Theta/Beta Ratio or not?: A Review Study of Specified QEEG Parameter for Diagnosis of ADHD Presentations

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Abstract

Background

Attention-deficit/hyperactivity disorder (ADHD), a neurodevelopmental disorder, is characterized by difficulty paying and maintaining attention, impulsivity, and hyperactivity. According to DSM-5-TR, three manifestations of ADHD are described: combined manifestations, mainly inattentive and mainly hyperactive/impulsive. Theta-beta ratio (TBR) or inattention index, refers to the increase in the power of the theta band (usually 4-7 Hz) and specifically the increase in theta power relative to the power of the The beta band (generally 13-30 Hz), has the highest reproducibility. Exploring psychology and physiology in ADHD.

Objectives

The present study aims to review the literature on QEEG parameters related to ADHD.

Results

TBR is considered as a consistent characteristic of ADHD. However, it is not the diagnostic measure for all individuals with ADHD. TBR is unnecessary in making the diagnosis for all ADHD presentations.

Conclusions

Review of studies suggests that TBR could not be a comprehensive diagnostic measure for all ADHD subtypes. It should not be generalized for all presentations. Rather, each presentation could have its specific QEEG measure. Therefore, a QEEG spectrum classification of ADHD population would be an important notification.

Introduction

Description of ADHD

Neurodevelopmental disorders such as ADHD are frequently treated by pediatricians [2]. This occurs in at least two contexts before age 12, as defined by DSM-5-TR, where hyperactivity and impulsivity become undesirable in terms of attention and behavior [3]. It is characterized by difficulty paying attention and maintaining attention, impulsivity, and hyperactivity [4]. Those with ADHD exhibit reduced levels of academic performance, peer support, and family operating [5, 6, 7].

ADHD: Presentations based on DSM-5

According to DSM-5, ADHD presentations can be considered: ADHD-I, ADHD-H and ADHD-C [1]. ADHD patients commonly experience psychosocial problems, including distraction, hyperactivity, and impulsivity. These symptoms are considered important. ADHD is typically diagnosed early in life, and it can persist for a long time. Given the heterogeneity of ADHD, the most desirable treatment approach should be multimodal in nature [8, 9, 10].

Given the wide range of outcomes and recurrence rates of ADHD, there is a surprising lack of data on the socioeconomic impact of persistent ADHD. The estimated annual income loss for adults with persistent ADHD in the United States is$77 billion [11]. Data from the United States show that direct medical costs per adult ADHD patient per year are 2,500 € [12], equivalent to approximately 46 billion € for all persistent ADHD patients in the EU.

A core component of ADHD is increased inattention [13], which is considered one of the most common symptoms of ADHD [14] and is found in both inattentive and combined presentations about ADHD according to DSM-5 [1].

People with ADHD-I often avoid or are unwilling to do things that require a lot of mental effort over long periods of time. He/She is easily distracted, often has difficulty focusing on tasks, and frequently switches from one activity to another [15].

Based on DSM-5-TR criteria to diagnose people with ADHD-H, often squirm in chair, get out of chair in conditions that require sitting still. Additionally, they often run or climb in unsuitable conditions. They operate as if they were “driven by a motor”. In addition, hyperactive and impulsive people often talk too much; blurt out an answer before the question is finished. Additionally, they interrupt or intrude on others [1].

Additionally, researchers at the National Institute of Mental Health [NIMH] have suggested that individuals who exhibit hyperactivity are in many cases extremely anxious and agitated. Hyperactivity-impulsivity at maladaptive levels, but not inattention, is the defining feature of ADHD -H. Additionally, impulsivity is defined as a manifestation of behavioral inhibition dysfunction and is often evidenced by deficits in motor impulse control manifested by diminished response inhibition [16].

According to DSM-5-TR[1], impulsive behavior is a key feature of ADHD and is associated with social/peer difficulties as well as difficult learning and annoyances to others. This is one of the primary characteristics of this disorder.

Impulsivity is described as the tendency to react quickly and unexpectedly to stimuli without considering negative consequences [17].

As defined by the National Institute of Mental Health, individuals who exhibit impulsivity may prefer to do things that provide immediate but less rewarding rewards rather than doing activities that may be more demanding. More effort brings greater but delayed rewards. They seem unable to restrain their immediate reactions or think before acting and often blurt out inappropriate comments, express their emotions without restraint, and act without regard for the consequences.

People with ADHD-C have difficulty with inhibition. Motivator responses limit behavior management, reduce planning and prediction, reduce sensitivity to errors, and poor self-monitoring [18; 19].

