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Original Article

The effects of additional cognitive and motor tasks on static and dynamic balance in school-age children

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Abstract

Aim: To evaluate the effects of dual-tasks on balance in school-age children aged 7-10 years.

Materials and Methods: In the present study, 28 primary school children aged 7-10 years were included. Static and dynamic balances were evaluated separately without any additional task and also in the presence of additional cognitive and motor tasks. The Sharpened Romberg Test and the One-Leg Stance Test were used to evaluate the static balance. The Five-Repetition Sit-To-Stand Test was used to evaluate dynamic balance. As a cognitive additional task, the children were asked to say "Yes" when they saw the red card and "No" when they saw the blue card. The motor additional task was designated as catching a ball.

Results: In the static balance tests, the scores performed in the presence of an additional cognitive task were higher than those obtained without any additional task. However, this difference was not statistically significant ($p>0.05$). Test scores obtained with an additional motor task were significantly lower than those obtained without any additional task ($p<0.001$). In the Five-Repetition Sit-to-Stand Test, the scores obtained in the presence of additional cognitive ($p = 0.003$) and motor ($p = 0.002$) tasks were significantly higher than those obtained without any additional task.

Conclusion: In our study, an additional motor task performed simultaneously with static balance tests negatively affected balance performance in children aged 7-10 years. Postural control also reduced by additional motor or cognitive tasks during the dynamic balance tests. The results obtained in this study will contribute to understanding the relationship between cognition and balance system in children.

Keywords: Balance; children; cognition; dual-task

INTRODUCTION

In order for individuals to maintain balance, they must perceive the stimuli in the environment and react appropriately to environmental changes, and maintain the center of gravity on the support surface. Balance is a complex process requiring interaction among proprioceptive, visual, vestibular, and cognitive systems (1). Many structures, from vestibular nuclei to the cerebral cortex, play a role in this process through vestibular reflexes (2).

In daily life activities, balance is achieved simultaneously with motor and cognitive tasks. Performing two tasks at the same time is called dual-tasking, while performing more than two tasks at the same time is called multi-tasking (3). Talking while walking, singing while cleaning, walking while carrying a tray, listening to music while running, and chatting with others while driving are examples of dual-tasks performed in daily life. During these activities, the individual needs cognitive processing more than ever (4, 5).

In order for the individual to perform both tasks properly in dual-tasks, the sources of attention are divided into two, which affects individual's balance performance (5). Performing a task simultaneously along with the primary task increases the demand for attention, and if processing capacities are exceeded, it can lead to an interference between the two tasks. This condition manifests itself in poor performance in one or both tasks. O'Shea et al. (2002) maintains that dual-tasking performance demands the focus of attention of the primary task as well as the execution of the secondary task (6). Dual-tasks include cognitive-motor or motor-motor interactions. (7).

In recent years, double task studies investigating the relationship between balance and cognitive system

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have gained importance (8). Studies have focused on the importance of using cognitive resources in providing postural control (9-13). In these studies, whether postural stability and cognitive performance are affected by each other has been investigated (2,7,9,14-18). However, such studies in the literature are mostly on adults and older adults. There are limited studies on whether dual-tasks affect balance functions in healthy children, and these studies have yielded varying results (10). Studies in which different auditory or visual stimuli are used as an additional task or tasks with different difficulty levels are implemented show that dual task performance varies according to the difficulty level of the tasks used and the type of stimulus used (auditory or visual stimulus) (10,19-21).

The aim of this study was to evaluate the effects of additional motor and cognitive tasks on balance in school-age children aged 7-10 years.

