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RESEARCH ARTICLE

Balance and motor skills differences between children and teenagers with autism spectrum disorder and neurotypically developing

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Abstract

This study examined the differences between children and adolescents with autism spectrum disorder (ASD) and neurotypically developing (NTD) in terms of balance, postural control, and motor skills. It also examined which motor skills are most affected and whether scores on different assessment tests in ASD children are correlated. A cross-sectional observational study with two research groups was conducted. Timed up and go test (TUG), short form of Bruininks-Oseretsky test of Motor Proficiency version 2 (SFBOT-2), and pediatric balance scale (PBS) were used. A total of 100 participants 50 with ASD and 50 with NTD engaged in the research. Statistically significant differences were obtained between control group and ASD group in TUG test and in SFBOT-2 standard score and total score (p-value = <0.01). A statistically significant difference (p-value = <0.01) was seen between ASD group's and control group's PBS scores. Poor correlation was noted between TUG and SFBOT-2, as well as between PBS and TUG. A moderate correlation was also found between SFBOT-2 and PBS. Children with ASD present difficulties in motor skills and in static and dynamic balance compared to children with NTD. Differences were observed in the motor skills of strength followed by manual dexterity, running speed and agility, fine motor precision, fine motor integration, and balance. The PBS item that showed the greatest difference between the ASD group and control group was maintaining monopodial support with hands on hips. Finally, poor to moderate correlations were obtained between the different tests with statistically significant differences.

Lay Summary

Children with ASD perform poorly on scales for the assessment of balance, postural control and motor skills. These findings are relevant to their application in clinical settings.

KEYWORDS

assessment scales and motor skills, autism Spectrum disorder, dynamic balance, postural control, static balance

Abbreviations: ASD, autism spectrum disorder; BOT-2, Bruininks-Oseretsky test of Motor Proficiency version 2; DSM-5, Diagnostic and Statistical Manual of Mental Disorders; IQ, intellectual quotient; MABC-2, Movement Assessment Battery for Children, 2nd edition; NTD, neurotypically developing; PBS, pediatric balance scale; SFBOT-2, Short form Bruininks-Oseretsky test of Motor Proficiency version 2; SS, standard score; TS, total score; TUG, timed up and go test.

INTRODUCCTION

Apart from the classic deficiencies in social interaction, communication, and atypical repetitive, steroid-like movements, people with autism spectrum disorder (ASD) frequently experience a range of motor difficulties that are almost as prevalent as intellectual disability. There is compelling evidence that one of the early developmental traits of children with ASD is delayed achievement of motor milestones. (Licari et al., 2020; Odeh et al., 2020) Early descriptions of autism included characteristic limitations of the individual's spontaneous activity and/or failures in postural adjustment. More recently, a growing number of ASD experts have reported the presence of various motor deficits, such as clumsiness, motor coordination abnormalities, postural instability, poorer postural control, impaired muscle tone, muscle weakness, increased falls, impaired fine, and gross motor movements, akinesia, bradykinesia, coordination difficulties, and gait disturbances, in relation to typically developing individuals. (Kaur et al., 2018; Licari et al., 2020; Odeh et al., 2020) The prevalence of motor impairments is estimated to be between 50% and 79% of children with ASD. (Licari et al., 2020) According to data from the SPARK research sample's Developmental Coordination Disorder-Questionnaire (DCD-Q), 87%–88% of children with ASD were at-risk for a general motor impairment that lasted until the age of 15 and was connected to their core and co-occurring issues. (Bhat, 2020) Despite growing scientific evidence supporting deficits in balance and postural control in subjects with ASD, (Bojanek et al., 2020; Lim et al., 2017) today it is not considered an implicit feature of this condition, but rather as "associated features supporting the diagnosis", such as clumsy gait, clumsiness, and other abnormal motor signs (e.g., tiptoeing). (American Psychiatric Association., 2013).

One of the most significant indicators of health in children is their motor skill competency, because early physical activity reduces the probability that many chronic diseases becoming manifest in adulthood. (Radanović et al., 2021) In the scientific literature we find a growing number of research on postural control in children with ASD. However, most studies use instrumental methods such as posturography.(Goulème et al., 2017; Memari et al., 2014; Miller et al., 2019) Despite being quite helpful in research, these instruments are costly and require examiner training. Observational assessment scales for static and dynamic balance and motor skills could be very useful in determining motor impairments in children with ASD without the need for more costly instrumental methods and could be used in therapeutic environments.

The purpose of this investigation was to analyze the differences in static and dynamic balance, postural control, and motor skills in children and adolescents with ASD with respect to children and adolescents with neurotypically developing (NTD) using balance and motor skills assessment scales and tests. In addition, the second aim of the present research was to analyze whether there is a correlation between the scores of the rating scales used in the study in children and adolescents with ASD. Finally, the last purpose of the present research was to analyze the motor skills in which children and adolescents with ASD have greater difficulty.

MATERIALS AND METHODS

Study design

The present research constitutes a cross-sectional observational study with two research groups. The first group included children and teenagers with ASD (ASD group) and the second group included children and adolescents with NTD (control group). The data were collected between February 2022 and July 2023.