ADHD: Prevalence and etiology

ADHD can be found in about 5% of children and about 2.5% of the adult population [1]. This disorder affects children's academic performance, social skills, job performance, and personality development, and its negative consequences last into adulthood [20].

Furthermore, it places an enormous burden on society in terms of psychological dysfunction [21]. Adolescents with ADHD are also considered to be at higher risk for specific developmental problems such as delinquency and high-risk behavior [22,23].

Proficient guidelines depict best hones for diagnosis [1] and treatment [24, 25]. Pharmacological and psychological methods should be combined for treatment [26].

Additionally, deficits in self-monitoring can hinder monitoring activities that require tight control [27]. The exact cause of this disorder is unknown; however, it is proposed to result from multifaceted interactions between the neuroanatomical and neurochemical systems. In addition, genetic, neurodevelopmental, psychosocial, and neurophysiological factors play an important role.

The neurodevelopmental theory proposed by Halperin and Schulz defines ADHD as having noncortical dysfunctions that are relatively stable. In essence, ADHD is linked to deficiencies in lower cognitive mechanisms [28].

In one study, Del Campo, Muller, and Sahakian [29] showed that the availability of dopamine transporters in the striatum of individuals with ADHD was persistently reduced, suggesting a problem in the synthesis of dopamine. In other words, the results suggest changes in monoamine transmission, especially dopaminergic function [30].

Overall, there is growing evidence that ADHD is considered a brain disorder [31]. There is a growing body of research examining possible differences in the social, interpersonal, and cognitive functioning of children and adults with ADHD compared with those without ADHD.

Regarding the pattern of cortical development in ADHD, Bolea-Alamañac and colleagues [32] proposed a “immaturity hypothesis” according to which ADHD patients need more time to reach similar developmental milestones compared to unaffected subjects.

Although many theories have been proposed regarding the neurological basis of ADHD, these theories are not well understood [30].

Factors such as the type of instrument and method applied to combine information across measures and informants may also influence ADHD diagnosis [33].

Early studies on brain processes in children with ADHD incorporated the use of electrophysiological measurements.

Specifically, EEG is used both in research contexts to characterize and quantify the fundamental neurophysiology of ADHD and also on a clinical level for evaluation/diagnosis and treatment[34].

Electroencephalography

Over the past few years, the situation has gradually changed. We are currently facing an EEG renaissance. This renaissance is associated with the emergence of the latest methods of EEG assessment in humans and new experimental findings in animal research that have allowed electrophysiologists to detect that changes in the patterns EEG oscillations play an important role in maintaining brain functions and can be used as an influential tool to diagnose brain dysfunction [35].

Electroencephalography [EEG] measurements show correspondence between intracranial electrical currents and voltages generated on the scalp, reflecting several aspects of the brain's electrical processing and function, e.g. their ability to respond to stimuli or in cognitive tasks [36]. Over the past several decades, Several studies have been conducted to investigate whether the brain wave patterns obtained from EEG exhibit differences between individuals with and without ADHD.

The EEG is commonly separated into four frequency ranges, namely the delta. Therefore, the use of EEG has been instrumental in revealing more about the neurobiological mechanisms of ADHD and was found to be highly sensitive in distinguishing ADHD from healthy control individuals.

Actually; Quantitative electroencephalogram [QEEG] reflects the local synchronization capacity of the network. This synchronization capability is tied to the integrative capabilities of the network and the characteristics of its inputs. This can be strongly modified by the state of brain activity. The results show that QEEG results can be applied to distinguish children with and without ADHD. Monastra et al. [37] also illustrated the usefulness of QEEG in the assessment of ADHD.

Recently, a QEEG spectral classification of the ADHD population has been proposed that identifies four main subgroups: Subtype I [abnormal increases in the central or frontal delta-theta frequency band], subgroup II [abnormal increase in midfrontal theta rhythm], subtype III [abnormally increased frontal beta activity], and subtype IV (increased alpha activity in the posterior, central, or frontal leads). The first and second types are clinically characterized by inattention, whereas in the third type, hyperactivity, impulsivity, and social maladjustment are common. Poor concentration is also the main reason why children have excess alpha [38].

Evidences for Utility of QEEG in Diagnosis of ADHD

EEG plays an important role in the assessment and classification of disorders. EEG is a widely accepted method for assessing cortical information processing and neurophysiological changes that occur during unconsciousness and various states of consciousness.

Electroencephalography [EEG] was the first measure applied to systematically verify cortical activity in the human brain [39].

