EFFECT OF REPETITIVE TRANS-CRANIAL MAGNETIC STIMULATION IN ATTENTION DEFICIT HYPERACTIVITY DISORDER IN RESPONSE TO ATTENTION AND MOTOR SKILLS IN SCHOOL GOING CHILDREN

Akshata Shinde[1] , Kani Mozhi[2] ,DivyaMidha[3] ,Narkeesh Arumugam[4]

[1]PostGraduate Student,[2] Professor & Principal, [3]HOD & Professor, Department of Physiotherapy, Desh Bhagat University, MandiGobindgarh, Punjab

ABSTRACT

Background: According to the American Psychiatric Association (2013), ADHD is marked by persistent inattention and/or hyperactivity-impulsivity that affects functioning or development. In India, its prevalence ranges from 1.3% to 28.9%, with higher rates in males (12.58%) than females (5.52%). This study aims to determine the effect of Repetitive Trans-cranial Magnetic Stimulation (rTMS) and structured exercise on attention, motor skills, and physical fitness in school-going children with ADHD.

Methodology: This experimental study examined the effects of rTMS and exerciseon attention and motor skills of school-going children with ADHD.

Result: Participants (mean age 8.6 years) showed improvement across all measures from Day 0 to Day 30, including motor coordination, endurance, and cognitive performance, as evidenced by better SLTHT, SMBTT, 9HPT, TMWT, and TMT scores. Additionally, the exercise sessions were acceptable and enjoyable to all children.

Conclusion: rTMS combined with structured exercise improves attention, motor function, and quality of life in children with ADHD. It is recommended that structured exercise programs be integrated into the school physical education curriculum, as they can serve as an effective and essential intervention to enhance attention, motor skills, and overall functioning in children with ADHD.

Keywords: rTMS; Attention Deficit Hyperactivity Disorder; Attention; Motor Skills.

INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is a chronic condition that affects substantial number of children and often continues into adulthood (Yustiansari et al., 2021). The essential feature of attention-deficit/hyperactivity disorder (ADHD) is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development (APA, 2013). ADHD is characterized by a persistent pattern of age-inappropriate levels of inattention and/or hyperactivity/impulsivity that results in functional impairment at work, education, or hobbies and affects family life, social contacts, and self-confidence (Austerman, 2015). The children with ADHD have poorer interpersonal, parent–child–sibling relationship, and less academic achievement in comparison to typically developing children, resulting in compromised self-esteem, inability to evaluate self, negative emotions, and so on (Joseph & Devu, 2019). A recent analysis revealed significant variation in the prevalence of ADHD among children and adolescents both globally and in India.

The global prevalence of ADHD is 7.6% among children aged 3 to 12 years and 5.6% among teenagers aged 12 to 18 years (Salari et al., 2023). In India, the prevalence of ADHD, based on school and hospital-based population studies, ranges from 4.7% to 29.2% (Pathan et al., 2024). ADHD is more commonly diagnosed in males than females, with a typical male-to-female ratio of about 4:1 (Ramtekkar et al., 2010). In India, the prevalence of ADHD among male children and female children is 9.40% and 5.20% respectively (Joseph & Devu, 2019).

In light of these prevalence rates, there is an increasing emphasis on adopting comprehensive, evidence-based treatment strategies for ADHD. The most successful evidence-based treatments for managing the fundamental symptoms of ADHD include group-based parental psycho-education, behavioural therapy (BT) or cognitive behaviour therapy (CBT), stimulant medication (Nazarova et al., 2022). New approaches to treating the ailment have been studied, among which is neuro-stimulation (Wong & Zaman., 2019). Studies also

found that acute exercise and regular physical activities can induce physiological and psychological mechanisms that not only promote physical and psychological health but also improve physiological and cognitive functions, including memory and executive function (Christiansen et al., 2019).

Neurostimulation is a non-invasive method that induces long-term changes in brain excitability or neurochemical activity, helping address neuropsychiatric conditions. Repetitive transcranial magnetic stimulation (rTMS) is a safe and non-invasive technique that uses electromagnetic pulses via a coil placed on the scalp to generate electric fields in the brain (Wong & Zaman, 2019). rTMS can modulate cortical excitability depending on frequency: low-frequency rTMS (≤5 Hz) reduces neuronal excitability and cerebral blood flow, while high-frequency rTMS (>5 Hz) increases them, offering therapeutic benefits for various neurological and psychiatric disorders (Wong & Zaman, 2019).

