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Standing Balance on Unsteady Surfaces in Children on the Autism Spectrum: The Effects of IQ

Brittany G. Travers^{1,2,3,*}, Andrea Mason¹, Kreg G. Gruben¹, Douglas C. Dean III³, and Kristine McLaughlin³

¹Kinesiology Department, University of Wisconsin-Madison

²Occupational Therapy Program in the Department of Kinesiology, University of Wisconsin-Madison

³Waisman Center, University of Wisconsin-Madison

Abstract

Background—Postural stability difficulties are commonly reported in people on the autism spectrum. However, it is unclear whether unsteady surfaces may exacerbate postural stability difficulties in children and adolescents with autism spectrum disorder (ASD). Understanding balance on unsteady surfaces is important because uneven surfaces are commonly encountered in daily life.

Methods—Twenty-one youth on the autism spectrum and 16 youth with typical development (ages 6-16 years, IQ = 79) stood on both a fixed and unsteady (tiltable) platform, and center of pressure was measured.

Results—The group with ASD exhibited differentially more postural sway on the unsteady surface compared to the group with typical development. However, there was substantial variability within the ASD group. Follow-up analyses suggested that much of the variability in postural sway in the ASD group was accounted for by IQ.

Conclusions—Clinically, these findings suggest that not all individuals with ASD struggle more with postural stability on unsteady surfaces. Instead children and adolescents with ASD and below-average IQ may have particular difficulty on unsteady surfaces and may require accommodations. Further, these findings lay the groundwork for future research to investigate the underlying mechanisms of poorer balance across the autism spectrum.

Keywords

autism spectrum disorders; balance; postural stability; postural control; center of pressure; motor

*Corresponding Author: Brittany G. Travers, ORCID ID: 0000-0002-8161-3858, Waisman Center, University of Wisconsin-Madison, 1500 Highland Avenue, Room 435, Madison, WI 53705 Tel: (608) 263-0282 Fax: (608) 263-0529, btravers@wisc.edu.

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Introduction

Maintaining balance during standing may be perceived by many as a simple task, but postural control requires complex adjustments to ever-changing internal and external input (Horak, 2006; Lockhart & Ting, 2007). In individuals on the autism spectrum, there is evidence for a diversity of motor difficulties (for a meta-analysis, see Fournier, Hass, Naik, Lodha, & Cauraugh [2010]) and atypical sensory profiles (for a review, see Baranek, Little, Diane Parham, Ausderau, & Sabatos-DeVito [2014]), which individually or in combination could result in postural stability challenges. The environment may further challenge postural stability, as much of the ground on which we balance has the potential to be unsteady (i.e., uneven terrain, slick surfaces, etc.). If people on the autism spectrum struggle to maintain balance on unsteady surfaces even more so than typically developing peers, this would create additional obstacles to being able to complete tasks required for independent living. Understanding how postural stability differs in autism compared to typical development will allow us to better determine appropriate accommodations for balance challenges in individuals on the autism spectrum. Moreover, by identifying who on the autism spectrum may struggle most with postural stability, we may better determine potential mechanisms underlying balance challenges in this population and to determine which individuals would benefit most from accommodations. Therefore, the purpose of the present study was to examine group differences in postural stability during upright standing on both fixed and unsteady surfaces in children and adolescents on the autism spectrum compared to age- and performance IQ-matched peers with typical development.