There is currently debate about the systematic use of QEEG. The American Academy of Neurology [AAN] considers QEEG to be the mathematical processing of DEEG to highlight specific components of a waveform, in order to convert the EEG into a format or domain that elucidates the information.

DEEG is defined by the AAN as the paperless, computerized collection and recording of EEG, with storage in digital format on electronic media and display of waveforms on an electronic display [40].

Abnormal EEG patterns can be considered as specific signs of brain dysfunction [40].

It is important to know whether children and adolescents with ADHD have underlying neurophysiological abnormalities that are responsible for their hyperactive/inattentive behavior and that can be identified. reliably determined by electroencephalogram.

EEG signal analysis, as an informative quantitative method, has revealed that EEG abnormalities in children with ADHD [41, 36] may reveal impairment in their cognitive function [36].

Because inattention is characteristic of most childhood mental disorders, it is often difficult to differentiate between ADHD and other disorders with similar manifestations, including autism spectrum disorder, mood and anxiety disorders and learning disabilities. Therefore, a sensitive and specific biological diagnostic test or biomarker for ADHD would be of great help. Based on previously reviewed findings, EEG measurements are considered promising biomarkers for ADHD [39].

Understanding the neurophysiology behind ADHD and learning disabilities is possible through QEEG, which also helps in distinguishing these conditions from others. Children with attention disorders are most likely to exhibit abnormal slow-wave activity, which is a result of dysfunctional thalamic and/or phalamatic pathways. By providing information that can help diagnose these patients better and design treatments to improve their outcomes, QEEG has a crucial role to play in their evaluation and treatment.

According to several large studies, QEEG can differentiate between children with attention disorders and/or learning disabilities [42], as it is highly sensitive and specific.

The most consistent findings in ADHD since the introduction of QEEG have been those of increases in absolute Theta power [43; 44; 45] and occasionally increases in absolute Delta EEG power [46].

Studies have shown that children with ADHD can be distinguished from non-ADHD children more than 96% of the time based on their QEEG signs. EEG helps distinguish the neural basis of attention deficits due to ADHD from the neural basis arising from attention deficits associated with other primary psychiatric disorders: depression, anxiety, OCD and oppositional defiant disorder [42].

In recent years, EEG research has revealed differences between groups of children with and without ADHD. These include an increase in theta activity [44] occurring mainly in frontal regions [45; 43], an increase in the posterior delta region [44], and a decrease in alpha and beta activity [47]. An increase in theta/alpha [44] and theta/beta [44] ratios has also been observed in children with ADHD compared to normal children.

Studies investigating whether EEG can differentiate between ADHD, learning disabilities, and other psychiatric disorders have shown that EEG is very sensitive (93% to 97%) and quite specific (84% to 90%) to distinguish ADHD from LD [36].

QEEG studies in children with learning disabilities have shown changes, such as increased absolute power in the delta and theta bands [48], decreased alpha activity [49], and decreased alpha and beta activity, as well as such as poor spatial discrimination.[50].

The AAN, in an evidence-based practice consultation, concluded that the ratio of EEG theta-beta power and EEG frontal beta power has the potential to accurately identify patients with ADHD (accuracy 89% to 94%) compared with clinical assessment.

The AAN suggests that EEG testing shouldnot be usedas a substitute for standardclinical assessment, as the use of theta/betA ratios can leadto diagnostic error between 6-15%. The validity of using the EEG theta/beta power ratio to confirm a diagnosis of ADHD or support additional testing is uncertain. The correlation between TBR changes in individuals with comorbid disorders like ODD and those with ADHD is not clear.

QEEG Findings in ADHD

Theta/Beta Ratio [TBR]

The most common approach to QEEG studies is to determine the absolute and relative power obtained from fixed frequency bands under resting conditions [eyes closed [EC] or eyes open [EO]] [51]. Therefore, studies on brain wave patterns in ADHD patients are primarily concerned with finding whether there is increased theta wave activity and TBR in these patients.

Lubar [52] compared QEEG data of children with ADHD with that of a control group. He concluded: “Excessive theta activity and lack of beta activity are the main neurological signs of ADHD.

The main QEEG frequency abnormalities observed in ADHD involve excess theta and in some cases low alpha [53].

Additionally, excess theta waves and low alpha waves may be due to low dopamine levels possibly due to impaired PFC function [54].

Studies have shown that increased TBR is a sensitive marker of ADHD [55] and is strongly correlated with age-related changes in ADHD behavioral symptoms over time [56].

Given the excess theta and reduced beta activity observed in children with ADHD, it is easy to understand that changing these parameters through treatment would lead to improvement in ADHD symptoms [57].