According to the Physical Activity Guidelines for Americans, 2018 recommend the positive effects of acute bouts of structured exercise lasting >20 min on childhood cognitive and brain health, a single exercise session may be an effective and complementary intervention to improve cognitive performance in children with ADHD (Govindan et al., 2020). Studies have demonstrated that short-term physical activity improves cognitive performance in multiple domains, particularly in children with attention deficit hyperactivity disorder (ADHD) (Yu et al., 2020).

Due to the high prevalence of ADHD, further research is needed on the effectiveness of rTMS in its treatment (Salari et al., 2023). This study evaluates the therapeutic impact of rTMS combined with exercises and physiotherapy in children with ADHD and compares its effectiveness against standalone treatments.

METHODOLOGY

Participants

A total of 5 school going children within 7-12 years of age diagnosed with ADHD were constituted in the population of the study. Participants represented a sample of convenience, and were recruited from Department of Physiotherapy at Desh Bhagat University, Mandi Gobindgarh, government and non-government schools, Mandi Gobindgarh and in Neuroots clinic, Patiala.

Children who were not willing to participate, children with metallic implants in the body (dental crown, dental braces, stunts), clinically significant or unstable medical disorders and or had a history of musculoskeletal, other neurologicalor cardiovascular or psychological disorders and children with history of epilepsy, head injury or loss of consciousness wereexcluded from the study. Informed consent and assent was taken from the parents andchildren respectively.As required by law, permission was also taken from the schoolprincipal(s).

Procedure

ADHD children selected for the study were diagnosed by a pediatricianand a schoolpsychologist as per DSM V guidelines. All childrenwere randomly measured at baseline (pre-test) and following theintervention period (post-test). Following initial assessment, astructuredexercise program was administrated to all children for 45 min per session,over a period of 30 days. The 60 min of program included strengthening exercises for the upper limb, lower limb, treadmill walking for ten-fifteen (10-15) minutes, Fine motor training was administered for five (5) minutes during each session and included stringing of beadsin a straw, thread, and soft filament. rTMS stimulation for 15 min. Attention training that consisted of a 'spot the difference activitywas administered for eight-ten (8-10) minutesduring each session.

Outcome measures

The following battery of reliable and valid tests were used to measurelevel of inattention, hyperactivity, motor skills.

The Single Leg Triple Hop Test

The Single Leg Triple Hop Test assesses lower limb power, balance, and neuromuscular coordination using minimal equipment. Participants perform three consecutive hops on one leg, and the distance of the third hop is measured from the start line to the heel's landing point. Each leg is tested in three trials, with the longest distance recorded. The test shows high reliability (r = 0.98), ensuring consistency across sessions (Lori & Keskula, 1997; Magee et al., 2007).

The Seated Medicine Ball Throw Test

The Seated Medicine Ball Throw Test evaluates upper body strength and coordination. Seated with back support, participants throw a 2 kg medicine ball forward using both hands, maintaining back contact with the chair. Three attempts are given, and the farthest distance from shoulder to landing point is recorded. The test demonstrates good reliability (r = 0.80), making it a consistent measure for upper body strength (Davis et al., 2008; Palao & Valdes, 2013).

The Nine Hole Peg Test

The Nine Hole Peg Test (9-HPT) assesses manual dexterity using a 9-hole pegboard and nine pegs. Seated participants place and remove the pegs one at a time as quickly as possible. Three trials per hand are conducted, and the best completion time is recorded in seconds. The test shows high reliability, with test-retest values between 0.92–0.95 and interrater reliability of 0.98–0.99 (Wang et al., 2011).

The 12-Minute Walk/Run Test

The 12-Minute Walk/Run Test measures aerobic endurance by recording the distance an individual covers in 12 minutes on a flat track. It requires minimal equipment: a stopwatch and measuring tools. VO2max can be estimated using the formula: VO2max = (22.351 × km covered) - 11.288. The test shows high reliability (r = 0.94) and is effective for assessing aerobic fitness in diverse populations (Doolittle & Bigbee, 1965; Bandyopadhyay, 2014).

