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Original Article

Influence of Working Memory Task and Time on Postural Control of Children with Attention Deficit Hyperactivity Disorder

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Abstract: [Purpose] To investigate how balance changes develop across time under different conditions (with or without a memory task) for children with Attention Deficit Hyperactivity Disorder (ADHD). [Subjects and Methods] The participants were 11 children with ADHD and 12 normal children. To determine their static balance ability, a force plate was used to measure the center of the pressure trajectory. [Results] The length of the sway path became slightly greater in both groups when an additional memory task was added, but the difference was not statistically significant. However, it was interesting to note a significant difference in memory task ability across groups with increasing time. The ADHD group showed a decrease sway path with increasing time for the memory task, but in the control group it increased. [Conclusion] At first, the memory task interfered with ADHD children's performance; however, the memory task may improve their performance after a few seconds.
Key words: Attention-deficit/hyperactivity disorder (ADHD), Sway path, Mental task

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INTRODUCTION

Postural control is not merely a reflex, but demands attentional resources[1)]. Since postural control requires attention, it has been suggested that the deficits of ADHD children in memory performance, and inability to allocate sufficient attention[1)] to postural control may contribute to the trend of further deteriorating postural balance under multi-task conditions. Recent research[1)] on ADHD children has investigated their postural control under single and dual task conditions demanding auditory memory. They found that irrespective of single or dual task conditions, the ADHD children showed significantly poorer performance in balance tasks than controls. Both ADHD and control groups also showed a significant decrease in sway amplitude and area under dual task conditions. However, we know that not all cognitive tasks interact with postural control processing in the same way. Previous studies have indicated that more difficult tasks may result in greater COP displacements due to attentional competition[2, 3)]. We hypothesized that a visual memory task would interfere with a balance task much more than a verbal memory task, because postural control is assumed to involve visual/spatial processing. To the best of our knowledge, little research has as yet been conducted to analyze visual working memory interference with the postural stability of ADHD children. Moreover, the influence on selection strategies over time is unknown. Most studies have discussed the average sway behavior over a time period, and it is not clear whether the focus of attention shifts to postural control at some later time Understanding modification strategies may provide useful information for the development of treatment strategies for ADHD children. Therefore, this study aimed to compare static balance ability under different conditions (with and without a visual-memory task) of children with ADHD. To evaluate the dynamic of postural control, the data was further separated into two temporal phases: early-phase and late-phase.

SUBJECTS AND METHODS

Ten boys and one girl, with a mean age of 8.91±1.92 years, diagnosed by a local hospital as having ADHD, and without other combined syndromes such as autism, were recruited for this study. Before formal testing, ADHD-participant's parents were asked to complete Conners' Rating Scale-Re-

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vised (CRS-R) questionnaire to rate their child's behavior. The mean T-score of Conners' ADHD index for CRS-R assessment was 64.73±6.22. Five ADHD subjects were treated with medicines for symptom control. However, all of these subjects took drug holidays during the study. In addition, twelve children (8 boys, mean age 9.41±1.69 years) without ADHD symptoms or other neuromuscular symptoms, were recruited from a local school as the control group. Informed consent was obtained from parents prior to their children's involvement in the study, and the study was approved by the Ethical Review Committee of Kaohsiung Medical University.

Static balance ability was assessed by a Kistler force plate (Kistler Instrument Corp, Winterhur, Switzerland). Signals were sampled at a frequency of 400 Hz and used to calculate the centre of pressure trajectory. Participants were instructed to stand upright on the force plate in their bare feet, with their heels together and arms in a relaxed position at the sides of the body. Each participant was asked to keep the head erect and eyes open during the experiment. The investigation was conducted under two conditions: simple task (ST), memory task (MT) − ST combined with a memory task. During ST, each subject was asked to focus on a red spot of a 5 cm radius on a white wall at eye level two meters ahead of them. During MT, each participant had to additionally answer a series of mental questions shown on a screen (78 × 55 cm) over a 15-second period, one trial, in order to assess sustained attention. Four equal squares were shown on the screen, each containing a number randomly selected from one to nine. The Stim^2 stimulus system (Compumedics Neurosacn, USA) was used in this study to edit the series of mental tasks. A new question appeared on the screen every 3 seconds, and remained for only one second. After one second, all numbers disappeared and were replaced by a marker, randomly displayed on one square. The participant had to indicate the number originally at that position. The marker remained until a new question appeared. Participants' answers were recorded by the researcher. The response accuracy (%) was calculated. The duration of one trial was 15 sec for each condition, and the force plate data were analyzed from the 3rd second to the 13th second. Each subject performed three trials under each condition. All data of the COP_{AP} and COP_{ML} time-series were filtered using a low-pass filter with a zero-lag, a fourth-order Butterworth filter, and a cut-off frequency of 12.5 Hz[4]. Subsequently, the sway path was calculated using Matlab 7 software (The Math Works, Inc). The length of the sway path (SP) was estimated from each point of the COP trajectory using the following equation and data from the 3 to 13 seconds of each 15-second trial.

