Journal of Iranian Medical Council, Volume 7, Issue no 4
http://dx.doi.org/10.18502/jimc.v7i4.16625

Check for updates

The Effect of Single-and Dual-Task Exercises on Functional Balance of Children with Autism Spectrum Disorder: A Randomized Clinical Trial

Maryam Yaghoubi[1], Parvin Raji[1]*, Seyedeh Tahmineh Mousavi[1], Hajar Mehdizadeh[1], Saeed Hadigol[2] and Fatemeh Salmani[3]

1. Department of Occupational Therapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran
2. Iran Autism Association, Tehran, Iran
3. Department of Epidemiology and Biostatistics, Faculty of Health, Birjand University of Medical Sciences, Birjand, Iran

*** Corresponding author**

Parvin Raji, PhD
Department of Occupational Therapy, School of Rehabilitation, Tehran University of Medical Sciences,Tehran, Iran
Tel: +98 21 7753 8798
Email: praji@tums.ac.ir

Received: 8 Nov 2023
Accepted: 30 Dec 2023

Citation to this article
Yaghoubi M, Raji P, Mousavi ST, Mehdizadeh H, Hadigol S, Salmani F. The Effect of Single-and Dual-Task Exercises on Functional Balance of Children with Autism Spectrum Disorder: A Randomized Clinical Trial. *J Iran Med Counc.* 2024;7(4):634-44.

Abstract

Background: Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder. According to the DSM-V, this condition has a variety of symptoms including impaired social relationships, and behavioral disorders. Various studies have shown that these children also have balance problems that are rarely investigated in this population. The purpose was to investigate the effect of single- and dual-task exercises on the functional balance of these children.

Methods: The study design was a clinical trial research. The participants were 40 children with ASD (9 to 14 years) who were randomly divided into two groups. The single-task exercise group only performed balance exercises, while the dual-task exercises group performed both balance exercises and cognitive tasks at the same time. The sessions consisted of 45-*min* sessions (3 times a week for 4 weeks). The functional balance tests were performed before and after the intervention.

Results: There were no significant differences between two groups in the Timed Up and Go test, 10-meter walk test and Mini-BESTest endpoint of the study, but there was a significant difference in Pediatric Berg Balance Scale (p=0.01, effect size=0.82). Dual-task exercises could not cause significant improvements in the functional balance of the participants compared to the single-task group.

Conclusion: It seems that evidence that dual-task exercises cause significant improvements of functional balance of the participants compared to the single-task group is inconclusive.

Keywords: Autism spectrum disorder, Child, Cognition, Diagnostic and statistical manual of mental disorders, Humans, Postural balance, Time and motion studies, Walk test

Copyright © 2024, Journal of Iranian Medical Council.
This work is licensed under a Creative Commons Attribution–NonCommercial 4.0 International License.

Introduction

Autism Spectrum Disorder (ASD) is a range of disorders, characterized by a series of symptoms, including limitations in communication, social interactions, and repetitive patterns of behavior, interests, and activities. These symptoms can vary from mild to severe. The prevalence of ASD in the United States is reported to be 1 per 68, while in Iran, it is 95.2 *per* 10,000 individuals (1).

Some studies indicated that children with ASD also experience difficulties with motor function (2-4) including clumsiness (5), impaired balance and bilateral coordination (6), slower walking and dysrhythmia in hand and foot (7), and impairment of postural stability (6). These motor deficits can lead to various consequences such as abstinence from activities, reduced concentration, low self-esteem, poor academic performance (8), and cognitive impairments (4). Enhancing motor skills is, therefore, an important goal of rehabilitation for these children, as it allows them to have more opportunities for physical activity with their peers (9). Among motor problems, postural control and balance have been the focus of attention in recent years, and studies have shown that the center of pressure excursion and mean velocity were greater in these children than in typically developing peers (10,11).

Studies have demonstrated that postural and balance control require high concentration (12). One of the most important training methods to enhance postural control is cognitive-motor training (13). This training allows the examination of the relationship between motor and cognitive function during cognitive-motor interventions using a dual-task paradigm (14). The dual-task paradigm in rehabilitation is designed to provide the individual with real-life conditions (15) such as talking over the phone when passing the lights. Dual-task involve the simultaneous implementation of two motor tasks such as walking with a tennis racket and hit the ball or a motor and cognitive task like standing on the subway train and reading (16) to examine balance ability under cognitive load conditions (17).

Research on the effects of motor-cognitive exercises on performance (18,19), executive function (19), walking (18) and cognitive skills (20) has been conducted in various populations, including individuals with traumatic brain injury (21), stroke (22), Parkinson (23) and developmental coordination disorder (14). However, the majority of studies on dual-task effects on autistic children have focused on evaluating the impact of cognition on a fixed task (1) and have not investigated intervention studies for these children.