The Trail Making Test (TMT)

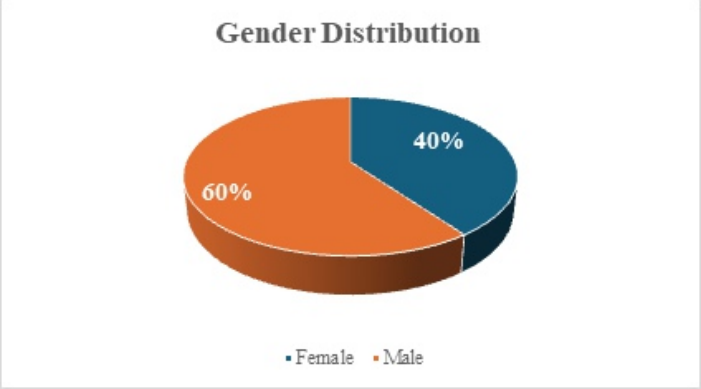
The Trail Making Test (TMT) evaluates attention, processing speed, and cognitive flexibility via two parts: Part A (number sequencing) and Part B (alternating numbers and letters). Participants complete tasks using paper and pencil within 5 minutes per part, with errors corrected during testing. The TMT is highly reliable (0.92–0.95) and is widely used to detect cognitive deficits in conditions like ADHD and traumatic brain injury (Reitan, 2004).

RESULT

All outcome variables were analysed using parametric test, the paired t-test—for comparing means across time points, as most followed a normal distribution with only minor deviations.

Gender Distribution

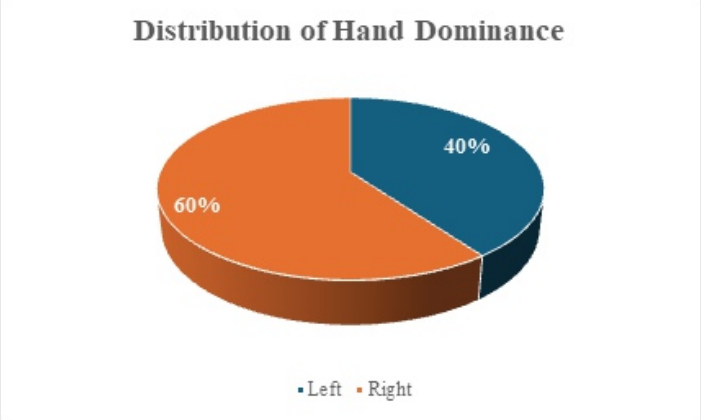
The participants in the study had a mean age of 8.60 years with a standard deviGraph :1 Comparison of Gender among the participantsation (SD) of 1.82.



Graph :1 Comparison of Gender among the participants

Among the five participants, 60% were male and 40% were female, indicating a slight male predominance in the sample.

Distribution of Dominance



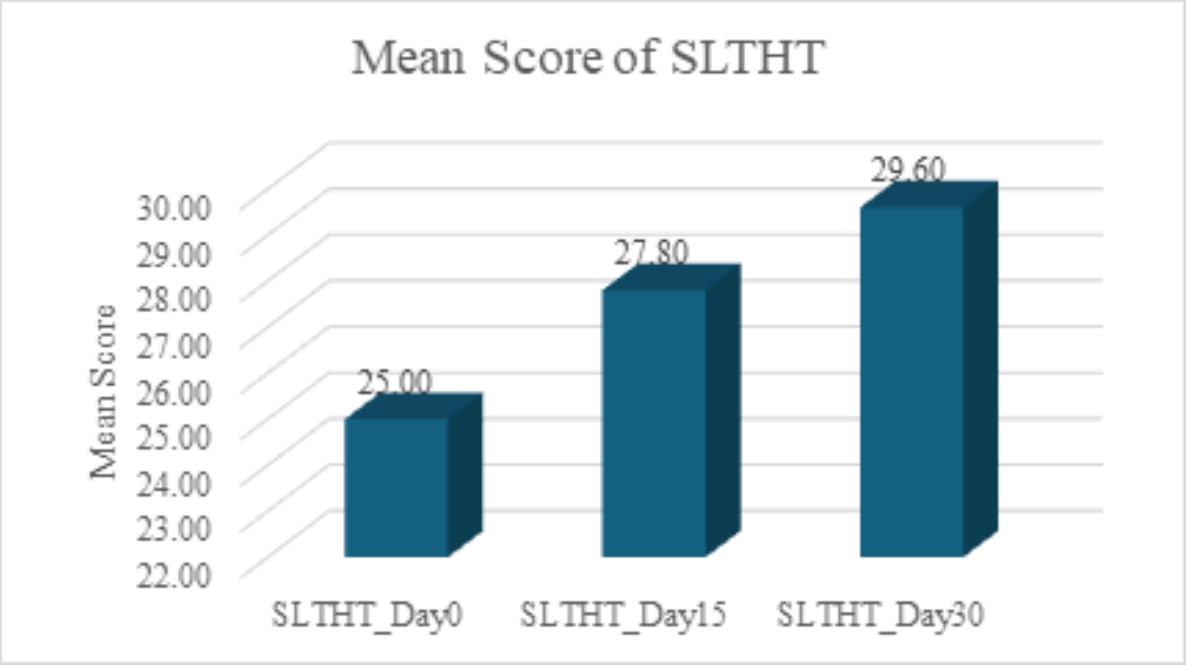
Graph 2: Comparison of Hand Dominance among the participants