A handful of studies suggest that balance may be impacted in people on the autism spectrum (for a review and meta-analysis, see Lim, Partridge, Girdler, & Morris [2017]). Standardized assessments that use balance times to measure postural stability have shown that people on the autism spectrum maintain standing balance for a shorter amount of time (or for a fewer number of hops) compared to typically developing peers (Ghaziuddin, Butler, Tsai, & Ghaziuddin, 1994; Green et al., 2002, 2009; Jansiewicz et al., 2006; Noterdaeme, Mildemberger, Minow, & Amorosa, 2002; Papadopoulos et al., 2012). Similarly, measures of postural sway, typically performed on a force plate or balance board, have indicated more sway in people on the autism spectrum during quiet standing (Fournier, Kimberg, et al., 2010; Kohen-Raz, Volkman, & Cohen, 1992; Radonovich, Fournier, & Hass, 2013) and dynamic standing (Wang et al., 2016). However, even in studies where no group differences in postural stability emerged in more basic balance poses (i.e., two-footed, eyes-open standing) (Travers, Powell, Klinger, & Klinger, 2013; Weimer, Schatz, Lincoln, Ballantyne, & Trauner, 2001), decreased postural stability was observed in people on the autism spectrum in the more challenging balance poses, such as one-footed standing (Graham et al., 2015; Travers et al., 2013; Weimer et al., 2001), dual-task conditions (Chang, Wade, Stoffregen, Hsu, & Pan, 2010; Memari, Ghanouni, Shayestehfar, & Ghaheri, 2014), eyes-closed standing (Molloy, Dietrich, & Bhattacharya, 2003), and standing on a foam cushion (Minshew, Sung, Jones, & Furman, 2004; Molloy et al., 2003).

A small number of the previously mentioned studies have also examined how individual differences within the autism spectrum moderate postural stability performance. Poorer postural stability in individuals on the autism spectrum was found to relate to more severe

social communication impairments (Travers et al., 2013), more severe repetitive behaviors symptoms (Radonovich et al., 2013; Travers et al., 2013), more severe emotional/behavioral challenges (Papadopoulos et al., 2011), and lower IQ scores (Minshew et al., 2004). These results underscore the need to better understand how postural stability under various conditions may interact with individual-difference variables to differentially impact the lives of individuals across the spectrum.

Taken together, the literature suggests that people on the autism spectrum may have postural stability difficulties, especially when the balance task presents a greater sensorimotor challenge. However, much of the research to date has focused on postural stability on fixed, horizontal surfaces. To our knowledge, only one study (Dumas, McKenna, & Murphy, 2016) has investigated postural control in ASD using a surface that could tilt. In that study, the front-to-back tilt of the surface continuously adjusted to how the body was leaning so that the same ankle angle was maintained across all tilt angles. This resulted in proprioceptive feedback no longer providing information regarding postural orientation. Dumas and colleagues (2016) found that young adults on the autism spectrum exhibited differentially more sway compared to the typically developing group in the tilt condition. While this study offers initial evidence that unsteady surfaces might be a particular challenge in adults on the autism spectrum, previous research suggests atypical development of the postural control system from childhood through adulthood in autism spectrum disorder (ASD) (Minshew et al., 2004). Thus, it is important to characterize the development of balance challenges on unsteady surfaces in children and adolescents on the autism spectrum. If postural stability on a tiltable platform were to be particularly challenging for children on the autism spectrum (even more so than in typically developing children), then this may have negative implications for functional activities such as playing on certain playground structures or even engaging in various types of exercises. Therefore, the primary aim of the present study was to examine postural stability in children and adolescents on the autism spectrum compared to children and adolescents with typical development during standing on a traditional fixed platform compared to a tiltable platform. We hypothesized that children and adolescents on the autism spectrum would exhibit differentially more postural sway on the unsteady surfaces when compared to their age-matched peers with typical development. Given the heterogeneity in clinical profiles within the autism spectrum, a secondary aim was to examine potential moderators of postural stability within the ASD group in order to identify who on the autism spectrum may have particular difficulty on unsteady surfaces and may be more likely to require accommodations.

Methods

Participants

This study received approval from University of Wisconsin-Madison's institutional review board (#2013-0857). Participants' consent was obtained according to the Declaration of Helsinki as revised in 2000. Written informed consent was obtained from a parent/guardian, and assent was obtained from the children. Twenty-one children/adolescents with ASD and 16 children/adolescents with typical development (ages 6-16 years) successfully completed the postural stability measurements as part of a broader study to assess multiple aspects of