We conducted an investigation to examine the impact of motor-cognitive exercise as a dual-task on the functional balance of these children. In this study, we hypothesized that there would be differences in the balance responses between the group that performed only balance exercises (single-task) and the group that performed both balance exercises and cognitive tasks (dual-task).

Materials and Methods

Design

The single-blind randomized clinical trial study was conducted from April 2019 to September 2020. The study was approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.FNM.REC.1397,086) and the Iranian Registry of Clinical Trials (IRCT20181014041341N1). The randomization process was performed by the first author and the assessments were conducted by an experienced occupational therapist. Another occupational therapist was responsible for carrying out the interventions.

Participants

Forty-four children, 15 girls and 29 boys aged 9 to 14 years with high-functioning ASD were selected from the Autism Schools of Tehran and Iran Autism Association using convenience sampling. According to the study (24), the sample size was determined using the following formula and the values of $\alpha = 0.05$, power = 0.8, and $\lambda = 7.85$ and considering 10% dropout of the sample size of 22 children.

$$\Delta = \frac{1}{\sigma^2} \sum_{i=1}^{k} (\mu_i - \bar{\mu})^2 \quad \Delta = 0.41$$

$$n = \frac{\lambda}{\Delta} \quad n = \frac{7.85}{0.41} = 19.14 \simeq 20 + 2 = 22$$

The inclusion criteria were as follows: a definitive diagnosis of high-functioning ASD by a psychiatrist, inability to stand on one leg for 30 seconds (25-27), no history of seizures and epilepsy, no history of neurological and orthopedic diseases, and not taking medicines with side effects on the balance.

The informed consent form was completed by the parents or caregivers. They were informed that: the intervention is completely harmless, participation in the study is voluntary and they can leave the study at any time, information about them would be kept confidential and the results of the study would be published without mentioning their names or details. After obtaining consent, the participants were randomly categorized into two groups: dual- and a single-task group. Using coded envelopes, 22 children with ASD were assigned to the single-task group and 22 to the dual-task group. The coded envelopes were kept in a box and the participants were asked to remove one of the envelopes. Those with envelope number 1 were part of the single-task group, while those choosing envelope number 2 were part of the dual-task group. During the study, two participants in each group dropped out. The flow diagram in the figure 1 shows the study's detailed process.

Interventions

Interventions were conducted in 12 sessions of 45 *min* each, three sessions per week for four weeks. The single-task group performed only balance excercises according to the Silsupadol protocol (18), while the dual-task group received simultaneous Silsupadol protocol and cognitive tasks.

The Silsupadol protocol involved balance exercises categorized into four classes: body stability, body stability plus manipulation, body transport, and body transport plus manipulation. In the body stability category, exercises such as standing, standing with eyes closed, tandem stance, and standing on an unstable surface were performed. The body stability plus manipulation category included exercises such as standing on a compliant surface while holding a glass of water, tandem stance with alternating hand movements in different directions, and throwing and catching the ball while standing. Body transport exercises comprised walking, backwards and sideways, and walking in low light. Lastly, body