Ethical aspects

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Rey Juan Carlos University (registration number: 3011202122821). Participants' parents, as well as those over 14 years old, signed their informed consent.

Participants

Subjects in the ASD group and in the control group matched by age and gender were asked to voluntarily participate. Selection criteria for children and teenagers with ASD included having an ASD diagnosis, being between the ages of 6 and 18, being able to follow verbal instructions (having a working memory and verbal comprehension score of at least 60 on the Wechsler Intelligence Scale-IV), being able to walk at least 10 m on their own and being able to sit and stand without an assistive device. If a participant had a diagnosis of any respiratory, metabolic, musculoskeletal, or cardiovascular ailment or any other condition that would interfere with this investigation, they were excluded from the study.

On the other hand, children and teenagers with NTD were selected according to the following criteria: age between 6 and 18 years old and did not have any neurological or psychological disorders. Participants were also not allowed to participate in the study if they had any respiratory, metabolic, musculoskeletal, or cardiovascular conditions that would make it difficult to do this test.

Instruments

The following assessment tools were used to carry out this study.

Timed up and go test (TUG) is an easy tool that was developed by Podsiadlo et al. in 1991. (Podsiadlo & Richardson, 1991) This test measures in seconds the time it takes an individual to get up from a standard chair, walk three meters, turn around, walk back to the chair, and sit down again. The modify version of TUG, proposed by Williams et al. (2005) for children and teenagers, was used. This modified version specifies the subsequent requirement: children were allowed to behave naturally, with no qualitative instructions given to ensure a naturalistic performance, timing was started as the child left the seat, rather than on the instruction, instructions were repeated throughout the test, a back support seat without arms was chosen from the children's environment and the seat height was acceptable if the child's knee angle was 90°, with a standard deviation (SD) of 10°. Better functional mobility is obtained with less time spent. This test has been validated in children with ASD. (Martín-Díaz et al., 2022) (Figure 1).

To assess motor performance Bruininks-Oseretsky test of Motor Proficiency version 2 (BOT-2), short form (SFBOT-2), was used. (Bruininks & Bruininks, 2005) SFBOT-2 is a standardized test designed to assess motor skills in children aged 4–21 years. Its abbreviated version collects scores from eight subtests: fine motor accuracy, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper limb coordination, and strength. According to a review, the BOT-2 is the most psychometrically appropriate for assessing motor competence in children with ASD. (Downs et al., 2020) The total SFBOT-2 score (max = 88) is determined by summing all the individual scores from the different tests. From the total score according to the manual norms, the standard score is obtained which ranges from 20 to 80 and includes both age and gender. Its mean is 50 (SD = 10). The cutoff point is one SD below 40, the total composite standard score that is considered suggestive of motor impairment. A categorical variable with five descriptive categories can be derived from the total score: well above average ("≥70"), above average ("60–69"), average ("41–59"), below average ("31–40"), and well below average ("≤30"). (Bruininks & Bruininks, 2005).

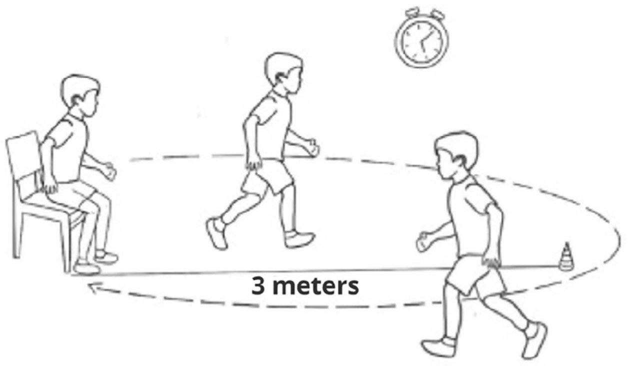

FIGURE 1 Timed up and go test. This artwork was designed using the app Procreate.

Pediatric balance scale (PBS) is a modification of the Berg's Balance Scale. (Berg, Maki, et al., 1992; Berg, Wood-Dauphinee, et al., 1992) It was developed for the purpose of assessing functional balance in school-age children with mild to moderate motor impairments. It consists of a scale consisting of 14 items assessed on a 5-point scale (0–4), where 0 is the minimum score and 4 is the maximum score. The maximum score of the PBS is 56 points. (Franjoine et al., 2003).

Pictograms of every assessment test item were made and shown to participants with ASD in advance to ensure their accurate comprehension of the tasks to be completed.

Procedure

The participants of this research were assessed according to the following protocol. First, all assessment tests were performed on participants with ASD until the sample size was reached. Secondly, children and teenagers with neurotypical development were selected from primary and secondary schools from the Community of Madrid (Spain), and they were matched by gender and age with the ASD group. All assessment tests were administered on the same day. The scales and assessment tests were administered and evaluated by the same qualified physiotherapist who knew which group each participant belonged to. The following scales were administered in the following order: TUG first, then PBS, and finally SFBOT-2.

Sample size

A sample size estimate was made with G-Power 3.1 software using the following parameters and using the Student's *t*-test for independent samples as the statistical test: two-tailed, a mean effect size of 0.6, an alpha error of 0.05, and a statistical power of 0.80. Based on these data and expecting a loss rate of 10%, a sample size of 99 participants (approximately 50 subjects per group) was estimated for the study.