The theta-beta ratio , known as the inattention index, was calculated by recording the EEG at a position Cz with reference to the two linked ears. It was found that this index was 3 times higher in children with combined ADHD and inattention aged 6-10 years compared to the normal group. Monastra et al. [55] demonstrated that the sensitivity of this index was 86% and the specificity was 98%.

Most media reports consider TBR to be the first brain test to diagnose children with ADHD [58]. However, this has not been confirmed in all studies.

In this regard, some authors have found a positive relationship between ADHD and higher TBR [59]. Therefore, most NF regimens for the treatment of ADHD aim to increase beta frequencies more rapidly, especially SMR, and reduce theta waves [60].

Increases in theta-band power (typically 4-7 Hz) and especially increases in theta-band power relative to beta-band power (typically 13-30 Hz) are potentially psychophysical findings in ADHD [61]. TBR measured at Cz has been reported to reliably discriminate between children with ADHD and controls [62].

In previous studies, ADHD was consistently characterized by increased low-frequency activity (i.e. absolute and relative theta), under resting conditions [EC or EO], especially when it was recorded again from previous positions [63; 46; 43; 44; 64; 39].

Studies show that an increase in theta/beta ratio has 87% sensitivity, 94% specificity, and 89% accuracy in diagnosing ADHD, while the rating scale is 47-58% [65] .

Theta/Beta Ratio (TBR) is not the only measure for Diagnosis of ADHD

The outcomes of QEEG study are not always dependable. Most recent studies show inadequate overall accuracy of 40.3–58% for TBR and 46.8–63% for theta power in distinguishing children with and without ADHD [66, 67]. According to Heinrich, Busch and colleagues [68], recent studies raise doubts about whether the majority of children with ADHD exhibit greater TBR in the resting EEG or not.

Moreover, one research discovered no connection between the QEEG ADHD parameter (TBR) and the Coolidge Personality and Neuropsychiatric ADHD (CPNI) scale [69]. However, participants reported positive results.

Buyck and Wiersema [70], Liechti et al [66], and others [72] observed no significant differences between children with ADHD and those who were typically growing up in any frequency range.

Additionally, Arns, Conners, and Kraemer [71] conducted a meta-analysis of TBR in the treatment of ADHD.

The Cz website examined Eyes Open TBR data on children/adolescents aged 6 to 18 years, with and without ADHD.

Results demonstrated that nine studies were identified with a total of 1,253 children/adolescents with and 517 children without ADHD. The average effect size for children 6 to 13 years old is .75 and for children 6 to 18 years old it is 62. However, examining heterogeneity still makes sense. The authors found that these effect sizes were not true and were overestimated.

The TBR difference between non-ADHD groups and other populations showed a decrease over time, which was explained by post-hoc analysis.

According to their suggestion, a high level of TBR is insufficient evidence for ADHD.

However, many patients who differ from this group also believe that TBT can be useful in predicting the future This group. Rather, this justifies its use as a prognostic measure rather than a diagnostic measure.

Poli et al [72] studied 46 ADHD patients and 68 controls. In this study, high-density EEG was recorded from 60 electrodes under eyes-closed resting conditions. No theta differences were found between children with and without ADHD. They reported a Cohen's D effect size of .17 for TBR between the two groups. However, in previous studies, Monastra et al. [37, 55] as well as Snyder et al. [62] large effect sizes [ES: 1.6–1.8] were reported [58].

Therefore, the results of the study conducted by Monastra et al. [37] suggested significant maturation effects of cortical PFC stimulation accompanied by cortical slowing.

The typical pattern revealed was excess theta [4-8 Hz] and reduced beta [13-21 Hz], as indicated by increased theta-to-beta power ratio compared to controls.

It should be noted that EEG profiles in ADHD during cognitive tasks are also important, as in most studies resting EEG has been studied. Therefore, increased TBR cannot be considered a reliable measure used to diagnose ADHD at present.

A recent study has shown that excess theta and TBR are present in primarily 25-40% of ADHD patients, supporting their prognostic value in improving treatment outcomes [71].

Russian scientists from the St.Petersburg Kropotov [73] demonstrated that TBR is only a good measure for a portion of the ADHD population. Comparing the peak position of this index to the normal population reveals significant differences in its relative strength over time. It is suggested that measuring this index at different electrode positions in the brain based on age would be more effective in distinguishing ADHD from healthy volunteers.