MATERIALS and METHODS

The study included 28 primary school children volunteers (13 girls, 15 boys) who were between the ages of 7 and 10 and studying at Ahmet Barındırır Primary School in 2018-2019 academic years. Those with any orthopedic, neurological, psychiatric, or cognitive problems, those with a vision problem that may affect balance, those with an ear disease or a history of ear surgery, and those without parental consent were excluded from the study. Information belonging to the child obtained from the family and the teacher (history of any orthopedic, neurological, psychiatric, or cognitive problems, vision problems that may affect balance, and history of ear disease or ear surgery) were recorded, and one child with dyslexia was excluded from the study. The study was completed with 28 participants. The study started after the "Informed Consent Form" was obtained from each child and parents included in the study. In our study, an in-group evaluation was performed. The research design was a Single Group Pretest-Posttest Experimental Design. This study was approved by Baskent University Institutional Review Board and Ethics Committee (Project no: KA18/395) and supported by Baskent University Research Fund.

The study was carried out in a quiet room at Ahmet Barındırır Primary School. The effects of additional cognitive and motor tasks on static and dynamic balance were assessed.

Evaluation of Static Balance

Static balance was evaluated with the Sharpened Romberg Test and the One-Leg Stance Test. For static stability assessments, a 45 mm x 100 mm paper tape was adhered on a hard surface across 100 cm. The purpose of the tape was to mark the point where the child should stand during the assessment. In both tests, the test was terminated when the child's foot/feet were out of the specified line.

The Sharpened Romberg Test was administered in a free position with eyes open and arms at sides. The child was asked to stand upright on the line, with the right foot in front of the left foot in the heel-to-toe position. The time period the child stood in the indicated position on the line was recorded using a stopwatch. The time was stopped when the child's foot/feet were out of line, that is, when the child lost balance. The measured time was recorded as the score. The test was terminated if the child maintained balance for 5 minutes (300 seconds).

In the One-Leg Stance Test, the child was asked to stand upright in a free position with open eyes and arms at sides on a point marked by paper tape. Just before starting the test, the child was asked to raise one foot and not touch that foot on the ground. At the same time, the child should not receive support from anywhere by hands or body. The time that the child could stand at the specified point in this position was determined with a stopwatch and recorded. The time was stopped when the child moved his/her foot beyond the specified point or when the other foot touched the ground/other leg. The test was terminated if the child maintained balance for 2 minutes (120 seconds).

Evaluation of Dynamic Balance

Dynamic stability was evaluated by the Five-Repetition Sit-To-Stand Test. Pardo et al. (2013) examined the validity and reliability of the Five-Repetition Sit-to-Stand test, which is used to measure dynamic balance. According to the results, the reliability coefficient of the test was calculated as 0.87. The researchers stated that this value is sufficient for the validity and reliability of the test (22). The Sit-to-Stand test is a valid and reliable test that is suitable for use in children. It is an easy-to-apply test and can be completed in a short time. Postural control evaluation can be made with the Sit to Stand test and the most common one is the Five-Repetition Sit-to-Stand test (23). In the tests performed with additional cognitive and motor tasks in our study, considering the conditions such as fatigue factor, attention span, and the test environment, the Five-Repetition Sit-to-Stand test was preferred. In this test, a fixed chair without armrests, which is also suitable in the height for the children was used. In this test, the child was asked to sit on and stand from the chair 5 times, and the time was measured with a stopwatch. At the 5th stand-up, the stopwatch was stopped and the total time was recorded as a score.

Static and dynamic balances were evaluated separately with and without the presence of additional motor and cognitive tasks. Visual information was used during additional tasks, so static and dynamic balance tests were performed eyes open. The tests were administered in random order with three-minute rest breaks between each test.

Additional Cognitive Task

Simultaneously with the static and dynamic balance tests, the participants were assigned an additional cognitive task. Blue and red cards (210 x 297 mm) were used for the cognitive additional task. During the static and dynamic balance tests, the red and blue cards presented randomly to the children and they were asked to say "Yes" when they saw the red card, and "No" when they saw the blue card.

Additional Motor Task

Simultaneously with the static and dynamic balance tests, the participants were given an additional motor task. A plastic ball with a diameter of 65-67 cm was used for the additional motor task. During the static and dynamic balance tests, the child was asked catch the ball thrown by the researcher, who was 2 m away from the child.