Statistical analysis

Statistical analysis was performed using Python version 3.8.13 with the following libraries: matplotlib 3.6.2, numpy 1.22.4, pandas 1.5.1, scipy 1.10.1, seaborn 0.11.2, sinfo 0.3.4, statsmodels 0.14.0.

Descriptive analysis was performed for all variables. Results were presented as the median and interquartile range for variables without a normal distribution and as the mean and SD for variables with a normal distribution.

The Shapiro–Wilk test was used to test whether the variables followed a normal distribution. The ASD group contained two outliers, which were identified and eliminated to test the sample's normality. The hypothesis that the variables of time in the TUG test and the SFBOT-2 total score and standard score followed a normal distribution was accepted. Consequently, the Student's *t*-test was used to compare the means of two independent samples. However, for the variable PBS the non-normal distribution hypothesis was accepted. Therefore, the Mann Whitney *U* test, a nonparametric test for unrelated samples, was used to compare the variables of both groups.

To analyze the differences in motor skills in each subtest of the SFBOT-2 between the ASD group and the control group, the following formula was used: $\frac{\text{mean subtest } X \text{ (ASD group)} - \text{mean subtest } X \text{ (control group)}}{\text{mean subtest } X \text{ (control group)}} \times 100$. Additionally, the following formula was applied to analyze the variations in static and dynamic balance in each PBS item between the ASD group and the control group: $\frac{\text{mean item } X \text{ (ASD group)} - \text{mean item } X \text{ (control group)}}{\text{mean item } X \text{ (control group)}} \times 100$.

The Pearson's r correlation coefficient was used. The following categories and terminology was used: $r \geq 0.75$, excellent correlation; $r = 0.41$–0.74, moderate correlation; and $r \leq 0.40$, poor correlation. The significance level was set to 0.05 for all tests. (Hinkle et al., 2003).

The statistical analysis was performed with a confidence level of 95%, so that values with a $p < 0.05$ were considered significant.

Cohen's d was used to calculate the effect size. If the Cohen's d value is less than 0.20, there is no influence; if it is between 0.21 and 0.49, there is a modest effect; if it is between 0.50 and 0.70, there is a moderate effect; and if it is over 0.80, there is a big effect. (Cohen 2013).

RESULTS

The final sample consisted of 100 subjects (86 males and 14 females), 50 of whom belonged to the ASD group (43 males and 7 females), and the other 50 belonged to the control group (43 males and 7 females). The age of the sample ranged from 6 to 16 years. (Table 1).

The sample was stratified by age into 4 age groups. The first group corresponds to ages 6–9 years, the second to 10–12 years, the third to 13–15 years and the fourth to 16–18 years.

Regarding the results of the TUG test, statistically significant differences were found between the ASD group and the control group (*p*-value = <0.01). The effect size measured by d-Cohen is 2.36, which means a big effect size. (Table 2). Statistically significant differences were also observed in the comparison of means in all age groups (age group 6–9 years *p*-value = <0.01; age group 10–12 years *p*-value = <0.01; age group 13–15 years *p*-value = <0.01; and age group 16–18 years *p*-value = 0.049). (Figure 2) (Table 2).

Considering the results without age stratification obtained in SFBOT-2 total score, a statistically significant mean difference was observed between the control group and the ASD group (*p*-value = <0.01). Furthermore, the effect size measured by d-Cohen is 1.66, which means a big effect size. (Table 2) Moreover, statistically significant differences were observed in all age groups (age group 6–9 years *p*-value = <0.01; age group 10–12 years *p*-value = <0.01; age group 13–15 years *p*-value = 0.013; and age group 16–18 years *p*-value = 0.02) between the ASD group and the control group in the variable SFBOT-2 total score. (Figure 3) (Table 2).

Furthermore, in the overall sample, a statistically significant mean difference was observed between the control group and the ASD group in the SFBOT-2 standard score variable (*p*-value = <0.01). Additionally, the d-Cohen effect size was 2.47, which means a big effect size. (Table 2) Likewise, the variable SFBOT-2 standard score showed statistically significant differences between the ASD group and the control group in all age groups (age group 6–9 years p = <0.01; age group 10–12 years p = <0.01; age group 13–15 years p = <0.01; and age group 1618 years $p = 0.016$). (Figure 4) (Table 2).

Comparing the findings of the SFBOT-2 descriptive categories, in the control group, 76% were "average," 2% were "below average," 0% were "well below average," 20% were "above average" and 2% were "well above average." On the other hand, in the ASD group 16% were "average," 62% were "below average," 22% were "well below average" and none of the participants in the ASD group received a descriptive category of "above average" or "well above average."

In addition, there was a statistically significant difference (*p*-value = <0.01) in the scores of the control group and the ASD group in the PBS when the Mann–Whitney *U* test was used to compare their results. Moreover, the effect size measured by d-Cohen is 1.16, which means a big effect size. (Table 3) (Figure 5).

However, when comparing the control group and the ASD group by age stratification, statistically significant differences were only observed in the age groups 6–9 years (*p*-value = <0.01) and 10–12 years (*p*-value = <0.01). (Table 3) (Figure 6).

