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Influence of Therapy Ball Seats on Attentional Ability in Children with Attention Deficit/ Hyperactivity Disorder

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Abstract. [Purpose] The aim of this study was to investigate the P300 in electroencephalography (EEG) and the reaction time in children with attention deficit hyperactivity disorder (ADHD) during an auditory oddball task when sitting on a classroom chair or therapy ball. [Subjects] Fifteen ADHD children with a mean age of 8.6 ± 2.1 years and 14 healthy children with a mean age of 8.7 ± 2.0 years were used as subjects in this study. [Methods] All subjects were asked to sit on a chair or therapy ball and perform simultaneously the auditory oddball task. A portable 40-channel EEG system and a sound operating system were employed to record and analyze the EEG and button reaction time signals. [Results] When seated on the chair, the ADHD group had a significantly longer reaction time than the control group. ADHD children seated on a therapy ball showed a significant improvement in reaction time compared with when seated on the chair. In the parietal lobe, the ADHD group had a significantly delayed P300 latency during chair seating compared with the control group. The ADHD group showed a significantly shorter P300 latency time when seated on a therapy ball. [Conclusion] The therapy ball has a significant advantage for enhancing the attentional ability in children with ADHD.
Key words: ADHD, Therapy ball, Event-related potentials

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INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is the most frequently diagnosed neurobehavioral disorder in childhood[1)] and is considered a disorder of relative "under arousal"[2)]. It is diagnosed two to four times more frequently in boys than in girls. ADHD children often show smaller amplitude responses in the brain to stimuli and signs[3)]. These children also show a slower physiological reaction than normal children[4)], and their brains are thought to work at lower levels of excitement[5)]. The symptoms of ADHD would also interfere with academic performance. For example, an ADHD child refuses to comply with adults' requests, has difficulty sustaining attention during tasks, or is easily distracted in class.

Many forms of sensory-based theories have been applied to therapy for children with special needs. In clinical practice, sensory integration techniques are often used by occupational therapists to assess and treat the ADHD population[6)]. Besides the main symptoms, many children with ADHD also suffer from sensory modulation deficits, a neurological underpinning that contributes to their ability to pay attention or focus[7)]. This makes them unable to pay attention to a lesson in a noisy classroom, or participate comfortably in family activities. Sensory integration techniques (SIT) appeal to the three basic sensory systems: the proprioceptive system that regulates the awareness of the body in space, the vestibular system that controls sensations of gravity and movement, and the tactile system that controls the sense of touch[8)]. Sensory integration therapy is tailored to an ADHD child's needs and often involves such techniques as moving on swings or working with an exercise ball[9)]. Therefore, the therapy ball seat is a treatment option for ADHD children and is often selected to help prevent or minimize troublesome behaviors at school and as part of a rehabilitation program.

Through classroom observation, school-based therapists and the teacher reported that ADHD children needed to keep at least one foot in contact with the floor while seated on the therapy ball in order to maintain sitting balance, thus minimizing classroom disruption. Therapists sometimes suggest that an overexcited child may be calmed down by rocking gently on a ball. Previous studies have also reported that children using therapy balls in a classroom appeared to improve in terms of ability to listen and attend, sit longer, remain calm and focused, and are able to finish class work[9–11)]. Although the teachers reported improvements in class work for ADHD children seated on balls versus on chairs, and both direct and indirect investigations recommended the use of therapy balls as classroom seating for children with ADHD, little formal assessment has been performed. To our knowledge, only one published study[10] verified the effectiveness of using a therapy ball to improve in-seat behavior and legible work productivity in children with ADHD. In the past, many researchers have used event-related brain potentials (ERPs) as a tool to observe brain excitation in ADHD children during an auditory oddball task[3, 12–14]. These studies revealed a significant difference in disturbances for cognitive task-related brain activation between ADHD and normal children. The abnormal ERPs observed in ADHD children include a raised P2 amplitude, slower N2 and P3 latencies[4] and reduced N2 and P3 amplitudes[3, 5] to target stimuli. The P3 (also known as P300) electrical brain wave response is widely known and accepted in the scientific community. It is emitted by the brain within a fraction of a second when an individual recognizes and processes an incoming stimulus that is significant or noteworthy. Therefore, the latency of P300 is thought to reflect the time required for evaluation and classification of the eliciting stimuli[15, 16]. The P300 amplitude declines progressively when attention is diverted from the stimuli[17] or when the subject is uncertain about having correctly perceived the unexpected event[18, 19]. The present study evaluated the usability of therapy ball therapy in ADHD children by examining their P300s in EEG and their reaction time on a chair and therapy ball during an auditory oddball task. The EEG and performance results of ADHD children were then compared with those of the control group of healthy children.