Sample Size Analysis

According to the results of the power analysis made with GPower 3.1, for the effect size (Cohen f) to be small, the partial n^2 value was taken as 0.06 and the effect size was found to be 0.2526456. The required sample size was found to be 27 with effect size = 0.2526456, $\alpha = 0.05$ error level, and $(1-\beta) = 0.80$ test power.

Statistical Analysis

In comparison of two continuous variables, in dependent groups, if the assumptions of parametric tests were provided, One-Way Analysis of Variance was used in repeated measures. If not provided, assumptions were evaluated using the Friedman Test. In independent groups, one-way ANOVA used if the assumptions of parametric tests were provided, and Kruskal-Wallis Variance Analysis was used when the assumptions were not provided. A p value of less than 0.05 was considered significant for statistical significance. It was examined whether there was a difference in balance scores in school-age children in two conditions: without any additional task and in the presence of additional cognitive and motor tasks. In case of a significant difference, the Tukey Test, one of the Post Hoc tests, was used. Statistical analysis of the research data was performed using the IBM SPSS (Statistical Package for the Social Sciences) 25.0 package program.

RESULTS

When the participants were grouped according to their age, 17.9% were 7 years old, 21.4% were 8 years old, 39.3% were 9 years old, and 21.4% were 10 years old (Figure 1).

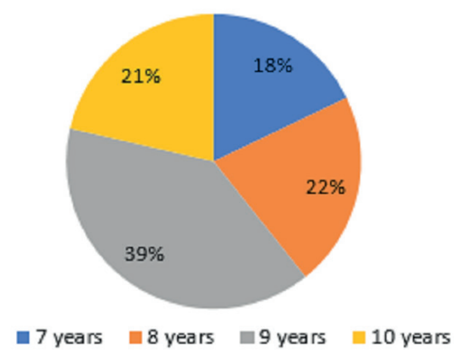

Figure 1. Distribution of the participants by age groups

Table 1. Comparison between static balance test scores obtained without additional task and those obtained with additional cognitive and motor tasks

Sharpened Romberg Test Score (Mean±SD)		One-Leg Stance Test Score (Mean±SD)	
197.04±21.69 sec		63.89±7.80 sec	
Sharpened Romberg Test score with Additional Cognitive Task (Mean±SD)	Sharpened Romberg Test score with Additional Motor Task (Mean±SD)	One-Leg Stance Test score with Additional Cognitive Task (Mean±SD)	One-Leg Stance Test score with Additional Cognitive Task (Mean±SD)
222.27±21.01 sec	88.94±18.17 sec	78.87±7.33 sec	23.72±4.5 sec
P	P	P	P
0.372	0.000	0.105	0.000

SD: Standard Deviation

Table 2. Comparison of dynamic balance test scores obtained without additional task with scores obtained with additional cognitive task and motor task

Five Repetition Sit-To-Stand Test Mean±SD	
10.36±2.43 sec	
Score for Five Repetition Sit-To-Stand Test with an Additional Cognitive Task (Mean±SD)	Score for Five Repetition Sit-To-Stand Test with an Additional Motor Task (Mean±SD)
10.03±0.66 sec	9.60±0.37 sec
P	P
0.003	0.002

SD: Standard Deviation

In the present study, the Sharpened Romberg Test and the One-Leg Stance Test were used to evaluate static balance. In the Sharpened Romberg Test performed with an additional cognitive task, the scores were higher than those obtained without any additional task. However, this difference was not statistically significant (p = 0.372). In the Sharpened Romberg Test performed with an additional motor task, the scores were lower than those obtained without any additional task. This difference was statistically significant (p<0.001) (Table 1). The Sharpened Romberg Test scores obtained with the additional cognitive task were found to be significantly higher than those obtained with the additional motor task (p<0.001). In the Sharpened Romberg Test, the additional motor task was determined as the parameter that made the difference.