In relation to the differences within each of the subtests of the SFBOT-2 between the ASD group and the control group, the ASD group performed 56.5% less on the "strength subtest" than the control group, 39% less on the "manual dexterity subtest" than the control group, 35% less on the "running speed and agility subtest" than the control group, 30.5% less on the "fine motor precision subtest" than the control group, 21% less on the "fine motor integration subtest" than the control group, 20.5% less on the ASD group than in the control group, and 18.5% less on the "balance subtest" than in the control group.

TABLE 1 Demographic characteristics of participants.

		ASD group	Control group
Age		9.54 (3.09)	9.54 (3.09)
Gender, *n* (%)		$n = 50$	$n = 50$
Male		43 (86%)	43 (86%)
Female		7 (14%)	7 (14%)
TUG (mean)	6–9 years	9.04 (1.38)	5.89 (0.73)
	10–12 years	10.10 (6.05)	5.99 (0.93)
	13–15 years	8.38 (1.32)	6.12 (1.02)
	16–18 years	8.67 (2.05)	6.40 (1.30)
	Total	9.13 (3.06)	6.00 (0.88)
PBS*	6–9 years	53.00 (51.25–54.00)	55.00 (55.00–56.00)
	10–12 years	54.00 (54.00–55.00)	56.00 (56.00–56.00)
	13–15 years	55.00 (54.00–56.00)	56.00 (56.00–56.00)
	16–18 years	55.00 (55.00–55.75)	56.00 (56.00–56.00)
	Total	54.00 (53.00–55.00)	56.00 (55.00–56.00)
SFBOT-2 (total score)	6–9 years	36.81 (15.18)	63.04 (6.82)
	10–12 years	56.00 (8.83)	74.00 (3.77)
	13–15 years	60.86 (10.38)	74.28 (2.98)
	16–18 years	61.67 (14.28)	79.33 (4.72)
	Total	47.38 (17.16)	68.98 (8.46)
SFBOT-2 (standard score)	6–9 years	33.85 (7.00)	53.92 (8.72)
	10–12 years	35.82 (4.14)	53.54 (6.02)
	13–15 years	36.57 (5.38)	47.00 (6.56)
	16–18 years	36.33 (8.59)	52.33 (10.58)
	Total	34.96 (6.40)	52.68 (8.27)
SFBOT-2 (percentil rank)	6–9 years	9.19 (9.41)	61.08 (24.59)
	10–12 years	9.64 (6.71)	60.18 (18.23)
	13–15 years	11.71 (9.43)	38.14 (22.50)
	16–18 years	14.67 (20.19)	55.33 (33.75)
	Total	10.30 (10.50)	56.98 (24.84)

Note: Data expressed as mean (standard deviation). * Data expressed as median (interquartile range).
Abbreviations: ASD, autism spectrum disorder; PBS, pediatric balance scale; SFBOT-2, short form Bruininks-Oseretsky test of Motor Proficiency version 2; TUG, timed up and go test.

TABLE 2 Differences in means between the ASD group and the Control group.

	TUG			SFBOT2 (TS)			SFBOT (SS)		
Age (years)	*T*	Cohen-d	*p*-value	*T*	Cohen-d	*p*-value	*T*	Cohen-d	*p*-value
6–9	10.30	2.86	<0.01*	−8.67	2.50	<0.01*	−9.59	2.69	<0.01*
10–12	4.46	1.98	0.000428*	−6.22	2.65	0.000026*	−8.04	3.43	<0.01*
13–15	5.11	2.64	0.001553*	−3.29	1.76	0.01337*	−3.25	1.74	0.006921*
16–18	2.29	1.32	0.049478*	−2.88	1.66	0.027729*	−2.88	1.66	0.016505*
Total	11.72	2.36	<0.01*	−8.14	1.66	<0.01*	−12.34	2.47	<0.01*

Abbreviations: SFBOT2, short form Bruininks-Oseretsky test of Motor Proficiency version 2, SS: standard score; TS, total score; TUG, timed up and go test.
**p*-value <0.05.

The children's lowest performance in the PBS occurred in items 9 (15% less score in the ASD group), 3 (10% less score in the ASD group), 2 (6% less score in the ASD group), 8 (5% less score in the ASD group), 11 (3% less score in the ASD group), 13 (2% less score in the ASD group), and 10 (1% less score in the ASD

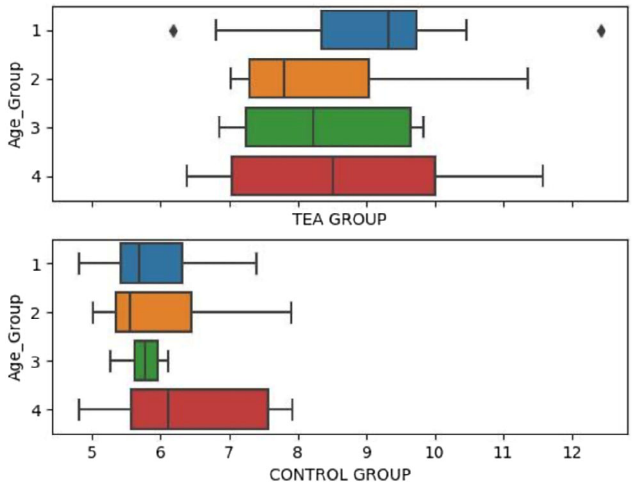

FIGURE 2 Box-and-whisker plot of the differences between the control group and the ASD group of the TUG stratified by age. This plot was created using Python version 3.8.13. ASD, autism spectrum disorder; TUG, timed up and go test.