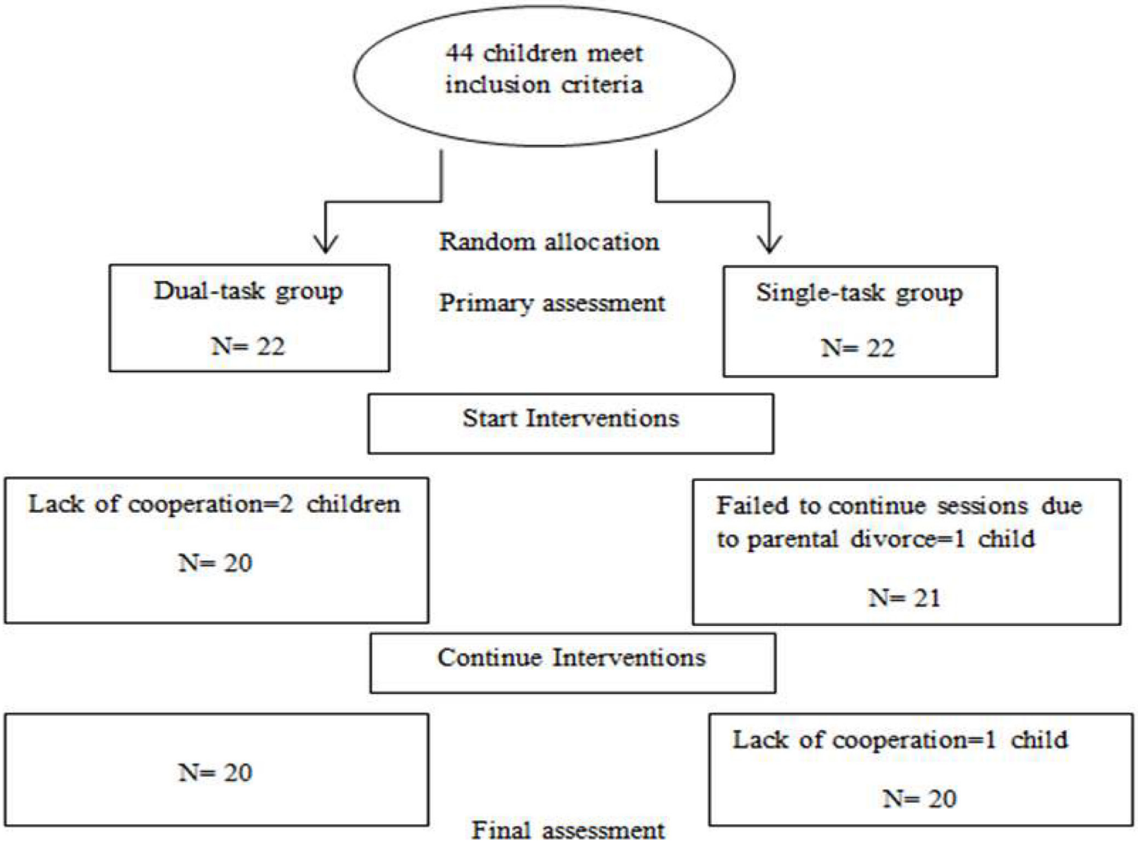


Figure 1. Flow diagram of the participants.

transport plus manipulation exercises included tasks such as carrying a glass or a basket while performing movement activities, or throwing a ball (18).

The cognitive tasks performed during the dual-task group included counting/reverse counting/auditory memory/naming fruits, animals, food, season, month, days of the week/using objects and the Raven test. The cognitive tasks related to each session were randomly selected by the participant at the beginning of each session.

Outcome measures

In two stages; before and at the end of the intervention, the Pediatric Berg Balance Scale (PBBS), Mini-BESTest, Timed Up and Go test (TUG), and 10-meter walk test were utilized.

Pediatric berg balance scale (PBBS)

The PBBS consists of 14 balance items, each scored from 0 to 4 (28). A score less than 54.6 may indicate decreased functional balance in typically developing children (29). PBBS is used for children with balance problems over 5 years old (28), including children with ASD (30,31). The Persian version of PBBS has been found to have high face validity and inter-rater and test-retest reliability with an ICC of 0.99 (32,33).

Timed up and go test (TUG)

The Timed Up and Go (TUG) test is a valid and reliable assessment tool for evaluating balance in typical and disabled children (34) including those with ASD (30,31). The test involves the child walking 3 meters, turning around, and walking back to the chair as quickly as possible, then sitting down (35). The assessor measures the duration of the test using a stopwatch and records the time for each individual (36). The typical time required to perform the TUG test in typically developing children ranges from 3.21 to 6.7 seconds (37). Psychometric studies of the TUG test's Persian version have been conducted, and the results indicate acceptable construct validity and Cronbach's alpha of 0.81 (38).

The mini-BES test

The Mini-BESTest is a shortened form of the Balance Evaluation Systems Test (BESTest), which investigates four areas of balance: transition/anticipatory, reactive postural control, sensory orientation, and dynamic gait. The test comprises 14 items (39-41) and is scored from 0–2 with a maximum score of 28 (42). A cut-off score of 16 out of 28 can indicate a history of falls (43).

The 10-meter walk test

The test was conducted in both single- and dual-mode conditions. In single-mode, or Single Gate Speed (SGS), the subject walked 10 meters at their usual speed and the examiner recorded the time of passing the middle 6 meters. In dual-mode or Dual Gate Speed (DGS), the subject answered the questions, including the sum of the numbers that were randomly selected by the individual before the test began, while walking (24). This test has demonstrated moderate-to-high reliability in children (44) and has been studied for its validity in the Iranian population. The concurrent validity was examined with the Functional Gait Assessment and the TUG, resulting in a significant correlation with both tests (45).

It should be noted that while these tests all assess balance, each focuses on specific aspects of static and dynamic balance. Additionally, a high score in all the tests, except the TUG test, reflects a high functional balance.

Data analysis

The data were analyzed using SPSS software version 19 (IBM Corp., Armonk, NY, USA). Mean and standard deviation were used to describe the population characteristics. The Kolmogorov-Smirnov test was utilized to check for normal distribution and the paired sample t-test was used to compare groups over time. Additionally, a 2×2 mixed ANOVA was used for comparing the groups. In this study, $p \leq 0.05$ was considered as statistically significant. The Cohen index (d) test was used to evaluate the effect size which can range from extremely negative to extremely positive. The values of 0.2, 0.5, and 0.8, express low, weak and high effect, respectively (46,47).