In terms of hand dominance, 60% of the participants were right-handed while 40% were left-handed, showing a slightly higher proportion of right-hand dominance within the group.

Gross motor skills

Based on the Shapiro-Wilk test results, most of the outcome variables show p-values greater than 0.05, indicating that they follow a normal distribution.

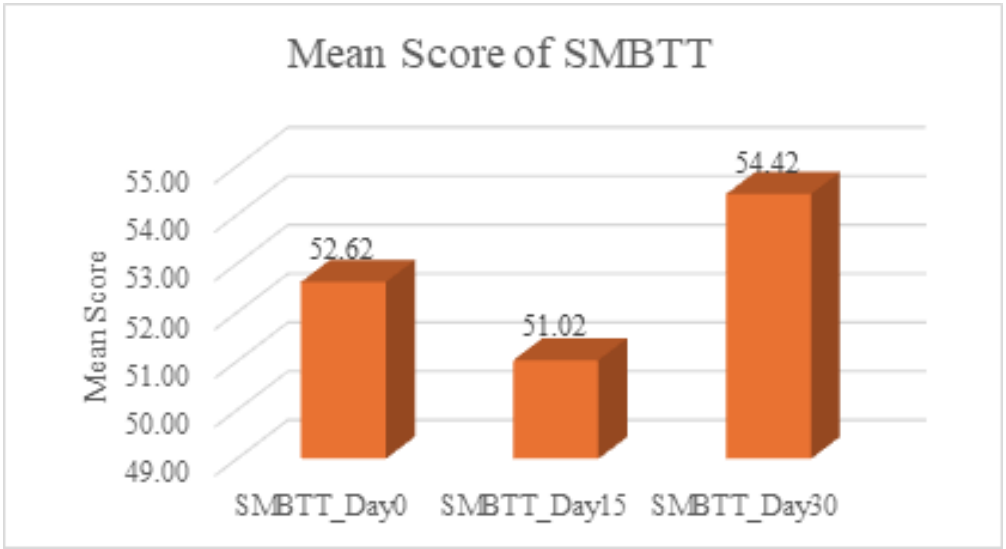
Single Leg Triple Hop Test (SLTHT)



Graph 3: Comparison of Mean scores of Single Leg Triple Hop Test among the participants

The comparison of SLTHT scores revealed no statistically significant improvement from Day 0 to Day 15 ($p = 0.200$) or from Day 15 to Day 30 ($p = 0.070$), despite slight increases in mean values. However, a statistically significant improvement was observed between Day 0 and Day 30 ($p = 0.043$), indicating a meaningful enhancement in SLTHT performance over the 30-day period.