The One-Leg Stance Test scores obtained with an additional cognitive task were higher than those obtained without any additional task. However, this difference was not statistically significant ($p = 0.105$). The One-Leg Stance Test scores performed with an additional motor task were lower than those obtained without any additional task. This difference was statistically significant ($p<0.001$) (Table 1). The Single Leg Stance Test scores obtained with the additional cognitive task were significantly higher than those obtained with the additional motor task ($p<0.001$). In the Single Leg Stance Test, the additional motor task was determined as the parameter that made the difference.

In the Five-Repetition Sit-To-Stand Test conducted with an additional cognitive task, the scores obtained were higher than those obtained without any additional task. This difference was found to be statistically significant ($p = 0.003$). In the Five-Repetition Sit-To-Stand Test conducted with an additional motor task, the scores obtained were higher than those obtained without any additional task. This difference was found to be statistically significant ($p = 0.002$) (Table 2). In the Five-Repetition Sit-To-Stand Test, no significant difference was found between the additional motor task and cognitive task ($p = 0.923$).

DISCUSSION

Seven-to-9 years old children begin to use a gravitational reference frame similar to adults, and they separate upper limb movement from the trunk. This age period is seen as a critical period when children master postural control, develop an internal representation of the body scheme, and master the eccentric orientation of body parts in space (24).

In the present study, in the static balance tests (Sharpened Romberg Test and One-Leg Stance Test), the test scores performed by assigning an additional cognitive task were higher than those obtained without any additional task. However, this difference was not statistically significant ($p>0.05$). Test scores obtained by assigning an additional motor task were significantly lower than those obtained without any additional task ($p<0.001$). The test scores obtained with additional cognitive ($p = 0.003$) and motor ($p = 0.002$) tasks in the Five Repetition Sit-To-Stand Test were significantly higher than those obtained without any additional task.

Studies on the effects of cognitive activity on postural control have gained popularity in recent years. In order to emphasize the importance of higher-level cognitive functions, researchers have focused on the relationship between dual-task performance, attention network, and executive functions, such as planning and distraction of attention (25,26). The importance of using cognitive resources during standing is emphasized (9). Studies have reported different results regarding the effect of cognitive activity on postural stability in adults and older adults (2,7,9,14-18). However, there are limited number of dual-task studies in children, especially investigating the relationship between cognition and balance (10). Few studies in children are also dual-task studies involving motor – motor interactions (27) or in which children are given additional cognitive tasks during straight-forward walking (11-13). Coordinating motor and cognitive tasks during a dual-task can result in performance degradation in one or both tasks. This occurs when two tasks interfere with each other, which is thought to be due to capacity limitation in cognitive abilities, which is known as a cognitive-motor interference (28). A limited number of studies showing the effects of age on the ability to coordinate motor–motor (27) and motor–cognitive tasks (10-13) have reported different results in children. Children perform dual-tasks in their daily lives in many settings, such as moving from room to room while carrying an object, writing while listening to the questions asked by the teacher in the classroom, and dribbling while looking for a teammate during sports. The ability to complete such tasks without errors requires attention and task prioritization. So, all tasks can be completed efficiently (29).

Otte and Mier (2006) conducted a dual-task study in which the participant performs a different task with each hand simultaneously. In this study, they asked 40 right-handed children aged 4, 5-6, 7-8, and 9-11 years to touch the shapes using their nondominant hands, and to follow a circle or square as quickly as possible using their dominant hands at the same time. Researchers evaluated the differences between one-handed and two-handed performances. The results showed that, consistent with developmental progress, tactile and tracking performance increased with age. Overall, it was found that children performed better in non-dual-tasks using the dominant hand. They suggested that tasks involving temporal matching involving the use of both hands are related to the subcortical areas or the anterior part of the corpus callosum (27). Baumgartner and Sumter (2017) investigated computer-based multi-tasking differences in 160 adults (65 males and 95 females) aged 18-75 years and 164 children (80 males, 84 females) aged 6-13 years. In addition, the study investigated how attention problems are related to computer-based multi-tasking. In four computer-based tabs, one main cognitive task and three separate distracting tasks were given. The study showed that children aged 6 to 13 years had difficulty focusing on the main activity in the presence of engaging media distractors. The study reported that children were distracted faster than adults, the time they stayed on the main task was shortened, and they made rapid transitions between tasks (30).