Results

In the single-task group, 65% of the participants were male and 34% were female, while in the dual-task group, 60% were male and 40% were female. There were no significant differences between the two groups in terms of age, height, weight, Body Mass Index (BMI), and sex distribution (Table 1).

Table 2 shows the within- and between-group analysis of TUG, Mini-BESTest, PBBS, SGS, and DGS before and after the intervention. The within-group analysis indicates a significant difference in TUG (before: 10.37±1.65 and after: 8.88±1.37), Mini-BESTest (before: 17.35±2.94 and after: 22.25±1.83), PBBS (before: 46.75±2.97 and after= 52.2±1.8), SGS (before: 0.79±0.19 and after: 0.97±0.19) and DGS (before: 0.58±0.15 and after: 0.71±0.13) in single-task (p<0.001).

The between-group analysis shows that before values of TUG (p=0.34), SGS (p=0.81), and DGS (p=0.45) were statistically similar to each other, but there is a significant difference between groups in Mini-BESTest (p=0.03) and PBBS (p<0.001) in baseline groups.

Also, there was a significant difference in TUG (before: 9.80±2.13 and after: 8.49±1.67), Mini-BESTest (before: 19.55±3.36 and after: 23.35±1.98), PBBS (before: 51.2±1.96 and after: 53.45±1.05), SGS (before: 0.81±0.18 and after: 0.92±0.19) and DGS (before: 0.62±0.17 and after: 0.74±0.17) in dual-task group in within-group analysis (p<0.001).

In the current study, no significant differences were found between two groups in the TUG, SGS, and DGS in baseline (p>0.05), but there was a significant difference in Mini-BESTest (p=0.03) and PBBS (p<0.001). For omitting this significancy, the difference between a change of TUG, Mini-BESTest, PBBS, SGS, and DGS were compared between single- and dual-task groups (Figure 2). There were statistical differences between single- and dual-task groups in PBBS (P<0.001). A large effect of dual-task intervention in Mini-BESTest (effect size=0.58

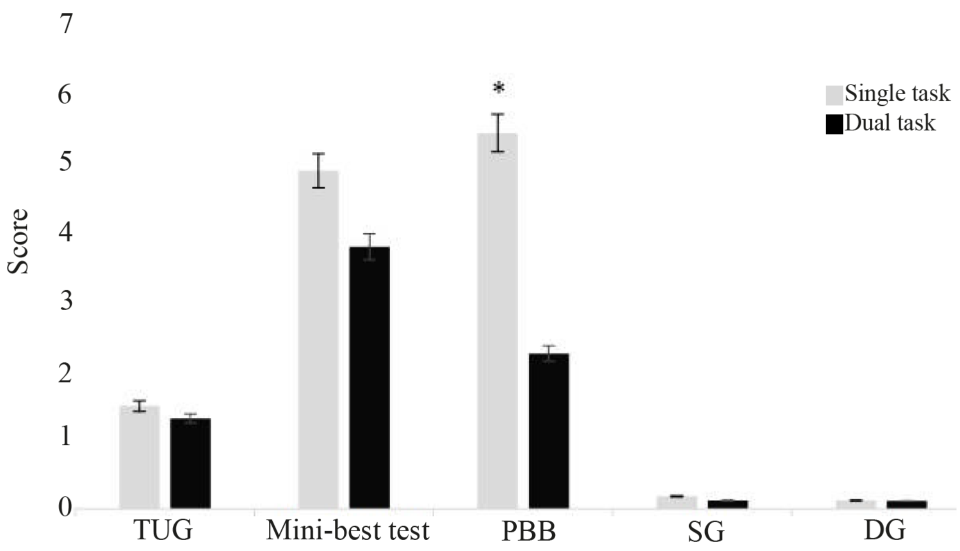
Table 1. Sociodemographic data in single and dual-task groups (n=20 per group)

Demographic characteristic	Single-task (n=20)	Dual-task (n=20)	Total (n=40)	p-value
Age (years)	11.15±1.89	11.5±2.13	11.52±2.02	0.55
Height (*cm*)	148.5±12.52	154.85±11.92	152.91±12.63	0.11
Weight (*kg*)	47.9±14.03	54±15.38	52.34±14.97	0.20
BMI (kg/m^2)	21.83±4.78	22.23±4.40	22.03±4.54	0.77
Sex [Male n(%)]	13(65.0)	12(60.0)	25(62.5)	0.74

Table 2. Before and after intervention TUG, Mini-BEStest, PBBS, SGS and DGS in the single task and Dual task groups based on 2×2 mixed ANOVA