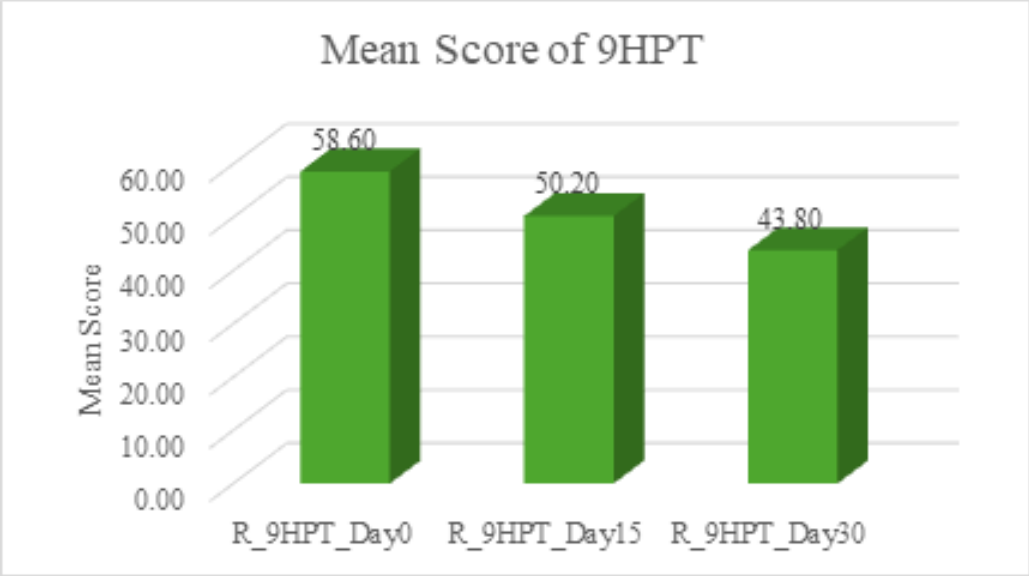
The Seated Medicine Ball Throw Test (SMBTT)



Graph 4: Comparison of Mean scores of The Seated Medicine Ball Throw Test among the participants

The analysis of SMBTT scores demonstrated no statistically significant change between Day 0 and Day 15 (p = 0.195). However, significant improvements were observed from Day 15 to Day 30 (p = 0.003) and from Day 0 to Day 30 (p = 0.037), indicating enhanced performance over time.

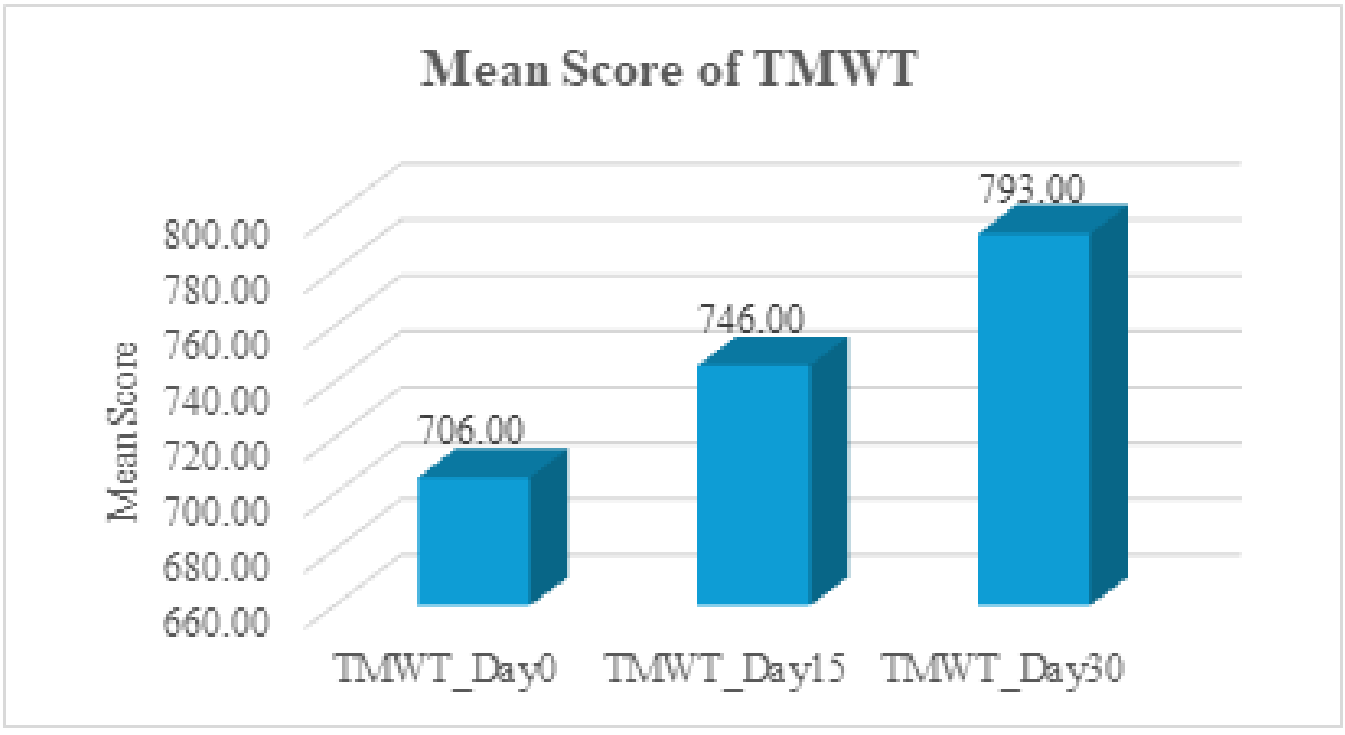
The Nine Hole Peg Test (9-HPT)