motor function in individuals with ASD. Participants were recruited through community fliers, and additional participants who met study criteria were recruited through the Waisman Center's participant registry. Participants with ASD were included if they had a previous diagnosis of autistic disorder, Asperger's syndrome, or pervasive developmental disorder not otherwise specified (PDD-NOS). Participants with ASD were excluded from this study if the family reported a known medical cause of ASD (i.e., fragile-X testing, tuberous sclerosis), hypoxia-ischemia, seizure disorder, or other neurological disorders. The Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999) was performed to determine that participants did not have co-occurring intellectual disorder (full-scale IQ < 70). Due to a scheduling conflict, we were unable to complete the IQ measures for one participant with ASD. Thus, this person was not included in analyses that included IQ as a variable. Autism spectrum symptoms were assessed using the Repetitive Behavior Scale-Revised (RBS-R) (Bodfish, Symons, Parker, & Lewis, 2000; Lam & Aman, 2007) and the Social Responsiveness Scale (SRS) (Constantino, 2002). Three participants had incomplete SRS data, and were therefore not included in analyses that included the SRS as a variable. An autism diagnosis was confirmed using the Autism Diagnostic Observation Scale-2nd edition (ADOS-2) (Lord et al., 2012). However, two participants with a previous diagnosis of ASD narrowly missed cutoff on the ADOS-2. Because the results were equivalent with and without these two participants, we report results with these participants included.

All participants with typical development were required to have a score of less than eight on the Social Communication Questionnaire (SCQ) (Rutter, Bailey, & Lord, 2003). This excluded three individuals with typical development from the broader study. Further, participants with typical development were required to not have a first-degree family member with ASD, as motor difficulties may exist across the broader autism phenotype (Mosconi et al., 2010). All participants were verbal at the time of testing and had English as their first language. Table 1 shows that participant groups were well-matched on age and performance IQ (PIQ), but the groups significantly differed in full-scale IQ (FSIQ) and verbal IQ (VIQ).

Procedures

Participants completed all tasks within a single, three-hour session, while parents completed caregiver questionnaires. The postural stability tasks were a subset of motor tasks (i.e., grip strength, reach-to-grasp, and two-minute walk) that were administered to the participants in the research session. The order of tasks was counterbalanced across all participants. To measure postural stability, ground reaction forces were recorded by a Nintendo Wii balance board connected via Bluetooth to a Linux-based laptop (similar to Travers et al., [2013]). The Wii balance board has demonstrated excellent reliability and validity compared to research-grade force platforms (Clark et al., 2010; Monteiro-Junior et al., 2015). To further maintain accuracy of measurement, the sensors of the Wii balance board were calibrated before every trial in the present study.

Participants performed two static balance tasks, the order of which was counterbalanced across all participants: 1) one trial of standing on the Wii balance board resting stationary (fixed) on the floor, and 2) and one trial of standing on the Wii balance board supported by a

small base that allowed it to tilt (The Real Balance Board Attachment for Wii Fit Balance Board). The tiltable board was limited to mediolateral (roll) tilt of $\pm 15^\circ$ and anteroposterior (pitch) tilt of $\pm 20^\circ$. In both the fixed and tiltable conditions, the participants were instructed to stand on the balance board with feet together on the center line and arms crossed at the chest (See Figure 1). The research team positioned the feet to confirm correct positioning (i.e., feet touching at the center line of the board). The balance board was placed approximately one foot in front of a wall. To ensure safety, participants faced the wall and were told that they could touch the wall if they felt they were losing balance. Three participants in the ASD group touched the front wall only in the unsteady surface condition. Once in position, participants were instructed to stand as still as possible. No visual cue was provided on the wall. Practice/familiarization trials were not presented in order to enhance the ecological validity of these measures (i.e., when we encounter unstable surfaces in the real world, we rarely have the opportunity to practice them beforehand).

Center of Pressure Data Reduction and Analyses

Processing of postural stability data was performed in *R* version 3.2.2 (R Core Team, 2015). For each task, we collected 50 seconds of data at 35 Hz. Force on each of the four balance board sensors was recorded and used to calculate Center of Pressure (COP), accounting for the distance between the four sensors on the Wii balance board (Bartlett et al., 2014).