Variables	Single-task			Dual-task			p ‡	p *	Effect size	Z score
	Before	After	p †	Before	After	p †				
TUG	10.37±1.65	8.88±1.37	<0.001	9.80±2.13	8.49±1.67	<0.001	0.34	0.65	-0.25	40%
Mini-BES test	17.35±2.94	22.25±1.83	<0.001	19.55±3.36	23.35±1.98	<0.001	0.03	0.13	0.58	72%
PBB	46.75±2.97	52.2±1.88	<0.001	51.2±1.96	53.45±1.05	<0.001	<0.001	<0.001	0.82	79%
SG	0.79±0.19	0.97±0.19	<0.001	0.81±0.18	0.92±0.19	0.003	0.81	0.19	-0.26	39%
DG	0.58±0.15	0.71±0.13	<0.001	0.62±0.17	0.74±0.17	<0.001	0.45	0.80	0.19	57%

†: Within-group p-value (Paired sample t-test). ‡: Group effects based on 2×2 mixed ANOVA. *: Time and group interaction effect based on 2×2 mixed ANOVA Significant level=0.05.



* Significant difference between single task and dual task changes (the after inter intervention score min nefore intervention score) group

Figure 2. Before and after difference between TUG, Mini-BESTest, PBBS, SGS and DGS.

and Z-score=72%) and PBBS (effect size=0.82, Z-score=79%) was detected in the values of effect size.

Discussion

A review of studies has shown that dual-task training can lead to improve balance in various conditions such as Parkinson (19), elderly (48), stroke (49) and congenital hemiparesis (50). These findings support the decision to study the effect of single- and dual-task exercises on functional balance in children with ASD. The results of the current study demonstrated a clear improvement in functional balance in both single- and dual-task groups. However, the difference between the groups was not statistically significant, which is line with the findings of Graham *et al* (51).

During dual-task interventions, motor performance tends to decrease in the early learning phase, whereas it does not in the late learning phase. It is believed that movement is attention-demanding in the early learning phase, hence the activity of the frontal and parietal area is reduced, which in turn results in a decrease in motor function. It is though to occur due to the competition for shared neuronal resources in these areas. In the late learning phase, the performance of the frontal and parietal areas does not decrease due to automatized performance mode, leading to better motor performance in this phase (52). The reason for this result may be attributed to the duration of interventions. Possibly, the participants have been in the early learning phase during the interventions, thus no significant changes in the balance were observed. The impact of simultaneous cognitive and motor tasks on functional balance may be better determined when interventions are longer and enter the late learning phase and automatized performance mode. Similar findings have been reported in other studies, such as one that found no significant changes in children with ASD following 4-week dual-task exercises (53).

Another cause of the lack of significant change in the current study may be associated with the inability of children to maintain sustained attention while performing cognitive tasks and balance exercises simultaneously. Dividing attention between the two tasks can lead to no significant changes in some balance tests in the dual-task group compared to the single-task one. Various studies have indicated that dual-task exercises can lead to decreased attention in children (54-56).

Studies have suggested that weak performance in individuals with ASD may be attributed to impaired cerebellar and prefrontal brain function (53,57,58). On the other hand, individuals with ASD have been found to pay much attention to the visual search tasks, which results in reduced balance performance in this population (59). Studies also demostrated that visual and somatosensory stimuli increase postural sway due to increased arousal (4,60). One of the cognitive tasks in the dual-task group was the Raven test, which required precision and visual search, but in the present study, perhaps due to the short duration of the intervention, no significant difference was observed between the two groups.

Several studies have highlighted the weakness in sensory integration and sensory-motor integration in individuals with ASD (61,62). This implies that the integration of visual, proprioceptive, and vestibular information is essential for postural stability, as well as for performing cognitive tasks. Based on the results obtained for the dual-task group in the current study, likely due to the poor sensory integration, the participants in this group had little ability to integrate information.

One of the cognitive tasks in the dual-task group was auditory memory, which required appropriate memory and verbal ability. The poor balance performance of the participants is this group could be attributed to several factors: memory weakness (63), motor activity during verbal activity (53) which may indicate that the participants were weak in simultaneous performing of balance and verbal exercises, adaptation mechanisms in autistic children that are unusual, and autistic children are less able to adapt to new situations than normal children (64,65), and sensory processing problems which clearly affect the postural control of individuals with ASD (6).

It should be noted that in this study, the effect size analysis revealed that time-dependent tests such as the TUG and 10-meter walk test showed no significant changes. However, the Mini-BESTest and PBBS tests indicated the impact of dual exercises on balance. It is believed that different tests evaluate different aspects of balance (66), and this period of intervention may have had a more significant effect on static balance than dynamic balance. If the treatment had been longer, more notable changes might have been observed.

The study was limited by not using valid objective balance scales as an outcome measure in children with ASD, such as force plate, valid cognitive tests, and fMRI for brain imaging. The use of these scales could have potentially provided more accurate results, as the scales used in the study were functional and subjective. In the study, one therapist provided offer both interventions in the control and intervention groups. Therefore, it is suggested that employing different therapists for the two groups would have been better.