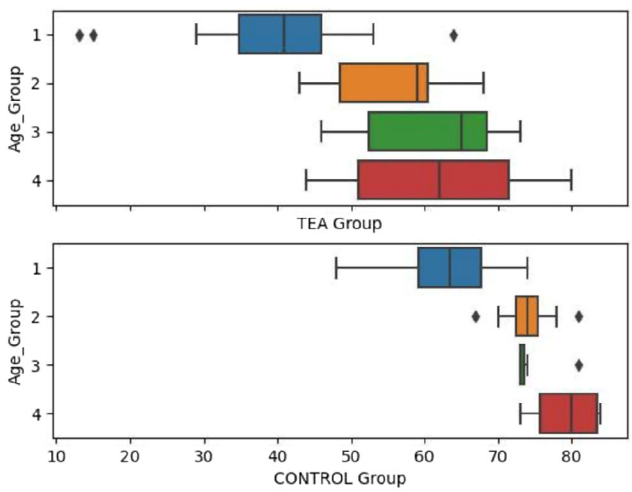

FIGURE 3 Box-and-whisker plot of the differences between the control group and the ASD group of the SFBOT-2 total score stratified by age. This plot was created using Python version 3.8.13. ASD, autism spectrum disorder.

group), which require them, respectively, standing on 1 foot, transfers, standing to sitting, standing with foot in front, turn to look behind, placing alternate foot on stool, and turning 360°.

Furthermore, the largest difference between the ASD group and the control group was seen in item 9 of the PBS, which has a 15% lower score and requires the participant to stand in monopodal support with hands on hips.

Finally, poor to moderate correlations were obtained between the different tests with statistically significant differences. Between the variable PBS and TUG a poor correlation ($r = -0.27$, p-value $= 0.05$), between

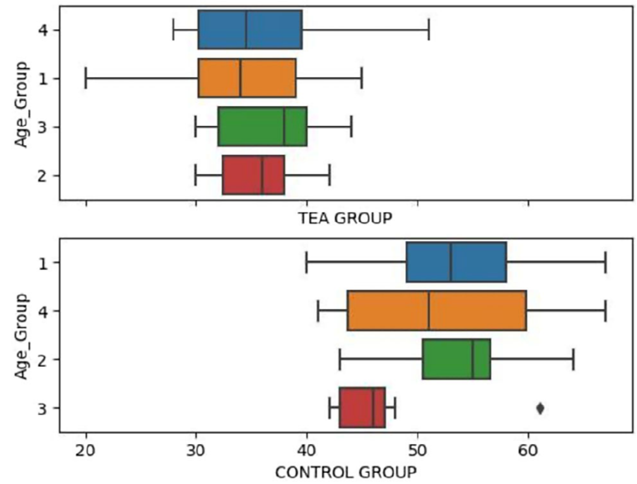

FIGURE 4 Box-and-whisker plot of the differences between the control group and the ASD group of the SFBOT-2 standard score stratified by age. This plot was created using Python version 3.8.13. ASD, autism spectrum disorder.

TABLE 3 Test *U* Mann–Whitney PBS.

Age (years)	*U*-val	*p*-value
6–9	95.0	0.000013*
10–12	13.0	0.000679*
13–15	13.0	0.099
16–18	8.5	0.10
Total	469.5	<0.01*

Abbreviations: PBS, pediatric balance scale; U-val, Mann–Whitney *U* test.
**p*-value <0.05.

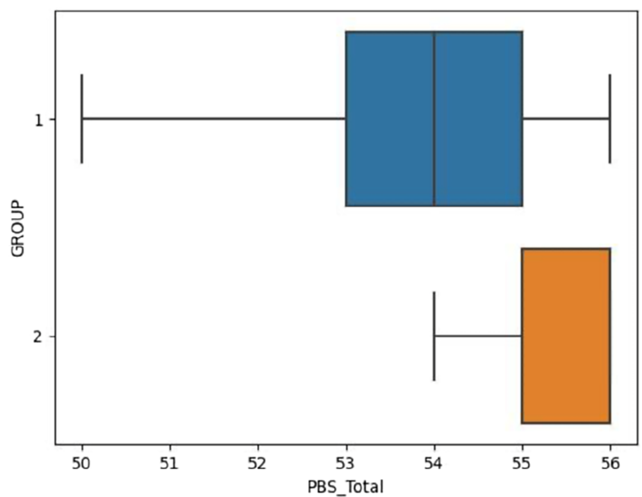

FIGURE 5 Box-and-whisker plot of the differences between the control group and the ASD group of the PBS total sample. This plot was created using Python version 3.8.13. ASD, autism spectrum disorder; PBS, pediatric balance scale.