Baumgartner and Sumter used a cognitive single main task and cognitive additional tasks in their study. In our study, we used static and dynamic balance tests and additional cognitive and motor tasks. When children were given additional motor tasks during static balance tests, their test scores decreased; that is, their balance time got shortened. Likewise, when additional cognitive and motor tasks were given separately during dynamic balance tests, the duration of children to stay in balance got shortened.

In the present study, similar to the work of Baumgartner and Sumter, with the addition of the motor task to static balance tests, and adding motor and cognitive additional tasks to the dynamic balance test, the kids had difficulty concentrating on the main task and maintaining postural stability (30).

Hagmann et al. (2016) examined age-related gait characteristics and focused on gait variability in single- and dual-task walking in 138 children (62 girls, 76 boys) aged 6-13 years, and examined the effects of dual-task on cognition and gait. It was observed that walking was negatively affected and walking speed slowed down in dual-task conditions compared to walking with a single task (12). Schaefer et al. (2010) conducted a similar study in children aged 9 years and young adults no more than 25 years old, and the participants were given cognitive tasks while walking on the treadmill and their movements were observed. Some numbers were announced to the participants both verbally and on the screen while they were walking on the treadmill. They were asked to say "yes" when the number they saw on the screen and the number they heard were the same. Step length and step time variability decreased in young adults with increasing cognitive load, while they increased in children. While the cognitive performances of the participants remained constant while sitting or standing, or moving at a constant speed; it was observed that their cognitive performance improve more while moving at the speed they want (13). In the present study, when an additional cognitive task was added to the static balance tests of the children, their duration of staying in balance was prolonged, which shows that children focus on achieving postural control in the presence of an additional cognitive task during static balance tests.

Fabri et al. (2017) conducted a study in 106 healthy children and adolescents (53 men, 52 women) aged 5-18 years, and they divided the participants into two groups: 5-11 age group (74 participants) and 12-18 age group (32 participants). The participants were given a motor assessment as a single task, cognitive assessment as a single task, and motor-cognitive assessment as a dual-task. Four tasks were assigned as a motor task, with eyes open and eyes closed on a solid surface, and eyes open and eyes closed on a foam surface. As a cognitive task, when the orange balls of the three-dimensional orange and yellow balls turned to yellow and their location changed, the participant was asked to find the orange-colored balls. In the dual-task, the motor task was performed only with eyes open in order to apply the cognitive task. Dual-task conditions resulted in decreased postural stability on the foam surface with greater variation. Postural stability decreased under dual-task conditions, but attention was maintained. Specifically, the difference between single and dual-task trials did not significantly affect the number of correct responses in measuring attention. Important findings were revelated in that older participants performed better both in postural stability and in attention (10).

In the present study, unlike the study by Fabri et al., when additional cognitive tasks were given during static balance tests applied on a hard surface, the duration of balance prolonged in children aged 7-10 years. In the literature, different results have been obtained on postural control-cognition in dual-task studies with children. One of the reasons for this difference in dual-task studies is the differences in the motor and cognitive additional task difficulty levels. An easy cognitive task can take the focus of attention away from postural control, leading to better postural control than a single task without cognitive load. However, a difficult cognitive task can cause postural release to be disrupted (10,19). Since the aim of the present study was to evaluate balance performance, a task that children could do without difficulty was chosen as a cognitive task. In the present study, low cognitive load during static balance tests may have increased balance performance.