We calculated the x and y COP coordinates for each time point. We then calculated the eigenvectors and eigenvalues of the covariance matrix formed from all the x and y coordinate pairs. While many different COP metrics have been used to measure postural control during static balance, we decided *a priori* to conduct our analyses on COP area (area of ellipse [mm²] that contains 95% of the data) (Winter, 2009), as this is the most commonly reported measure in the literature. We had originally hoped to additionally examine total mean velocity. However, we thought it conservative to stick with postural sway area, given the lower resolution of the Wii balance board. Because only sway area was examined, no filtering was performed on the data. From these eigenvectors and eigenvalues, we calculated the semimajor and semiminor axes of the ellipse with Equations 1 and 2.

$$Semimajor = \sqrt{5.99\lambda_1} \quad (1)$$

$$Semiminor = \sqrt{5.99\lambda_2} \quad (2)$$

where λ_1 and λ_2 correspond to the first and second eigenvalues, respectively. We then calculated the area of the best fit ellipse that encapsulates 95% of the data (Chi-Square critical value of 5.99) with Equation 3:

$$Area = 5.99\pi\sqrt{\lambda_1\lambda_2} \quad (3)$$

See supplemental materials Figure S1 for examples of COP data and the 95% confidence ellipses.

Statistical Analyses

Statistical analyses were performed in IBM SPSS Statistics version 23. To investigate group differences in postural sway area on a fixed versus unsteady platform, we conducted a 2 (ASD vs. TD) $\times$ 2 (fixed vs. unsteady surface) mixed ANOVA. Diagnostic group was the between-subjects independent variable. Surface condition was the within-subjects independent variable. *Post-hoc*, follow-up correlations examined the variables that accounted for the substantial variability in postural sway area in each group separately. These variables included age, body mass index (BMI), IQ, SRS total raw scores, and RBS-R scores and were selected based on associations found between one or more of these variables and postural sway area in ASD in previous research (e.g., Minshew et al. [2004], Radonovich et al., [2013], and Travers et al., [2013]). An FDR correction was used to account for multiple comparisons.

Results

All assumptions of GLM were examined. The assumption of homogeneity of variance and of normal distribution were not met, even after attempting standard data transformations. An inspection of the data suggested that this was due to wide variability of sway area within the ASD group. Because the wide variability was specific to the ASD group and because of the lack of a non-parametric test for this analysis, the 2 (ASD vs. TD) $\times$ 2 (fixed vs. unsteady surface) mixed ANOVA was performed, but follow-up analyses examined potential sources to account for variability within the ASD group. Data and descriptive statistics for this analysis can be seen in Figure 2. As hypothesized, there was a significant interaction between group and surface condition, $F(1,35) = 4.40$, $p = .04$, $\eta_p^2 = .112$. There were additionally main effects for group, $F(1,35) = 5.40$, $p = .03$, $\eta_p^2 = .134$, and surface condition, $F(1,35) = 11.56$, $p = .002$, $\eta_p^2 = .248$.

To examine variables that might account for the substantial variability observed within the ASD group, we performed correlations examining how postural sway area on the fixed and unsteady surfaces correlated with age, BMI, SRS total raw scores, RBS-R total raw scores, VIQ, PIQ, and FSIQ. As seen in the results reported in Table 2, postural sway area was significantly correlated with VIQ in both the fixed and unsteady surface conditions. Also within the ASD group, postural sway area was significantly correlated with FSIQ only in the unsteady surface condition. Age and SRS scores demonstrated medium-to-large correlations with postural sway area in the fixed surface condition, but these correlations did not reach significance with FDR correction. As a point of comparison, we ran parallel analyses in the typically developing group (Table 2). In contrast to the ASD group, there were no significant correlations among the behavioral variables and the postural sway data. Figure 3 illustrates how VIQ and FSIQ relate to postural sway area in ASD compared to typical development under both surface conditions. However, because the groups were not well-matched on VIQ nor FSIQ, it was deemed not appropriate to statistically examine the potential interaction between diagnosis and IQ.