SFBOT-2 total score and TUG a poor correlation ($r = -0.40$, p-value $= 0.004$), between SFBOT-2 standard score and TUG a poor correlation ($r = -0.40$,

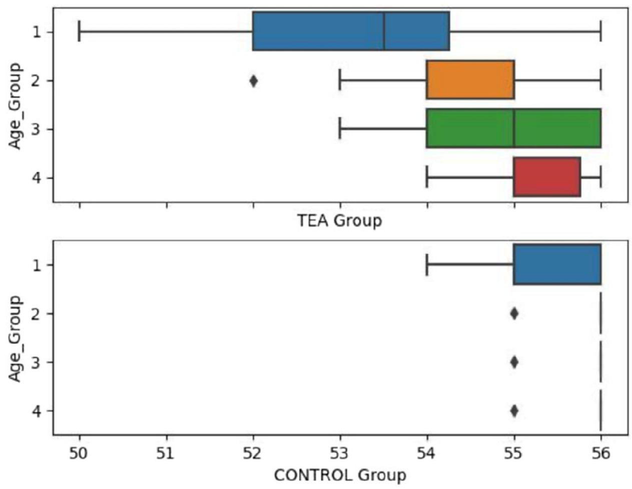

FIGURE 6 Box-and-whisker plot of the differences between the control group and the ASD group of the PBS stratified by age. This plot was created using Python version 3.8.13. ASD, autism spectrum disorder; PBS, pediatric balance scale.

p-value = 0. 004), between SFBOT-2 total score and PBS a moderate correlation ($r = 0.51$, *p*-value = 0.001), and between SFBOT-2 standard score and PBS a moderate correlation ($r = 0.52$, *p*-value = 0.002). When examining the correlations between the scales after stratifying the sample into age groups, statistically significant differences were only seen in age group 1 (children ages 6–9), where a poor correlation between the SFBOT-2 total score and PBS ($r = 0.40$, *p*-value = 0.04) and a moderate correlation between the SFBOT-2 standard score and PBS ($r = 0.59$, *p*-value = < 0.001) were found. (Figure 7) (Table 4).

DISCUSSION

The present study focused on analyze the differences in static and dynamic balance, postural control, and motor skills in children and adolescents with ASD with respect to children and adolescents with NTD, analyze which motor skills are most affected and to assess whether there are correlations between scores on different scales and assessment tests in children with ASD.

Previous studies have looked at balance and postural control using posturography where they found that children with ASD showed higher postural sway scores than children with NTD. (Abdel Ghafar et al., 2022; Bucci et al., 2017; Fears et al., 2023; Fournier et al., 2010; Memari et al., 2014) However, posturography is a costly instrumental test, which requires maintenance and training by the assessment professional. In the present study we used observational assessment scales and found that children with ASD had difficulties in both static and dynamic postural control, with lower PBS and SFBOT-2 scores and longer TUG times.

Timed up and go test

Regarding the TUG test, we found that it had strong intra- and inter-rater reliability values, a low percentage of measurement errors, and no discernible bias based on test repetition in a prior study conducted by the research group of the current study. (Martín-Díaz et al., 2022) In this study, we found that children with ASD obtained longer times to complete the test than children with NTD, with statistically significant differences between the ASD group and the control group and statistically significant difference in all age groups when the sample was stratified by ages. According to Williams et al. (2005) the TUG test requires sophisticated control of balance and movement by planning, initiating, executing, and completing an integrated movement sequence. Because of this, longer test times are associated with poorer motor control and poorer dynamic balance.

Bruininks-Oseretsky test of Motor Proficiency version 2 short form

The results showed that the SFBOT-2 score was lower in the ASD group. In addition, comparing the sample divided into age groups showed that the ASD group scored lower than the control group. In a study conducted in 2022, Odeh et al. (2020) used the BOT-2 and the second edition of the Movement Assessment Battery for Children (MABC-2) to analyze the motor profile of children with ASD. They also discovered statistically significant differences in overall balance performance between the ASD and NTD groups on both the MABC-2 and BOT-2. In that study, the ASD group scored 36.91 (±4.085 SD) on the gross motor quotient of the BOT-2 scale, while the control group scored 51.50 (±8.8 SD). These results align with the findings of the current investigation where the SFBOT-2 standard score for the ASD group was 34.96 (±6.40 SD), whereas the control group's score was 52.68 (±8.27 SD).

Kaur et al. compared the gross and fine motor, praxis/imitation, motor coordination, and interpersonal synchrony abilities of three groups of children, aged 5–12: children with ASD and high IQ, children with ASD and low intellectual quotient (IQ), and children with NDD. They did this by using an extensive set of assessments. On the SFBOT-2, they found that, of the two ASD groups, the low IQ group performed worse than the high IQ ASD children. Similar to the current study, children with ASD had lower SFBOT-2 scores than children with NTD.