To improve the analyzing the results, it is recommended to performe a more detailed cognitive test on children with ASD to make them more homogeneous. Additionally, future research should be conducted in more than 12 sessions to obtain more accure results.

Conclusion

The impact of dual-task and single-task exercises on functional balance in children with ASD appears to be approximately similar.

Ethics approval and study registration

This study was approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS. FNM.REC.1397,086) and Iranian Registry of Clinical Trials (IRCT20181014041341N1).

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgement

This study is a part of the thesis at the Master's Degree in Occupational Therapy, supported by Tehran University of Medical Sciences with code of ethics Committee of Tehran University of Medical Sciences (IR.TUMS.FNM.REC.1397,086). We would like to thank and appreciate children with ASD and their parents for their kind cooperation.

Conflict of Interest

The authors have stated that they had no interests which might be perceived as posing a conflict or bias.

References

1. Samadi SA, McConkey R. Screening for autism in Iranian preschoolers: contrasting M-CHAT and a scale developed in Iran. J Autism Dev Disord 2015;45(9):2908-16.

2. Fournier KA, Hass CJ, Naik SK, Lodha N, Cauraugh JH. Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. J Autism Dev Disord 2010;40(10):1227-40.

3. Lloyd M, MacDonald M, Lord C. Motor skills of toddlers with autism spectrum disorders. Autism 2013;17(2):133-46.

4. Stins JF, Emck C. Balance performance in autism: a brief overview. Front Psychol 2018;9:901.

5. Ghaziuddin M, Tsai LY, Ghaziuddin N. Brief report: a reappraisal of clumsiness as a diagnostic feature of Asperger syndrome. J Autism Dev Disord 1992;22(4):651-6.

6. Lim YH, Partridge K, Girdler S, Morris SL. Standing postural control in individuals with autism spectrum disorder: systematic review and meta-analysis. J Autism Dev Disord 2017;47(7):2238-53.

7. Jansiewicz EM, Goldberg MC, Newschaffer CJ, Denckla MB, Landa R, Mostofsky SH. Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. J Autism Dev Disord 2006;36(5):613-21.

8. Venetsanou F, Kambas A, Aggeloussis N, Serbezis V, Taxildaris K. Use of the Bruininks–Oseretsky test of motor proficiency for identifying children with motor impairment. Dev Med Child Neurol 2007;49(11):846-8.

9. Pan CY, Chu CH, Tsai CL, Sung MC, Huang CY, Ma WY. The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. Autism 2017;21(2):190-202.

10. Cheldavi H, Shakerian S, Boshehri SNS, Zarghami M. The effects of balance training intervention on postural control of children with autism spectrum disorder: role of sensory information. Res Autism Spectrum Disord 2014;8(1):8-14.

11. Memari AH, Ghanouni P, Shayestehfar M, Ziaee V, Moshayedi P. Effects of visual search vs. auditory tasks on postural control in children with autism spectrum disorder. Gait Posture 2013;39(1):229-34.

12. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture 2002;16(1):1-14.

13. Cockburn J, Haggard P, Cock J, Fordham C. Changing patterns of cognitive-motor interference (CMI) over time during recovery from stroke. Clin Rehabil 2003;17(2):167-73.

14. Schott N, El-Rajab I, Klotzbier T. Cognitive-motor interference during fine and gross motor tasks in children with Developmental Coordination Disorder (DCD). Res Dev Disabil 2016;57:136-48.

15. Patel P, Lamar M, Bhatt T. Effect of type of cognitive task and walking speed on cognitive-motor interference during dual-task walking. Neuroscience 2014;260:140-8.

16. Plummer-D'Amato P, Altmann LJ, Saracino D, Fox E, Behrman AL, Marsiske M. Interactions between cognitive tasks and gait after stroke: a dual task study. Gait Posture 2008;27(4):683-8.

17. Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. 3rd ed. Pennsylvania: Lippincott Williams & Wilkins; 2007. 612 p.

18. Silsupadol P, Siu KC, Shumway-Cook A, Woollacott MH. Training of balance under single-and dual-task conditions in older adults with balance impairment. Phys Ther 2006;86(2):269-81.

19. Fernandes Â, Rocha N, Santos R, Tavares JMR. Effects of dual-task training on balance and executive functions in Parkinson's disease: a pilot study. Somatosens Mot Res 2015;32(2):122-7.

20. Lee YY, Wu CY, Teng CH, Hsu WC, Chang KC, Chen P. Evolving methods to combine cognitive and physical training for individuals with mild cognitive impairment: study protocol for a randomized controlled study. Trials 2016;17(1):1-10.

21. Mathias JL, Wheaton P. Changes in attention and information-processing speed following severe traumatic brain injury: a meta-analytic review. Neuropsychology 2007;21(2):212.