Graph 5: Comparison of Mean scores of Right The Nine Hole Peg Test among the participants

The 9-HPT scores showed statistically significant improvements across all time points, with performance enhancing from Day 0 to Day 15 (p = 0.033), Day 15 to Day 30 (p = 0.008), and Day 0 to Day 30 (p = 0.001), indicating progressive improvement in hand motor function.

The Twelve (12) Minute Walk/Run Test (TMWT)

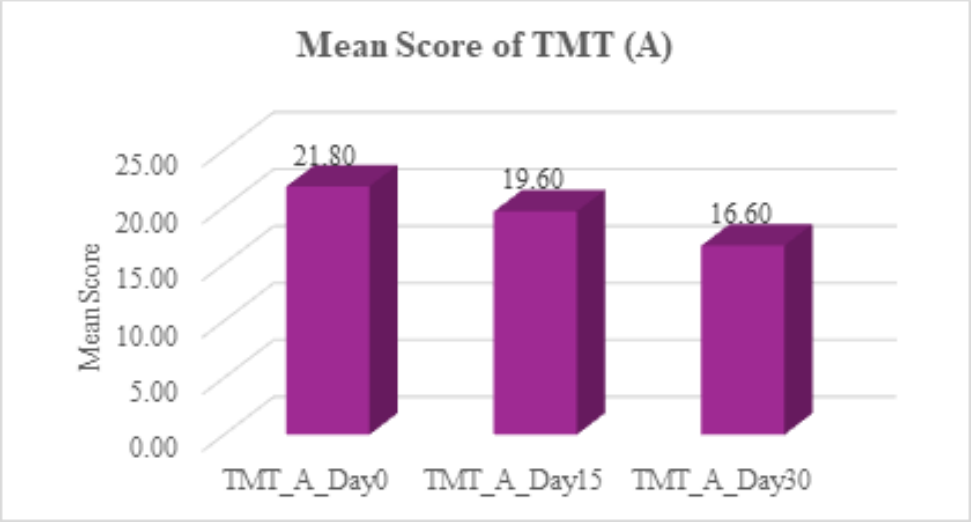


Graph 6: Comparison of Mean scores of 12 Minute Walk/Run Test among the participants

The Twelve (12) Minute Walk/Run Test scores demonstrated a trend toward improvement from Day 0 to Day 15 ($p = 0.058$), with statistically significant gains observed from Day 15 to Day 30 ($p = 0.046$) and from Day 0 to Day 30 ($p = 0.014$), indicating progressive enhancement in cardiovascular endurance and physical fitness.

The Trail Making Test

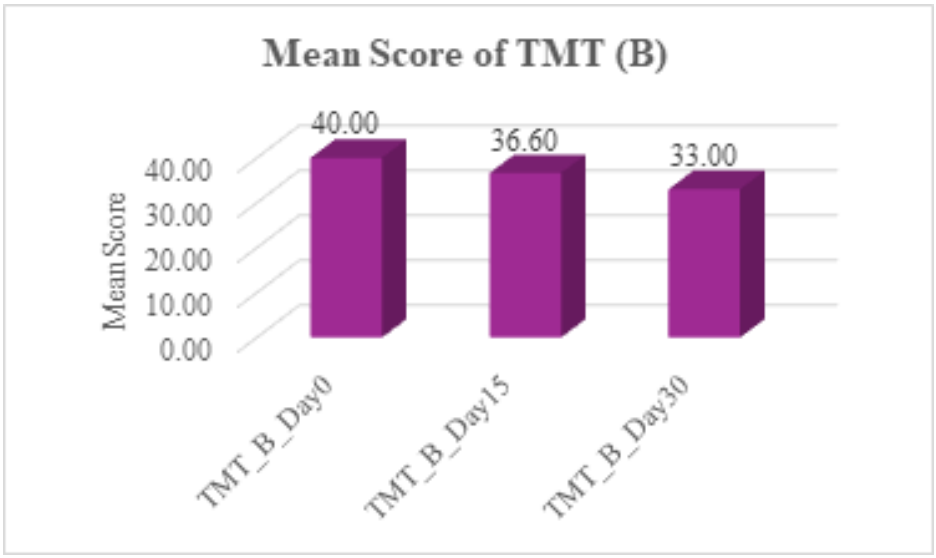
The Trail Making Test - A (TMT - A)