SUBJECTS AND METHODS

Fifteen children (eleven boys and four girls) diagnosed with ADHD at a medical hospital or local rehabilitation clinic and without other combined syndromes, such as autism, were recruited. They had a mean age of 8.6 ± 2.1 years, mean height 128.01 ± 5.02 cm, and mean weight 30.8 ± 5.38 kg. Five ADHD subjects were treated with medicines for symptom control. However, all these subjects took drug holidays during the study. Fourteen age-matched children (7 boys and 7 girls, with a mean age of 8.7 ± 2.0 years, mean height of 133.22 ± 6.35 cm, mean weight of 31.02 ± 5.72 kg, and without neuromuscular disease) were recruited from a local school as the control group. There were no significant differences in mean age, body weight, and height between the two groups. Informed consent, approved by the university ethics review committee, was obtained from parents prior to participation in the study.

A 48-cm-diameter therapy ball at different degrees of inflation was used in this study to enable each participant to sit comfortably with his/her feet flat on the floor and with the knees and hips flexed to about 90 degrees. A plastic loop pipe was put under the therapy ball to provide stability and to keep the ball from rolling too much. The outer diameter, inner diameter, and total length of the loop pipe were 48.2 cm, 35.0 cm and 151 cm, respectively. It enabled the sway distance of the ball to be less than one centimeter in each direction. The therapy ball was soft, pliable, and capable of bouncing. The subjects could sit on it and bounce lightly. Its main function was to create an unstable surface. A general wooden classroom chair without armrests (height, 61 cm; depth, 38 cm; width, 30 cm; seat height, 32 cm) was borrowed from an elementary school. The sound operating system (STIM2 Acquisition Software, Compumedics Neuroscan, USA) was employed to provide a stimulus tone to the subject. A portable 40-channel EEG system (NeuroScan NUAMPS, Compumedics Neuroscan, USA) was utilized to record EEG data during the experiment. During reaction time (RT) and accuracy tests, a self-assembled radio telemetry handheld trigger was employed to signal a response. The stimulus tone, reaction signal, and EEG signals were recorded simultaneously on a notebook computer.

For EEG analysis, Ag-AgCl electrodes were placed at 3 medial electrodes (frontal [Fz], central [Cz], and parietal [Pz] according to the international 10–20 system, referenced to a linked earlobe electrode). and with a forehead electrode as a ground electrode. Impedances were maintained below 5 k ohm and measured from each lead at the beginning and end of each session. The participants got familiarized with the two different tones (2 kHz target tones and 1 kHz nontarget tones) before the formal test and were instructed to press the button with the dominant hand upon hearing a "high-frequency" tone signal. Each subject was also instructed to keep their most comfortable sitting position on the classroom chair or therapy ball during measurements.

Prior to the experiment, the subjects had 30 minutes to sit on the balls or classroom chair to get acclimatized to the experimental conditions. When sitting on the chair, the subjects were asked not to lean against the backrest. After that, a standard stimulus oddball procedure (auditory oddball task) was employed to elicit the late auditory-evoked potential and test the degree of attention for ADHD children and normal children. The participants were instructed to keep their arms hanging naturally down the side of his/her body and hold the radio telemetry handheld trigger with the dominant hand. They were then asked to press the button on the trigger as quickly as possible after hearing a "high-frequency (2 KHz)" target tone signal and to do nothing when they heard the "low-frequency (1 KHz)" nontarget tone signal. The experiment was divided into three test sessions for each seating condition (chair or ball). In total, there were 120 nontarget and 30 target tones presented for each seating condition, with the only constraint being that the two targets could not appear consecutively. The stimulus signal was programmed to trigger every 1.5 seconds. The rest interval was 60 seconds for each session. The total duration of the auditory oddball task was approximately 5 minutes for each seating condition. Each subject sat on a therapy ball or the chair in random order to avoid systematic effects of practice. They were allowed a rest period of five minutes during each transition to a new testing condition.