Discussion & Implications

The present study set out to examine postural stability in children and adolescents on the autism spectrum on both fixed and unsteady platforms in order to examine balance on unstable standing surfaces. To our knowledge, this study is the first to examine postural stability on an unsteady platform in youth with ASD, which is important as children encounter many unsteady surfaces in daily life (i.e., playground structures, diving boards, loose concrete, etc.). As hypothesized, we found that balance on an unsteady platform was differentially more difficult for the autism group compared to the typically developing group. However, there was substantial variability within the ASD group that was not observed in the typically developing group. Follow-up analyses suggested that those with ASD and lower VIQ demonstrated more balance challenge regardless of the surface condition, whereas those with ASD and lower FSIQ demonstrated balance that was more affected by the unsteady surface. As discussed in more detail below, these results suggest that IQ may be an important factor to help determine who on the autism spectrum may need accommodations for balance on steady and unsteady surfaces.

Consistent with previous findings of differentially poorer balance in ASD during more challenging conditions (Chang et al., 2010; Dumas et al., 2016; Memari et al., 2014; Minshew et al., 2004; Molloy et al., 2003; Travers et al., 2013; Weimer et al., 2001), the results demonstrated that as a group, balance in children and adolescents with ASD was more impacted in the unsteady-surface condition compared to the fixed-surface condition. However, the present findings extend upon previous work to show that VIQ and FSIQ (even when group-matching on performance IQ) are important factors within the ASD group. Specifically, individuals with ASD with below-average IQ tended to have the greatest balance challenge on the unsteady surface, whereas IQ was not associated with postural sway in the group with typical development. While prior investigations found that IQ related to postural sway in a wide age range of individuals with ASD (Minshew et al., 2004) and in a sample with an age range similar to the present study (Radonovich et al., 2013), the relation of IQ in the present study was somewhat surprising, given that all participants had IQs ≥ 79 , meaning that no participant with ASD had a co-occurring diagnosis of intellectual disability. Therefore, a novel aspect of the present study is that cognitive factors may play a role in balance even in children who have IQs that fall within 1-2 standard deviations of the normal range.

The present findings add to the literature by suggesting that postural stability is unlikely to be a global impairment in youth with ASD. Instead, factors such as IQ may predict who experiences more challenge when engaging in complex balance tasks. However, this phenomenon may not be specific to ASD. In older adults with typical development, there is evidence that cognitive factors, such as allocation of attention, may exacerbate balance challenges by diminishing cognitive control of the muscle responses (for a review see Woollacott & Shumway-Cook [2002]). Similarly, we speculate that IQ (including VIQ) may reflect, or be associated with, broader cognitive factors in children with ASD that also exacerbate balance challenges, such that children with lower IQ are more likely to experience a greater cognitive load during balance tasks. A key direction for future research is to examine other cognitive factors (i.e., executive function, attention, and processing

speed) that may further exacerbate balance challenges in this population. Moreover, given the present results, it is possible that individuals on the autism spectrum with below-average IQ may have different underlying mechanisms of balance challenge compared to individuals on the autism spectrum with average or above-average IQ. Therefore, future research can use this specific cohort to better understand variation in the potential underlying mechanisms of balance in ASD.

Of note, the present results raise the question of how IQ is accounted for in studies of motor function in ASD. The present study, like the majority of the research on postural stability in ASD, matched the groups on chronological age and performance IQ. Despite this matching, we still found a significantly moderating effect of VIQ across all balance conditions and a significantly moderating effect for FSIQ in the more challenging condition. By definition, a moderator is a variable that impacts the direction and/or strength of the relation between an independent and dependent variable (Barron & Kenny, 2006). In other words, the moderator interacts with the independent variable to change the dependent variable. In contrast, a covariate is a variable known to impact the dependent variable (often erroneously thought to control for between group differences of a variable [Miller & Chapman, 2001]). The distinction between a moderator and covariate may appear slight, but whether IQ is statistically enacted as a moderator or covariate may profoundly impact our understanding of the impact of ASD on motor function. Including moderators like IQ in motor in ASD research may be particularly important for understanding sources of individual variability across the heterogeneous autism spectrum.

Others have eloquently discussed the challenge of determining appropriate matching strategies in autism research (i.e., Burack, Iarocci, Flanagan, & Bowler, 2004). However, if we had matched groups tightly on IQ or covaried¹ for IQ in the present models, we would have been unable to identify this potentially important factor when it comes to balance in ASD. The present results suggest that future research would benefit from conceptualizing IQ and VIQ as moderators (interacting variables) rather than something to be controlled for (i.e. covariate or matching variable) in studies of motor functioning, especially if those studies examine performance under more challenging conditions.

