD (n = 7) were submitted to four minutes of data collection of Alpha, SMR and Beta cortical waves during rest and activity with attention demand. In the intra-group comparison, the Alpha (A), SMR (B) and Beta (C) bands did not show a difference between rest and activity for the N-ADHD group; however, for the ADHD group there was a difference and the comparison between rest and activity as well as being different from the activity for the N-ADHD group. The t test was used to determine intragroup differences, ANOVA ONE WAY with Tukey's posterior test was used to determine the intergroup difference, both with 5% of significance. (A, B and C \* = p < 0.05 Resting vs. Activity) and (\*\*=p < 0.05 ADHD Activity vs. N-ADHD).

Analyzing the correlation indexes presented in Table 1, a distinction is made in the variation of the cortical pattern, during rest and motor activity with attentional demand, of children with and without ADHD.

The data showed that in children affected by ADHD, none of the waves observed presented a correlation index higher than 0.30, regardless of the test used, which shows a low correlation between these moments. This pattern was not repeated in children who did not present ADHD, since all indexes were higher than 0.70; the alpha wave stands out with a correlation index of 0.94.

**Table 1.** presentation of the Pearson and Spearman correlation indices in the moments of rest and execution of a skillful motor task with cognitive demand.

	ADHD Correlation Coefficient	N-ADHD Correlation Coefficient
Alpha	0.29*	0.94*
SMR	0.22*	0.77*
Beta	-0.29**	0.82**

\* Score obtained from the Spearman correlation coefficient (rs) and (\*\*) Score obtained from the Pearson Correlation Coefficient (r).

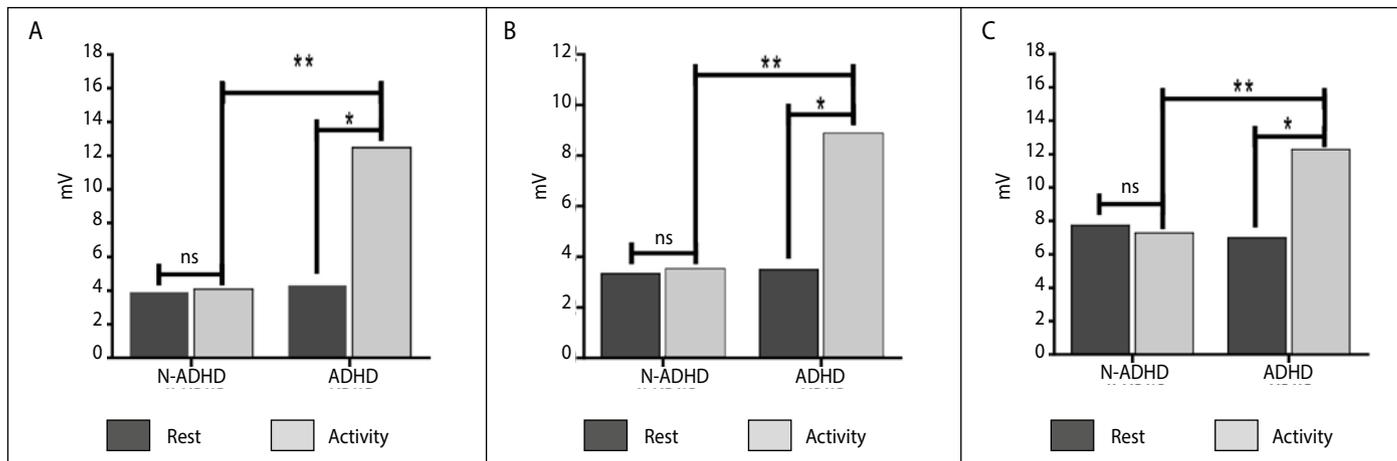
### DISCUSSION

The present study is the first to use the approach described differences in Alpha, Beta and SMR EEG band between children with and without ADHD diagnosis. For this, two data collections were performed, one without attention demand involved and another with high attention demand in two groups, one with diagnosis of ADHD and another without this diagnosis. It was observed here that, first, the execution of a task with some demand for attention provides alterations in the cortical tracing of the individuals regardless of the presence of comorbidity, and second, that the relationship between cause and effect may support the idea of difference between children with and without ADHD of Alpha, Beta and SMR bands of EEG.

It is important to note at this point that due to the variability found in some samples, which influenced the normality of the data, it was necessary to adopt two different correlation coefficients: one for parametric samples, Pearson's coefficient (r), and another for non-parametric samples, Spearman's coefficient (rs). However, it was evident that in children without ADHD, the correlation between the cortical waves during the moment of rest and during the execution of a motor activity with attentional demand is high, different from that presented by children without this disorder.

Was demonstrated that frontal brain activity in patients with ADHD is decreased when compared to people without the disorder.<sup>11</sup> The obtained through the EEG can bring elements for neurophysiological distinction between children with ADHD and healthy children, based on different cognitive aspects.<sup>12</sup>

Such assertions underpin the theoretical possibility tested in this study that different cognitive scenarios may reveal differentiated patterns in the EEG of children with and without ADHD. The first interesting observation is the confirmation that the change from the cognitive setting of rest to the accomplishment of a motor task with cognitive demand provoked an increase in the cortical activity that was more accentuated in the children of the ADHD group than in the control group; it was sought to establish a differential correlation pattern in children with ADHD between the two cognitive scenarios to which they were submitted. This attempt at correlation was supported, where it was demonstrated



**Figure 1.** intragroup and intergroup evaluation of cortical waves.

that the EEG of children with ADHD presented improper activation of the central executive neural networks during continuous action tasks.<sup>13</sup>

Data from the correlations showed that there was a distinct pattern in each group of this study. Children diagnosed with ADHD presented very low correlation indices between the two cognitive scenarios studied (<0.30). Nevertheless, children without ADHD had a high correlation (>0.70) in all brain waves observed.

The data hypothesize that children with ADHD, during the execution of motor tasks with attentional demand, have considerably higher Alpha, SMR and Beta wave activity than that observed in children without this disorder. This hypothesis seems plausible and justifies the lack of correlation observed in the group of children with ADHD. Although significant, the data is insufficient; however, it does shed light to understanding

the real scientific possibility of developing more knowledge about this deficiency. Regarding the methodology used in this study, it will be necessary to perform prospective, randomized and double blind studies to increase the robustness of the data presented herein.

So, we may conclude that children with ADHD show different Alpha, Beta and SMR power output pattern in EEG during skillful-motor task with demands of attention.

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