All signals from the stimulus tone, radio telemetry receiver, and EEG system were collected at 1000 Hz for 3.75 minutes. Reaction time (RT) was calculated from the difference in time between the onset of the stimulus tone signal and that of the trigger signal. The accuracy of responses was defined as the ratio of the number of correct responses to the total number of target tones. Auditory-evoked potentials in EEG measurement were recorded and filtered with a band-pass of 0.1–30 Hz. ERPs were made for 1200 ms, beginning at 200 ms prior to stimulus onset and 1000 ms after stimulus onset, with an amplification of 100 V/unit sensitivity. The ERPs for correct detections of targets were then across the across Pz, Cz, and Fz electrode positions in all participants. Finally, the P3 latencies and amplitudes were measured and averaged for the Pz, Cz, and Fz recordings, respectively.

A two-way repeated measures ANOVA was employed for statistical analysis of the data with one repeated measure factor, seating condition (chair and ball), and one independent measure factor, group (two groups). Neurophysiologic parameters (P300 amplitude and latency from ERP recordings), reaction time (RT), and accuracy of the choice task in tone discrimination were compared between the two seating conditions and between the two groups. All analyses were carried out using the SPSS 17.0 program. Results were considered statistically significant when the p-value was less than 0.05.

RESULTS

The reaction time and accuracy for each of the two groups and two seating conditions are shown in Table 1. The latency and amplitude of the P300 from three midline electrodes under the two seating conditions for normal children and ADHD children are shown in Table 2. The grand-averaged waveforms of ERP at three midline electrodes for the two groups are presented in Figure 1.

Normal children showed a faster reaction time under the chair condition than the ADHD children (445.90 ms vs. 536.73 ms, $p=0.003$, Table 1). The results also showed that ADHD children had faster reaction times when sitting on the therapy ball (457.92 ms vs. 536.73 ms, $p=0.01$). However, no statistically significant difference between the two seating conditions was observed in the control group.

In the parietal lobe, ADHD group had a significantly delayed P300 latency during chair seating compared with the control group (563.00 ms vs. 462.86 ms, $p=0.042$). The ADHD group showed a significantly shorter P300 latency at Pz when sitting on the therapy ball compared with sitting on the general classroom chair (490.80 ms vs. 563.00 ms, $p=0.046$).

DISCUSSION

Much research has recently focused on cognitive control and attention in children with attention deficit hyperactivity disorder (ADHD). The hypothesis for the present study stated that therapy ball seating will cause a change in the P300 in EEG and the reaction time in children with ADHD during an auditory oddball task, which can help determine the usability of this strategy for such children.

Information processing deficit in children with ADHD is always accompanied by markedly slowed reaction times. In this study, normal children indeed showed a faster reaction time under the chair condition than ADHD children (445.90 ms vs. 536.73 ms, $p=0.003$, Table 1). However, it was also found that the accuracy scores were not significantly worse in the ADHD group (97.60% vs. 97.07%, $p=0.884$, Table 1), suggesting that although it took them longer to process the cognitive task, their response accuracy was not affected. In other words, ADHD children in this study could inhibit their impulse activity when performing the oddball task, but such inhibition would interfere with their reaction time. The results also showed that ADHD children had faster reaction times when sitting on a therapy ball (457.92 ms vs. 536.73 ms, $p=0.01$), indicating that while ADHD children showed poorer reaction times in the normal class environment compared with normal children and that sitting on a therapy ball can help alleviate the situation. Through the therapy ball treatment, ADHD children showed significantly faster reaction times compared with when they sat on the chair. In addition, the difference in reaction time between the normal and ADHD children when sitting on the therapy ball narrowed and became insignificant (control: 463.62 vs. ADHD: 457.92, $p=0.604$). These results verified that changes in learning environment have a positive effect in enhancing the ability to focus and maintaining the attention of ADHD children.