22. Yang YR, Chen YC, Lee CS, Cheng SJ, Wang RY. Dual-task-related gait changes in individuals with stroke. Gait Posture 2007;25(2):185-90.

23. Yogev G, Plotnik M, Peretz C, Giladi N, Hausdorff JM. Gait asymmetry in patients with Parkinson's disease and elderly fallers: when does the bilateral coordination of gait require attention? Exp Brain Res 2007;177(3):336-46.

24. Silsupadol P, Shumway-Cook A, Lugade V, van Donkelaar P, Chou LS, Mayr U, *et al*. Effects of single-task versus dual-task training on balance performance in older adults: a double-blind, randomized controlled trial. Arch Phys Med Rehabil 2009;90(3):381-7.

25. Bohannon RW. Single limb stance times: a descriptive meta-analysis of data from individuals at least 60 years of age. Topics Geriatric Rehabil 2006;22(1):70-7.

26. Condon C, Cremin K. Static balance norms in children. Physiother Res Int 2014;19(1):1-7.

27. Frzovic D, Morris ME, Vowels L. Clinical tests of standing balance: performance of persons with multiple sclerosis. Arch Phys Med Rehabil 2000;81(2):215-21.

28. Franjoine MR, Gunther JS, Taylor MJ. Pediatric balance scale: a modified version of the berg balance scale for the school-age child with mild to moderate motor impairment. Pediatr Phys Ther 2003;15(2):114-28.

29. Franjoine MR, Darr N, Held SL, Kott K, Young BL. The performance of children developing typically on the pediatric balance scale. Pediatr Phys Ther 2010;22(4):350-9.

30. Casey AF, Quenneville-Himbeault G, Normore A, Davis H, Martell SG. A therapeutic skating intervention for children with autism spectrum disorder. Pediatr Phys Ther 2015;27(2):170-7.

31. Oliveira KSC, Fontes DE, Longo E, Leite HR, Camargos ACR. Motor skills are associated with participation of children with autism spectrum disorder. J Autism Dev Disord 2021:1-10.

32. Alimi E, Kalantari M, Nazeri AR, Baghban AA. Test-retest & inter-rater reliability of Persian version of pediatric balance scale in children with spastic cerebral palsy. Iran J Child Neurol 2019;13(4):163.

33. Kalantari M, Alimi E, Irani A, Nazeri A, Akbarzadeh Bagheban A. [Content and face validity of Pediatric Balance Scale in children with spastic cerebral palsy.] J Rehab Med 2016;5(3):104-10. Persian.

34. Williams EN, Carroll SG, Reddihough DS, Phillips BA, Galea MP. Investigation of the timed 'up & go'test in children. Dev Med Child Neurol 2005;47(8):518-24.

35. Salem Y, Gropack SJ, Coffin D, Godwin EM. Effectiveness of a low-cost virtual reality system for children with developmental delay: a preliminary randomised single-blind controlled trial. Physiotherapy 2012;98(3):189-95.

36. Pourghayoomi E, Negahdar F, Shahidi G, Hassani Mehraban A, Ebrahimi I, Taghizade G, *et al*. Correlation between functional balance and mobility tests and postural sway measures in dual task paradigm in Parkinson's disease (a pilot study). J Basic Clin Pathophysiol 2014;2(2):1-12.

37. Nicolini-Panisson RDA, Donadio MVF. Timed "Up & Go" test in children and adolescents. Rev Paul Pediatr 2013;31:377-83.

38. Aslankhani MA, Farsi A, Fathirezaie Z, Zamani Sani SH, Aghdasi MT. [Validity and reliability of the timed up and go and the anterior functional reach tests in evaluating fall risk in the elderly.] Iran J Ageing 2015;10(1):12-21. Persian.

39. Dewar R, Claus A, Tucker K, Ware R, Johnston L. Reproducibility of the balance evaluation systems test (BESTest) and the Mini-BESTest in school-aged children. Gait Posture 2017;55:68-74.

40. Sibley KM, Beauchamp MK, Van Ooteghem K, Paterson M, Wittmeier KD. Components of standing postural control evaluated in pediatric balance measures: a scoping review. Arch Phys Med Rehabil 2017;98(10):2066-78. e4.

41. Horak FB, Wrisley DM, Frank J. The balance evaluation systems test (BESTest) to differentiate balance deficits. Physical Ther 2009;89(5):484-98.

42. King L, Horak F. On the mini-BESTest: scoring and the reporting of total scores. Physical Ther 2013;93(4):571-5.

43. Yingyongyudha A, Saengsirisuwan V, Panichaporn W, Boonsinsukh R. The mini-balance evaluation systems test (Mini-BESTest) demonstrates higher accuracy in identifying older adult participants with history of falls than do the BESTest, Berg Balance Scale, or timed up and go test. J Geriatr Phys Ther 2016;39(2):64-70.