Moreover, 62% of the ASD group had descriptive category scores of "below average" and 22% of "well below average" based on the SFBOT-2 criteria. These findings are consistent with those of a study by Ozboke et al. (2022), which used the SFBOT-2 scale to assess 31 individuals with ASD who were between the ages of

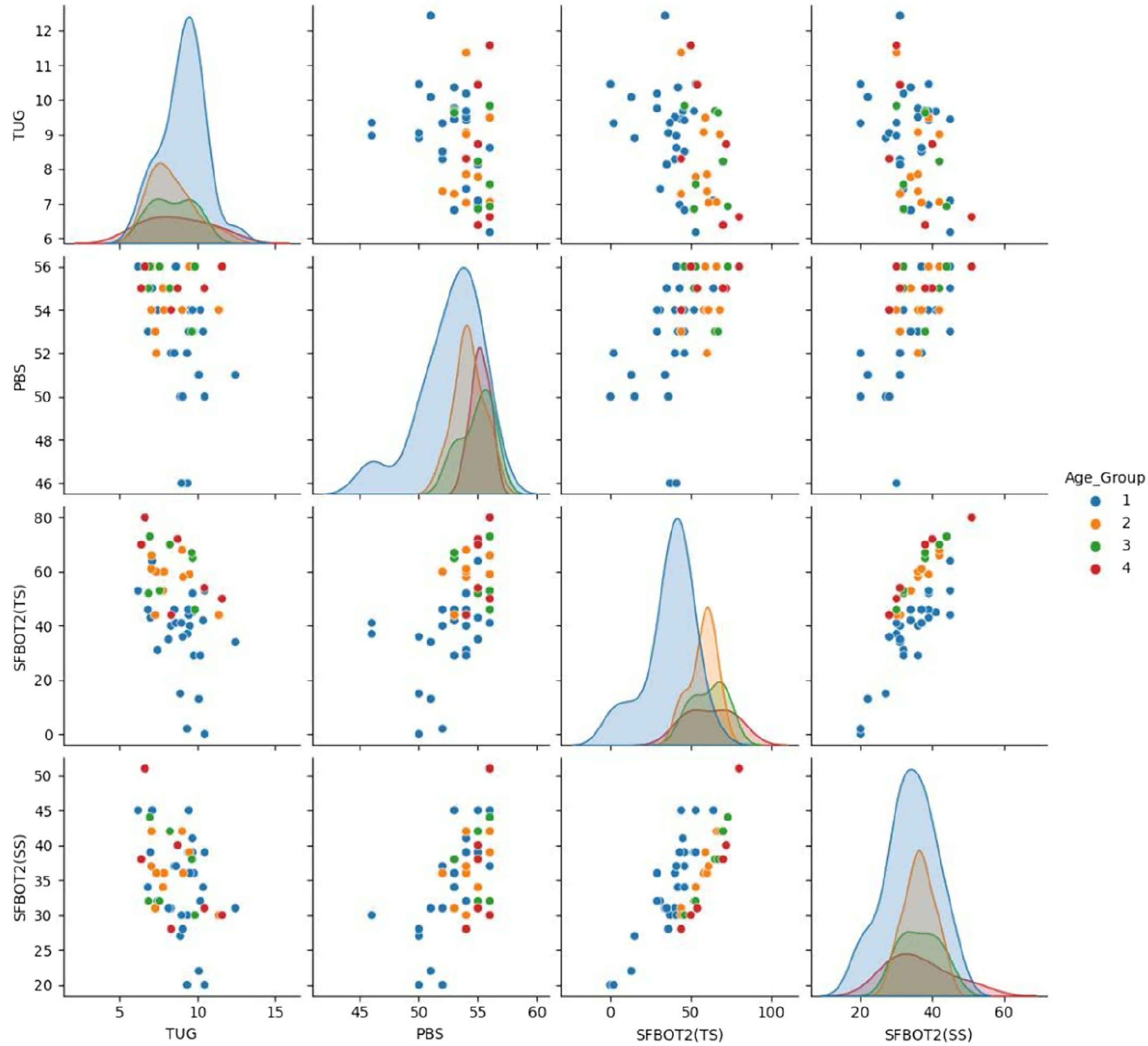

FIGURE 7 Graph of correlations between the different scales and assessment tests by age group (1 = 6–9 years, 2 = 10–12 years, 3 = 13–15 years, and 4 = 16–18 years). This plot was created using Python version 3.8.13.

13 and 18. They discovered that 93.5% of the participants fell into the descriptive category of "well below average," while 6.5% fell into "below average." This supports the theory that, although not being included in the diagnostic criteria for ASD, motor abilities and static, and dynamic balance are critical to involvement in various daily living activities.

Pediatric balance scale

Cordeiro-Gomes et al. (2021) found that children with ASD obtained high scores on the PBS and did not show much difficulty in completing the tests. Similarly, in the present study, although statistically significant differences were obtained between the ASD group and the control group, the scores varied very little and were close to the maximum score. Moreover, Cordeiro-Gomes et al. observed that children's lowest performance on the PBS was on items 7, 8, 9, 10, 11, and 14, which require them, respectively, to stand with feet together, stand with 1 foot in front, stand on 1 foot, turn 360°, turn to face backwards and extend arms forwards. Following these results in the present investigation we also found that the children's lowest performance in the PBS was in items 8, 9, 10, and 11 apart from items 2, 3, and 13 which require them, respectively, to transfer, stand to sit and to alternately place their feet on a stool.

TABLE 4 Pearson correlation coefficient (r) ASD group.