According to the research results for ERPs, the ADHD group showed a significantly faster P300 latency at Pz when sitting on the therapy ball compared with sitting on the general classroom chair (490.80 ms vs. 563.00 ms, $p=0.046$). This result shows that using the therapy ball can increase the ability of the ADHD children to pay attention and decrease the difference between ADHD and normal children. Past research has shown that changing the sitting position can enhance the learning effect for ADHD children[20] and that using a therapy ball can improve in-seat behavior and legible work productivity in them[10]. These changes in behavior have now been verified by EEG and performance approaches. We can infer that when subjects sit on the ball, it creates an unstable surface. This activates the human proprioceptive and vestibular systems. As Schilling et al.[10] found, students appeared to use the stability balls as a form of "self-modulation of personal sensory needs." Movement and physical activity appeared to keep them in their seat and on their task. This explains why the students' attention increased.

When recorded by electroencephalography (EEG), the P300 signal elicited using the oddball paradigm is typically measured most strongly by the electrodes covering the parietal lobe[21]. The presence, magnitude, topography, and timing of this signal are often used as metrics of cognitive function in decision-making processes. Past research found an increased P300 latency[4] and decreased P300 amplitudes[3, 5] in ADHD children. In the present study, the P300 wave under the audio oddball tasks showed a similar tendency for an increase in P300 latency and exhibited a significant difference in the parietal lobes. A previous study[22] found that adolescents with ADHD presented significant impairments in their ability to allocate attentional resources. This impairment was associated with significant aberrations in the parietal attentional system. It is well known that the parietal atten-