The present findings of the effect of IQ on balance in ASD has substantial clinical implications, suggesting that children and adolescents with below-average IQ may be more likely to experience balance challenges on unsteady surfaces, whereas those with average or above-average IQ may not struggle on unsteady surfaces. Unsteady surfaces are commonly encountered in the environment, and these findings suggest that caution may be warranted when a child with ASD who has below-average IQ engages in certain playground activities, stands on moving surfaces (i.e., a train, bus, or moving escalator), or walks on uneven surfaces. Intensive balance training (Cheldavi, Shakerian, Boshehri, & Zarghami, 2014; Travers et al., 2017) or hippotherapy (Ajzenman, Standeven, & Shurtleff, 2013) may be able

¹Because IQ affected postural stability in the ASD group differently than in the typically developing group, including IQ as a covariate in the original model would have violated one of the GLM assumptions of using a covariate (Cohen & Cohen, 1983). See Dennis et al. (2009) for an in depth discussion on using IQ as a covariate in research in neurodevelopmental disorders.

to alleviate postural stability challenges in ASD, although it is unclear if these interventions translate to better balance on unsteady surfaces.

While the current study had a number of strengths, key limitations exist. One limitation is that this study was not designed to understand the mechanisms underlying poorer postural stability in ASD. Nevertheless, these results answer key questions regarding how postural stability may be impacted in ASD on unstable surfaces and who is likely to be the most impacted. Importantly, these findings can speak to clinical decision making when trying to treat balance challenges in ASD and may lay the groundwork for future research to examine the underlying mechanisms. Similarly, this study was not designed to assess age-related changes in postural stability development, nor was it able to examine fine or gross motor skills that may interact with postural stability impairments in ASD. Future research is needed to examine postural stability in light of other potential motor challenges, and longitudinal studies will be needed to determine whether development of postural stability is similar in ASD compared to typical development. Statistical limitations of this study included the distribution of the data that violated assumptions of the statistical test and the relatively small sample size. Follow-up analyses were performed to clarify the sources of the non-normally distributed data within the ASD group, but future research is needed to investigate balance on unsteady surfaces in larger samples. Another limitation was the lack of matching the two groups on FSIQ, as the lowest FSIQ in the group with typical development was 96 (as compared to 79 in the group with ASD). This lack of matching prevented us from being able to test whether lower FSIQ in the typically developing group impacted balance on an unsteady platform. Further, we did not have autism symptom severity measures in our typically developing group, which prevented us from including those variables in the individual-differences models for that group. Although the Wii balance board has many advantages (i.e., portability and ability to collect data on a tilting surface), a disadvantage is the lower resolution of the four-sensor Wii balance board compared to traditional force plates. However, we were able to detect large-sized effects between the fixed and unsteady surface conditions, suggesting that the balance board provided sufficient resolution for measurements of postural sway area. Another disadvantage was that three participants touched the wall during the unsteady condition to prevent falling. An alternative strategy would have been to use a safety harness. However, in designing this task in conversation with parents of children with ASD, we determined that wearing a safety harness could differentially affect the children with ASD (compared to children with typical development) due to sensory features common in children with ASD. Finally, we measured balance while on an unsteady surface in order to enhance the ecological validity of these measurements, particularly in light of the fact that many surfaces we stand on in our day-to-day lives are not steady. While this measure is more ecologically valid than classic measures of postural stability, future studies would benefit by including measures that can more directly assess balance during functional tasks.