Despite the fact that resting EEG encompasses both feature points and status signs, Hagemann et al [74] suggests it is more appropriate to use it during task processing. Heinrich and colleagues [68] reported that in contrast to recent resting EEG studies [e.g.The theta and alpha bands showed significant differences between children with ADHD and typically development. These bands were significantly higher in children with ADHD. In the ADHD-C group, the effect was larger when considering the frequency range from 5 to 10 Hz [higher theta/lower alpha].

Overall, there was no significant group effect for the theta/beta ratio in this analysis, so most children with ADHD did not have higher levels of the theta/beta ratio.

Additionally, Poil et al. [72] reported higher beta and lower alpha power in adults with ADHD-C compared with controls; however, this was not consistent with their observations of ADHD-C children.

Therefore, it would be a great idea to consider specific EEG measurements for each presentation; this is especially important in treatment protocols based on EEG biofeedback.

ADHD was found to differ from controls in certain areas, such as decreased relative beta activity, increased absolute and relative theta activity or an increase in the theta-beta levels [75, 76,45, 37], but other studies have revealed that ADHD may be associated with a distinct subtype, presenting in combination with low IQ] of ADHD [43].

Heinrich et al [68] have emphasized that in previous studies; only a single EEG channel was typically used to calculate feedback information in EEG NF training. For theta/beta training in ADHD, most often electrode Cz is considered. In their data, increased upper-theta/lower-alpha activity in the ADHD-C group and a higher theta/beta ratio in the ADHD-I group were not topographically specific, i.e., they were not restricted to/particularly pronounced at a certain electrode. Looking at single electrodes, effects at electrode Cz appeared rather smaller than larger compared to frontal, electrodes (F3, Fz).

Therefore, when considering resting EEG, EEG during a cognitive task, various representations of ADHD, as well as electrode placement, are of great importance. Not all ADHD representations can be characterized by TBR, nor can the Cz electrode be accounted for in theta/beta entrainment in all ADHD subtypes.

Accordingly, midfrontal theta (involved in cognitive control and working memory processes; 77) may interfere with the more general theta pattern mentioned in e.g. theta/beta training if Feedback is only calculated from Cz.

According to Heinrich et al,[68], it is possible to achieve a more precise response signal by combining multiple electrodes instead of utilizing merely one channel.

When topography-specific EEG patterns are not a part of NF training, distributed electrode grids may be more suitable.

Conclusion

Numerous EEG thinks about have detailed that ADHD is characterized by an lifted theta/beta proportion [TBR]. RBD due to increased theta is considered a consistent feature of ADHD. Some groups recommend the use of TBR under resting conditions, with eyes open or closed, as an adjunct to the diagnosis and monitoring of ADHD. In any case, it has been detailed that the genuine utilitarian noteworthiness of this degree is obscure which expanded theta action may be a nonspecific marker of cortical brokenness common to these disarranges. others such as epilepsy, bipolar clutter and polysubstance manhandle. Arns et al.'s [71] meta-analysis of ADHD theta/beta ratio studies suggests that TBR can be used as a prognostic measure but not as a diagnostic measure.

According to their observations, a decrease in ES for TBR was observed over time.They stated that the increase in TBR in control groups was primarily responsible for this effect, not a decrease in it in those with ADHD. However, they found no correlation between these findings and the results.

It was argued by Arns and Gordon [58] that TBR is not a distinct marker for all ADHD cases, and there is no identifiable biomarker that can differentiate all individuals with the disorder from those without it.

It could be argued that conventional neurofeedback protocols aimed at reducing inattention and impulsivity, including enhancing operant beta activity and inhibiting theta activity, cannot be used for all symptoms of ADHD.

Therefore, neurofeedback protocols should be tailored to each presentation based on its specific QEEG measures. Therefore, a review of studies suggests that EEG plays an important role in the assessment, classification, and monitoring of disorders.

Accordingly, atypical EEG signals can be classified as indicative of brain dysfunction.

Based on the findings reviewed previously, EEG measures are considered promising biomarkers for ADHD.

Understanding the underlying neurophysiology of ADHD can be achieved through QEEG, which may help in distinguishing between ADHD and other conditions.

However, QEEG ADHD parameters [theta/beta ratio; TBR] cannot be considered complete QEEG parameters for all subgroups. Therefore, it may be suggested that TBR is not necessary for diagnosis all manifestations of ADHD. In other words, TBR cannot be a comprehensive diagnostic measure for all ADHD subtypes. This should not be generalized to all presentations. Instead, each presentation can have a specific QEEG measurement. Therefore, the QEEG spectrum classification of the ADHD group will be an important announcement. Furthermore, this may have important implications for EEG biofeedback.

Conflict of Interest

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