44. de Baptista CR, Vicente AM, Souza MA, Cardoso J, Ramalho VM, Mattiello-Sverzut AC. Methods of 10-meter walk test and repercussions for reliability obtained in typically developing children. Rehabil Res Pract 2020:2020:4209812.

45. Akbari Kamrani AA, Zamani Sani SH, Fathi Rezaie Z, Aghdasi MT. Concurrent validity of functional gait assessment, timed up and go, and gait speed tests in the Persian community-dwelling elderly. Iran Rehabil J 2010;8(2):15-20.

46. Elliott AC, Woodward WA. Statistical analysis quick reference guidebook: with SPSS examples: Sage Publications; 2007. 280 p.

47. Usman M. On consistency and limitation of independent t-test Kolmogorov Smirnov test and Mann Whitney U test. IOSR J Mathematics 2016;12(4):22-7.

48. Pichierri G, Coppe A, Lorenzetti S, Murer K, de Bruin ED. The effect of a cognitive-motor intervention on voluntary step execution under single and dual task conditions in older adults: a randomized controlled pilot study. Clin Interv Aging 2012;7:175.

49. Kim GY, Han MR, Lee HG. Effect of dual-task rehabilitative training on cognitive and motor function of stroke patients. J Phys Ther Sci 2014;26(1):1-6.

50. Elhinidi EIM, Ismaeel MMI, El-Saeed TM. Effect of dual-task training on postural stability in children with infantile hemiparesis. J Phys Ther Sci 2016;28(3):875-80.

51. Graham SA, Abbott AE, Nair A, Lincoln AJ, Müller RA, Goble DJ. The influence of task difficulty and participant age on balance control in ASD. J Autism Dev Disord 2015;45(5):1419-27.

52. Rémy F, Wenderoth N, Lipkens K, Swinnen SP. Dual-task interference during initial learning of a new motor task results from competition for the same brain areas. Neuropsychologia 2010;48(9):2517-27.

53. de Souza FHN, Lisboa AKP, Maia MDFT, Dos Santos MRD, da Silva Filho EM, Cezarino LG, et al. Effects of dual task training on gait temporal-spatial parameters of children with autism. Manual Ther Posturol Rehabil J 2017:1-5.

54. Tenenbaum E, Amso D, Abar BW, Sheinkopf SJ. Attention and word learning in autistic, language delayed and typically developing children. Front Psychol 2014;5:490.

55. Bucci MP, Doyen C, Contenjean Y, Kaye K. The effect of performing a dual task on postural control in children with autism. ISRN Neurosci 2013:2013:796174.

56. Stins JF, Emck C, de Vries EM, Doop S, Beek PJ. Attentional and sensory contributions to postural sway in children with autism spectrum disorder. Gait Posture 2015;42(2):199-203.

57. Donovan A, Basson MA. The neuroanatomy of autism–a developmental perspective. J Anat 2017;230(1):4-15.

58. D'Mello AM, Crocetti D, Mostofsky SH, Stoodley CJ. Cerebellar gray matter and lobular volumes correlate with core autism symptoms. Neuroimage Clin 2015;7:631-9.

59. Kaldy Z, Giserman I, Carter AS, Blaser E. The mechanisms underlying the ASD advantage in visual search. J Autism Dev Disord 2016;46(5):1513-27.

60. Ghanouni P, Memari AH, Gharibzadeh S, Eghlidi J, Moshayedi P. Effect of social stimuli on postural responses in individuals with autism spectrum disorder. J Autism Dev Disord 2017;47(5):1305-13.

61. Tomchek SD, Dunn W. Sensory processing in children with and without autism: a comparative study using the short sensory profile. Am J Occup Ther 2007;61(2):190-200.

62. Goulème N, Scheid I, Peyre H, Maruani A, Clarke J, Delorme R, et al. Spatial and temporal analysis of postural control in children with high functioning autism spectrum disorder. Res Autism Spectrum Disorders. 2017;40:13-23.

63. Stoodley CJ. The cerebellum and cognition: evidence from functional imaging studies. Cerebellum 2012;11(2):352-65.

64. Millin R, Kolodny T, Flevaris AV, Kale AM, Schallmo M-P, Gerdts J, et al. Reduced auditory cortical adaptation in autism spectrum disorder. Elife 2018;7:e36493.

65. Turi M, Burr DC, Igliozzi R, Aagten-Murphy D, Muratori F, Pellicano E. Children with autism spectrum disorder show reduced adaptation to number. Proc Natl Acad Sci U S A 2015;112(25):7868-72.

66. Cattaneo D, Jonsdottir J, Zocchi M, Regola A. Effects of balance exercises on people with multiple sclerosis: a pilot study. Clin Rehabil 2007;21(9):771-81.