Conclusions

To our knowledge, the present study is the first to examine standing balance on both fixed and unsteady surfaces in children and adolescents on the autism spectrum. The results demonstrated that youth on the spectrum who had lower VIQ exhibited greater balance

challenges regardless of condition, and youth on the spectrum who had lower IQ exhibited more balance challenge in the unsteady surface condition. Therefore, IQ should be taken into account when determining whether a youth on the autism spectrum might have difficulty maintaining balance in more true-to-life settings where balance is required. These findings identify who on the autism spectrum may be most likely to need accommodations or interventions for balance challenges, and these findings lay the groundwork for future research to investigate the underlying mechanisms of poorer balance across the autism spectrum.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Highlights

- Youth with ASD may have balance difficulties when standing on unsteady surfaces.
- However, there was substantial variability in postural sway within the ASD group.
- IQ accounted for variability within the ASD group but not within the control group.
- IQ may be an important factor for postural stability on unsteady surfaces in ASD.

Figure 1.
A researcher demonstrating the balance procedures on A) the static platform and B) the unsteady platform. Once on the platforms, participants were asked to keep feet together on the center line and arms crossed at the chest.

Figure 2.

Postural sway area as a function of group and surface condition. Postural sway area was measured as the area (mm²) of the ellipse surrounding 95% of the center of pressure data. There was a significant group-by-surface-condition interaction, but there substantial variability within the ASD group. The boxplots represent the 25th quartile, median (center line), and 75th quartile. The table represents the mean (*M*) and standard deviation (*SD*) of the postural sway area (mm²) for each group and each condition.

Figure 3.

A) Postural sway area as a function of group and verbal IQ (VIQ). B) Postural sway area as a function of group and full-scale IQ (FSIQ). VIQ was related to postural sway area under both surface conditions within the ASD group but not within the group with typical development. FSIQ was related to postural sway area within the ASD group in the unsteady surface condition but not within the group with typical development.

Table 1

Descriptive statistics for the demographic information in each group.

	ASD (n=21)	Typically Developing (n =16)	p-value	Cohen's d
% Males	85.7%	87.5%	–	–
Age, Mean(SD)	9.63(2.09)	9.64(2.78)	.99	0.004
Age, Range	6.36-14.34	6.37-16.47	–	–
BMI, Mean(SD)	18.03(4.79)	17.75(4.20)	.85	0.062
BMI, Range	13.39-30.49	10.88-27.35	–	–
FSIQ, Mean(SD)	102.20(12.85)	117.56(15.15)	.002	1.093
FSIQ, Range	79-133	96-143	–	–
VIQ, Mean(SD)	99.05(12.20)	120.50(14.39)	<.001	1.608
VIQ, Range	74-116	94-146	–	–
PIQ, Mean(SD)	104.80(17.91)	110.50(16.77)	.34	0.329
PIQ, Range	71-143	87-145	–	–
SRS Total Raw, Mean(SD)	87.28(23.11)	–	–	–
SRS Total Raw, Range	41-131	–	–	–
RBS-R Total Raw, Mean(SD)	29.36(21.33)	–	–	–
RBS-R Total Raw, Range	2-88	–	–	–

ASD, autism spectrum disorder; FSIQ, full-scale IQ; PIQ, performance IQ; RBS-R, Repetitive Behavior Scale-Revised; SRS, Social Responsiveness Scale; VIQ, verbal IQ.

Table 2

Pearson correlations examining the relation between postural sway area (under both fixed and unsteady surface conditions) and individual characteristics previously found to be associated with balance. Correlations were performed in each group separately with an FDR-correction for multiple comparisons.

<i>ASD Group</i>		
	Fixed Surface Sway Area	Unsteady Surface Sway Area
VIQ	-.61 ***	-.65 ***
PIQ	-.21	-.40
FSIQ	-.52 *	-.65 ***
BMI	-.25	-.28
Age (years)	-.50 *	-.13
SRS	+.51 *	+.43
RBS-R	+.11	+.01
<i>TD Group</i>		
	Fixed Surface Sway Area	Unsteady Surface Sway Area
VIQ	+.05	-.41
PIQ	-.04	+.26
FSIQ	+.01	-.05
BMI	+.02	-.03
Age (years)	-.42	-.46

ASD, autism spectrum disorder; BMI, body mass index; FSIQ, full-scale IQ; PIQ, performance IQ; RBS-R, Repetitive Behavior Scale-Revised; SRS, Social Responsiveness Scale; VIQ: verbal IQ.

* $p < .05$ uncorrected,

*** $p < .05$ FDR-corrected