Graph 7: Comparison of Mean scores of Trail Making Test A among the participants

TMT-A scores showed statistically significant improvements across all intervals, with reduced completion times from Day 0 to Day 15 ($p = 0.020$), Day 15 to Day 30 ($p = 0.001$), and Day 0 to Day 30 ($p < 0.001$), indicating progressive enhancement in attention, cognitive processing speed, and visual scanning abilities.

The Trail Making Test - B (TMT - B)



Graph 8: Comparison of Mean scores of Trail Making Test B among the participants

TMT-B scores demonstrated statistically significant improvements across all time points, with reduced completion times from Day 0 to Day 15 ($p = 0.007$), Day 15 to Day 30 ($p = 0.002$), and Day 0 to Day 30 ($p < 0.001$), indicating marked and progressive enhancement in executive functioning and cognitive flexibility over the intervention period.

Analysis of all outcome measures indicates significant improvements across physical and cognitive domains over the 30-day intervention. SLTHT and SMBTT reflect enhanced limb strength and power, 9-HPT shows improved fine motor skills, TMWT demonstrates increased cardiovascular endurance, and TMT indicates better cognitive processing and executive function. These results suggest a positive, comprehensive impact of the intervention on participants' overall performance.

DISCUSSION

Attention Deficit Hyperactivity Disorder (ADHD) is an etiologically complexdisorder characterised by ore symptoms of inattention, hyperactivity and impulsivity beginning its course in childhood and can progress to adulthood as well (Choudary et al., 2013; Corteses et al., 2015). The worldwide prevalence of ADHD among children and adolescents is estimated to be 8.0%, with a 95% confidence interval ranging from 6% to 10%. Boys are approximately twice as likely as girls to receive an ADHD diagnosis (Gore & Morgan, 2025).

In this study, 60% of participants were male and 40% female, reflecting the higher ADHD prevalence in boys. This aligns with literature showing boys are diagnosed more often, with referral ratios ranging from 3:1 to 16:1 in clinical settings (Ayano et al., 2023; Young et al., 2020).ADHD is typically managed using psychoactive medications, psychoeducation, and therapy, with multi-modal approaches proving most effective (Young et al., 2020). High-frequency rTMS targeting the left DLPFC improves attention (Qian et al., 2025), while physical activity reduces anxiety, depression, and aggression, and enhances mood and social functioning. Therefore, the present study aimed to evaluate the effectiveness of rTMS in comparison to structured exercise programs in improving attention among school-going children diagnosed with ADHD.

The present study demonstrated significant improvements in motor performance, cognitive function, and attention following a 30-day intervention involving rTMS and structured exercises in children with ADHD. These findings are consistent with previous studies highlighting the benefits of such interventions. Improvements in gross motor skills and overall physical fitness align with the existing literature(Jeyanthi et al., 2021), who emphasized the effectiveness of structured physical activity in enhancing motor function in children with ADHD. Enhanced upper body strength and fine motor coordination observed in the present study further support the positive impact of targeted exercise interventions, (Jeyanthi et al., 2021). The marked increase in physical endurance aligns with existing literature (Canepa et al., 2020), suggesting that improved aerobic capacity can also contribute to better cognitive functioning. Moreover, significant gains in cognitive flexibility and processing speed, as demonstrated by performance on the TMT-A, support the use of rTMS and exercise in improving executive functions, consistent with existing evidence (Nigg et al., 2002). The observed cognitive and motor improvements may be attributed to enhanced neural plasticity and increased dopaminergic activity. (Holmes et al., (2009) (Strafella et al., 2001) (Levkovitz et al., 2001).

CONCLUSION

The study concludes that combining rTMS with structured exercises significantly improved attention and motor functions in children with ADHD, enhancing overall quality of life. rTMS was well-tolerated, with only minor side effects, supporting its efficacy and safety in this population.

DECLARATION OF COMPETING INTEREST

None.

ACKNOWLEDGEMENT

Nil.

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