Another reason why the results of dual-task studies differ from each other is that auditory tasks are used in some studies and visual tasks are used in others. In a study by Demirci et al. (2016) conducted in 25 patients between the ages of 20 and 50 years, the additional task was that when the clinician says 'blue', the person is asked to say 'No', and when s/he says 'Red', the person is asked to say 'Yes', which is an auditory stimulus. In the present study, the additional cognitive task was that the children were asked to say "No" when they saw the blue card, and "Yes" when they saw the red card, which was a visual stimulus (20).

Bonnet and Baundry (2016) conducted a review study to explain the effect of active visual tasks on postural control and reported that postural sway decreased during active visual tasks in young adults compared to controls (31). The researchers stated that the reason for this decrease is the synergetic relationships between the postural and visual systems (31,32). In the present study, the reason for observing a decrease in the time to stay in balance with the cognitive additional task along with visual stimuli in the dynamic balance test may be that, in Five-Repetition Sit-To-Stand Tests together with head and trunk movements, there is vestibulo-ocular reflex (VOR) involvement in visual attention tasks. In static balance tests, unlike the dynamic balance tests, the visual attention task given to children as an additional cognitive task prolonged the period of staying in balance. The purpose of VOR is to keep the visual field constant during head movements. This result obtained in the static balance tests is thought to be due to the fact that the head movements are restricted as much as possible and the children are asked to maintain their constant balance and the VOR influence is much less compared to the dynamic balance tests.

Explanatory theories and models have been developed to explain the different findings in the literature (5,19,33,34). In our study, the capacity is divided between different sensorimotor tasks when it is necessary to maintain postural control while performing the motor task simultaneously with the static and dynamic balance tests. Likewise, attention is divided between sensorimotor and cognitive tasks when it is necessary to maintain balance while simultaneously performing cognitive tasks with dynamic balance tests. According to the capacity allocation theory, cognitive-motor interaction consists of a finite processor that divides resources between tasks. This situation shows that the capacity for each task is reduced, further reducing the dual-task performance (34). In the present study, in case of the presence of additional motor tasks during static balance tests and the presence of additional cognitive and motor tasks during dynamic balance tests, the duration of balance may have been shortened due to capacity sharing. According to the competition model between domains, postural control and cognitive activity compete for sources of attention, thus postural performance in dual-task conditions varies compared to the single postural task performance. Due to the sharing of the source of attention, balance performance decreases in dual-task conditions (5). The inter-domain competition model also explains why balance performance decreases when motor tasks are performed simultaneously with static balance tests and when motor or cognitive tasks are performed simultaneously with dynamic balance tests. Şeker (2015) examined the variables affecting dual tasks and reported that factors such as gender, education, and geographical region did not results in statistical significance (35).

LIMITATIONS

One of the limitations of our study was the inability to reach a sufficient sample size to compare cognitive and motor additional tasks and static and dynamic balance performance in relation with gender and age. Since different age groups could not be compared in our study, age-related effects of additional cognitive and motor tasks on balance could not be revealed. Also, dual-task performance was not compared using additional tasks with different degrees of difficulty. Using additional tasks of different difficulty levels can affect balance performance. Further studies with additional tasks of different difficulty levels, both visual and auditory, and with participants of different age groups, such as children, young adults and seniors, are recommended. Information about the participants had cognitive problems or not was obtained from the parents and the teacher via an information form. Before the tests were applied, more comprehensive evaluations of the cognitive skills of the participants are recommended in future studies.

CONCLUSION

In conclusion, in our study, the motor task performed with static balance tests negatively affected balance performance in children aged 7-10 years. Likewise, postural control was reduced by assigning additional motor or cognitive tasks during the dynamic balance tests. The results obtained from this study will contribute to understanding the relationship between cognition and balance system. At the same time, based on the effect of motor and cognitive additional tasks on the balance system, it is thought that it will help the rehabilitation process of children with disability. Understanding the relationship between cognition and the balance system in children with attention deficit hyperactivity disorder is also important in establishing intervention programs.

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