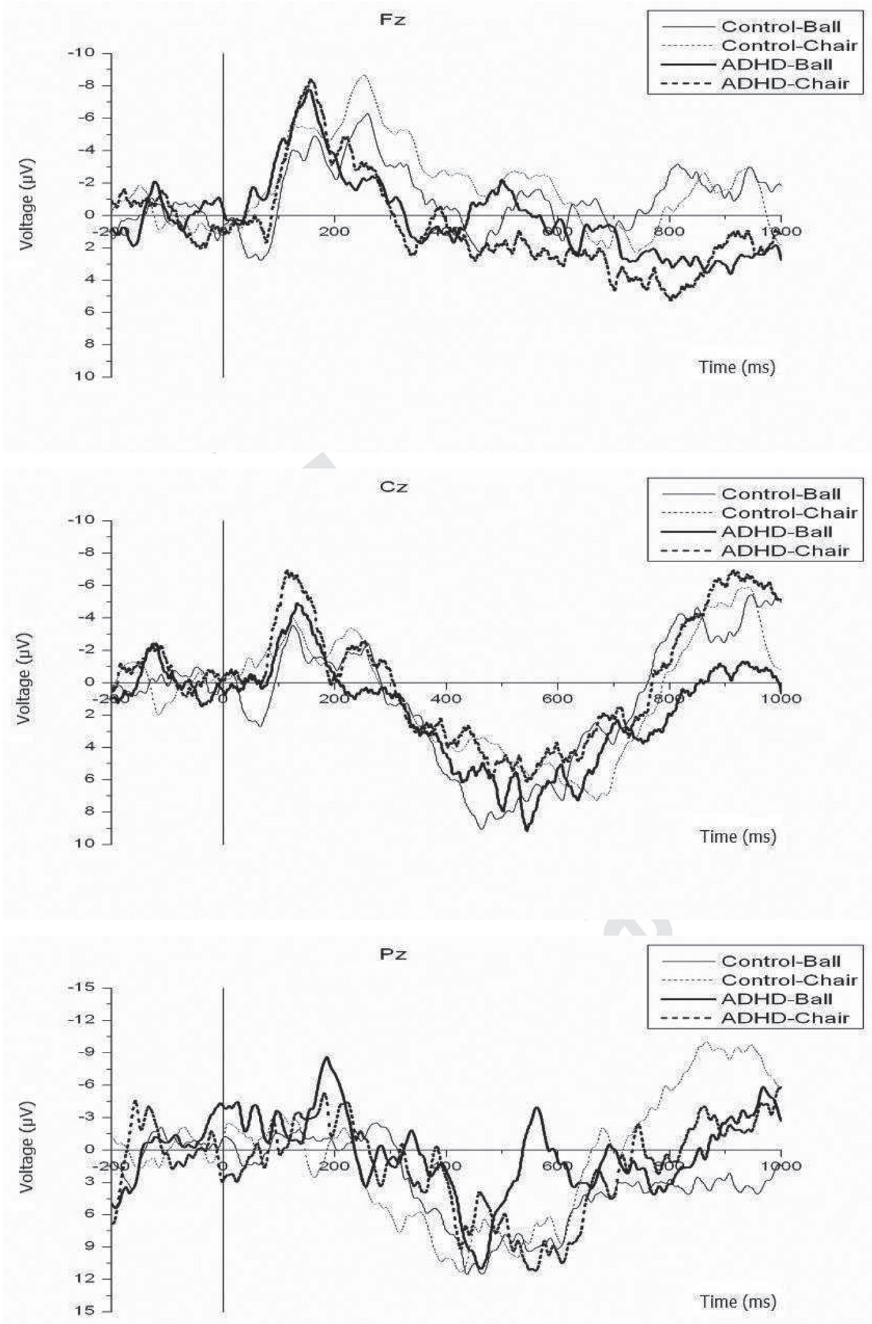

Fig. 1. Grand-averaged event-related brain potential waveforms for the auditory oddball task when sitting on the classroom chair or therapy ball.

tional system plays a significant role in attention shifting and detecting specific or salient targets. Thus, dysfunction in the parietal attentional system may lead to the poor ability in ADHD children to focus and maintain attention.

The findings of this study reveal that sensory integration equipment, i.e., a therapy ball, can indeed improve the attentional abilities of ADHD children. As we know, cognitive processing involves a sequence of responses in a variety of neural structures; faster processing thus reflects more integrated and efficient brain functioning. Higher integration of brain functioning is naturally associated with more integrated functioning of the physiology as a whole. Among the aspects of the sensory nervous system that are most intimately connected with brain functioning are the proprioceptive, vestibular, and tactile systems, which are under direct influence of the brain. Therefore, further studies are suggested to investigate how sensory integration techniques can influence development of the cognitive level when sitting on a therapy ball. Also, the present study, although preliminary, suggests an immediate effect of sitting

Table 1. Mean values of accuracy (%) and reaction time (ms) for controls and ADHD children under the two seating conditions

		Ball	Chair
Accuracy (%)	Control	97.10 (4.28)	97.60 (2.59)
	ADHD	96.71 (4.64)	97.07 (3.47)
Reaction time (ms)	Control	463.62 (30.12)	445.90 (36.36)#
	ADHD	457.92 (73.83)*	536.73 (83.94)

*Denotes $p < 0.05$ compared with the chair condition. #Denotes $p < 0.05$ compared with the ADHD group.

Table 2. Mean values of event-related potential amplitude and latency of P300 for controls and ADHD children under the two seating conditions

			Ball	Chair
Fz	Amplitude (μV)	Control	7.87 (4.56)	5.38 (5.79)
		ADHD	4.08 (5.20)	8.55 (5.73)
	Latency (ms)	Control	491.22 (75.53)	508.00 (72.54)
		ADHD	500.20 (71.35)	506.40 (65.71)
Cz	Amplitude (μV)	Control	14.05 (5.54)	10.99 (6.89)
		ADHD	10.79 (5.85)	11.33 (4.84)
	Latency (ms)	Control	483.78 (71.19)	479.44 (66.04)
		ADHD	498.50 (69.00)	525.10 (61.26)
Pz	Amplitude (μV)	Control	12.48 (7.23)	12.42 (5.11)
		ADHD	10.56 (4.84)	13.62 (4.53)
	Latency (ms)	Control	480.14 (72.01)	462.86 (48.74)#
		ADHD	490.80 (47.70)*	563.00 (31.27)

*Denotes $p < 0.05$ compared to chair condition. #Denotes $p < 0.05$ compared to ADHD group.

on a therapy ball on enhancement of attentional ability in children with ADHD, and indicates that further research into the sustainability of the effect may be warranted.

In conclusion, the result shows that children with ADHD have indeed poorer attentional ability than healthy children. In addition, therapy ball has a significant advantage in improving the attentional ability of ADHD children, thus enhancing indirectly the learning effect. The findings of this study also verify that changes in learning environment have a positive effect in enhancing the ability of ADHD children to focus and maintain attention.

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