$$SP = \sum \sqrt{\left(\frac{X_n}{StdX} - \frac{X_{n+1}}{StdX}\right)^2 + \left(\frac{Y_n}{StdY} - \frac{Y_{n+1}}{StdY}\right)^2} \quad (1)$$

(X: the component of COP displacement in the medio-lateral direction; Y: the component of COP displacement in the anterior-posterior direction; n: represents a partition of the time; and Std X and Std Y are the standard deviations of X and Y, respectively).

Table 1. Demographic information and descriptive statistics of sway path (SP) and response accuracy (mean value with standard deviation in parentheses) under the simple task (ST) and mental task (MT) conditions

	ADHD (n=11)	Control (n=12)
Height (cm)	131.13 (11.08)	133.14 (8.37)
Response accuracy (%)	52.43 (21.03)	63.57 (19.06)
early-phase (3–8 s)	58.33 (38.83)	66.67 (32.53)
late-phase (8–13 s)	45.83 (30.54)	55.56 (27.21)
SP (mm)		
ST (3–12 s)	24.82 (5.94)	24.36 (4.15)
MT (3–12 s)	28.08 (5.53)	26.20 (3.34)
ST		
early-phase (3–8 s)	24.99 (6.52)	25.08 (4.64)
late-phase (8–13 s)	24.64 (5.81)	23.64 (3.69)
MT		
early-phase (3–8 s)	29.72 (5.85)	25.68 (3.43)
late-phase (8–13 s)	26.44 (4.98)	26.71 (3.35)
Increment ratio		
Simple task	0.01 (0.14)	−0.04 (0.201)
Memory task	−0.10 (0.15)	0.05 (0.091)*

* p value calculated using the Mann–Whitney test (ADHD vs. control) of less than 0.05

Moreover, each trial was separated into two temporal phases: 3–8 sec (early-phase) and 8–13 sec (late-phase) in order to investigate how balance changed over time. The increment ratio was calculated using the following formula:

$$\text{Increment ratio} = \frac{(\text{late phase} - \text{early phase})}{(\text{early phase})} \quad (2)$$

A positive value of increment ratio represented an increase in the length of SP; while a negative value indicated a decrease in the length of SP. A nonparametric independent t-test, (Mann-Whitney test) was used to detect differences in response accuracy, SP and the dynamic increment or decrement in values of SP between the groups. Wilcoxon's signed rank test was used to compare the differences in the values in each group. All analyses were performed using the SPSS 17.0 program (SPSS Inc.).

RESULTS

The result of the Mann-Whitney test shows a significant difference in the increment ratio of MT ($p<0.05$, Table 1) between the groups; however, no significant difference was found for ST. No other significant differences were found.

DISCUSSION

In this study, there were no significant SP differences between the groups under either condition. Although statistical analysis also indicated there were no significant differences between the conditions of ST and MT in the ADHD group ($p=0.14$) and the control group ($p=0.09$), there was

a tendency of increasing SP value in both groups when the memory task was added. Generally, when the memory task was added, subjects in both groups showed increased SP. Initially, the ADHD group and the control group showed similar total SP length for the ST (24.82 mm in the ADHD group; 24.36 mm in the control group). However, it is interesting to note that when the additional memory task was added, the SP value became slightly longer in the ADHD group (28.08 mm) than in the control group (26.20 mm). These findings demonstrate ADHD may influence postural control. The results were consistent with the findings from most previous research that children with ADHD show increased sway speed in the standing stability test under different conditions, or fall during the more difficult tasks due to impaired balance management[1, 5–9].

For the ADHD group, a difference in postural control was manifested between the two tasks. A negative increment ratio under the MT condition represented an improvement in postural control with time; however, this was not observed under the ST condition. Moreover, compared to the control group, the ADHD group showed a significantly smaller increment ratio of SP (Table 1, p=0.03). This suggests that postural performance improvement in the late-phase when faced with a memory task occurred in the ADHD group, but not in the control group. Attention shift to balance control or enhanced balance control by reinforcing balance automaticity[6] may both be potential factors attenuating body sway in the ADHD group. Our results suggest that ADHD children probably shift the focus of their attention from a cognitive task to a postural task at a later time so as to improve their postural control after that. The experimental results indicate that a shift away from the cognitive task led to a slight decrease in response accuracy (58.33 vs. 45.83).

The findings of this study contribute to our understanding of postural control in children with ADHD and may also offer some information for therapists for the design of suitable training methods.

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