	Age (years)	r	p-value
TUG and PBS	6–9	−0.32	0.11
	10–12	0.14	0.69
	13–15	−0.55	0.19
	16–18	0.16	0.77
	Total	−0.27	0.05
TUG and SFBOT-2 (TS)	6–9	−0.36	0.07
	10–12	−0.33	0.34
	13–15	−0.09	0.84
	16–18	−0.66	0.15
	Total	−0.40	0.004*
TUG and SFBOT-2 (SS)	6–9	−0.35	0.08
	10–12	−0.26	0.46
	13–15	−0.15	0.73
	16–18	−0.66	0.15
	Total	−0.40	0.004*
PBS and SFBOT-2 (TS)	6–9	0.40	0.04*
	10–12	0.27	0.45
	13–15	−0.37	0.41
	16–18	0.45	0.37
	Total	0.52	0.0001*
PBS and SFBOT-2 (SS)	6–9	0.59	0.001*
	10–12	0.46	0.18
	13–15	−0.22	0.64
	16–18	0.51	0.30
	Total	0.51	0.0001*

Abbreviations: SFBOT2, short form Bruininks-Oseretsky test of Motor Proficiency version 2, SS: standard score; TS, total score; TUG, timed up and go test.
*p-value <0.05.

Correlations

Hallemans et al. (2020) analyzed the correlation between the TUG and the balance subscale of the MABC-2 in healthy children and found a poor correlation ($r = -0.347$, p-value $= 0.007$). Gan et al. (2008) used the Pearson correlation coefficient between the TUG and the Berg balance scale in children with cerebral palsy and obtained an excellent correlation ($r = -0.88$, p-value <0.01). In the present study, using Pearson's correlation coefficient, we observed a poor correlation between the PBS and the TUG test ($r = -0.27$, p-value $= 0.05$) and between the SFBOT-2 and the TUG test ($r = -0.40$, p-value $= 0.001$) and a moderate correlation between the SFBOT-2 and the PBS ($r = 0.52$, p-value $= 0.02$). Because each scale utilizes a different measurement—for instance, the PBS measures the score obtained on the various items, whereas the TUG test measures time—it is possible that the correlations found between the rating scales and tests were poor to moderate. However, the correlations were statistically significant. This is crucial because children with ASD who score highly on the TUG test will probably score poorly on the SFBOT-2.

Age-related findings

In the present study we can observe that there were slight improvements in the mean scores of all tests administered as age increased. These results correlate with studies on developmental differences in motor performance during childhood and adolescence, which indicate modest, or no improvement with age. (Bhat, 2023; Fournier et al., 2010).

Strengths of the current study

One of the strengths of the present study is that it includes a large sample of children with ASD compared to the same number of children with NTD. Previous studies such as Kaur et al. assessed gross and fine motor performance, praxis, bilateral motor coordination including solitary, and social motor coordination, as well as interpersonal/social synchrony in school-aged children with ASD using standardized tests such as the BOT-2 or the bilateral motor coordination subtest of the Sensory Integration and Praxis Test and behavioral paradigms. However, the sample of this study was 24 children with ASD and 12 children with NTD. In our study we included a sample of 50 children and adolescents with ASD and 50 children and adolescents with NTD.

Limitations

This study has a few drawbacks. First, a higher percentage of male subjects than female subjects were included in the sample, which can be partially explained by the higher prevalence of ASD in the male community. As a result, the scale and assessment test results are more applicable to the male population than the female population. Second, it was hard to assess how the participants' motor and balance abilities were impacted by the disease because the degree of ASD was unknown. Moreover, there was not enough information to say whether IQ affected how impaired motor skills and balance were. Future research should collect data on IQ and the severity of ASD to determine whether there is a relationship between scores on different scales and tests of motor and balance skills, and the degree of impairment caused by ASD. Furthermore, it is crucial to point out that participants were selected from a group of individuals who satisfied the inclusion criteria up to the estimated sample size was attained using a nonprobabilistic selection technique. The participants were selected by a professional using not randomly selected approaches and preset criteria, such as study interest and availability. The sample bias that may result from a nonprobabilistic sampling technique would limit the generalizability of the results to a broader base population.

In conclusion, statistically significant differences in TUG, SFBOT-2, standard and total scores, and PBS were observed between the control group and the ASD group. Furthermore, statistically significant differences were observed in all age groups in the TUG and SFBOT-2, standard and total scores, when stratifying the sample by age group and in the age group 6–9 and 10–12 years in the PBS. Therefore, it seems reasonable to state that children and adolescents with ASD present difficulties in static and dynamic balance, postural control, and motor skills measured with scales and observational tests for assessing balance and motor skills. Furthermore, a poor correlation was noted between the TUG test and SFBOT-2, as well as between PBS and the TUG test. Moreover, a moderate association was also found between SFBOT-2 and PBS. In addition, differences were observed between the ASD group and the control group in the motor skills of strength followed by manual dexterity, running speed and agility, fine motor precision, fine motor integration, and balance. Finally, the PBS item that showed the greatest difference between the ASD group and the control group was item 9, which consists of maintaining monopodial support with hands on hips.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests.

CONSENT TO PARTICIPATE

Informed consent was obtained from parents or legal representatives of all participants. Likewise, informed consent was obtained from those participants over 14 years of age.

CONSENT TO PUBLISH

All persons.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of This protocol was approved by the local ethics committee (3011202122821).

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