Evaluation of mental maturity and right-left orientation and correlations with gait and balance in children with Autism Spectrum disorder: preliminary study

Avaliação da maturidade mental e da orientação direita-esquerda e correlações com a marcha e o equilíbrio em crianças com Transtorno do Espectro do Autismo: estudo preliminar

DOI: 10.55905/revconv.16n.9-120

Recebimento dos originais: 21/08/2023
Aceitação para publicação: 19/09/2023

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ABSTRACT
Children with autism spectrum disorder (ASD) have cognitive difficulties and delayed development, with deficits in gross and fine motor markers as well as postural balance, leading to poorer quality of life. The objective was to evaluate mental maturity and right-left orientation in children with ASD compared to children with typical development and correlate the findings with balance and gait performance. A convenience sample composed of 21 male and female children between six years and nine years 11 months of age was submitted psychological and functional motor tests. The findings suggest correlations between mental maturity/right-left orientation and functional mobility/balance in children with autism spectrum disorder. The severity of the disorder and mental maturity were correlated with variables that demonstrated motor abnormalities, such as functional balance and gait speed.

Keywords: Autism Spectrum Disorder, motor control, cognitive function.

RESUMO
As crianças com transtorno do espectro autista (TEA) têm dificuldades cognitivas e atraso no desenvolvimento, com déficits nos marcadores motores grossos e finos, bem como no equilíbrio postural, o que leva a uma pior qualidade de vida. O objetivo foi avaliar a maturidade mental e a orientação direita-esquerda em crianças com TEA em comparação com crianças com desenvolvimento típico e correlacionar os achados com o desempenho do equilíbrio e da marcha. Uma amostra de conveniência composta por 21 crianças de ambos os sexos, entre seis anos e nove anos e 11 meses de idade, foi submetida a testes psicológicos e motores funcionais. Os resultados sugerem correlações entre maturidade mental/orientação direita-esquerda e mobilidade/equilibrio funcional em crianças com transtorno do espectro do autismo. A gravidade do transtorno e a maturidade mental foram correlacionadas com variáveis que demonstraram anormalidades motoras, como equilíbrio funcional e velocidade da marcha.

Palavras-chave: Transtorno do Espectro do Autismo, controle motor, função cognitiva.

1 INTRODUCTION
In 1911, Eugen Bleuler was the first to use the term “autistic” in studies on schizophrenia. However, it was in 1943 that Leo Kanner defined the term based on observations of a group of
children with peculiar behavior characterized by an innate inability to establish affective interpersonal contact (Gadia et al., 2004).

The Diagnosis and Statistical Manual of Mental Disorders (DSM-5, 2014) defines mental disorder as a syndrome characterized by a clinically significant disturbance in cognition, emotional regulation or behavior that reflects a dysfunction in the psychological, biological or developmental processes underlying mental functioning. Mental disorders are often associated with significant suffering or incapacity that affects social, professional or other important activities.

In the fourth edition of the DSM, the specification previously denominated “invasive development disorders” became known as “global development disorders”. In the DSM-5, however, the American Psychiatric Association (APA) no longer uses the classification “global development disorders”, which had encompassed specific disorders besides autism, such as Rett syndrome, childhood disintegrative disorder, Asperger syndrome and invasive development disorder without other specifications, and officially adopts the term “autism spectrum disorder” (ASD), the level of which is measured by severity specifiers. These specifiers refer to impairment: Level 3- requiring very substantial support; Level 2- requiring substantial support; Level 1- requiring support (DSM-5, 2014).

The new presentation of disorders in the DSM-5 (2014) classifies neurodevelopmental disorders as a group of conditions with onset in the period of development. Development deficits range from very specific limitations regarding learning or the control of executive functions to the global impairment of social skills or intelligence, the symptoms of which include repetitive stereotyped behaviors, restricted interests, sensory abnormalities, difficulty maintaining eye contact and delayed motor development.

According to Papalia and Feldman (2013), cognitive development is explained by the processing of information through an analysis of the understanding of the information received and the effective performance of a given task. Psychological processes (learning, thought, emotions, attention, memory, reasoning, planning strategies, decision making and goal setting) are fundamental to the progression of children in the development of cognitive, emotional and motor aspects, thereby forming the personality. The authors state that the brain is like a computer that stores information to be used in similar situations in the future and can learn to apply this knowledge correctly and with greater effectiveness.
Bee and Bokd (2011) cited by Gazzola et al. (2018) explain the theories of Piaget and Vygotsky in the natural development of children. Piaget’s theory is the development of reasoning in four universal stages. Vygotsky’s theory addresses the “zone of proximal development” and the specific stages a child goes through between birth and seven years of age.

Children with ASD have impairments in terms of socialization, communication and behavior. The difficulty in interpreting social cues and the intentions of others impedes such individuals from correctly perceiving certain situations in the surrounding environment. According to Gadia et al. (2004), the repetitive, stereotyped patterns of behavior that are characteristic of autism include resistance to change, insistence on particular routines, excessive attachment to objects and a fascination with movement of parts.

In the case series published by Kanner in 1943, ASD was described with a focus on the severe impairment of socioemotional capacity and communication. However, motor markers generally indicative of limited fine motor coordination in this population were described as “very skilled” in the sample studied by the author, although some of his patients presented gross motor deficits.

Gross and fine motor deficits are prevalent in this population (Greenspan & Wieder 1997; Fournier et al. 2010; Ming et al. 2007; Miyahara, 1997; Provost et al. 2007; Wing, 1981). Individuals with ASD have difficulties in performing qualified motor movements (Jones & Prior 1985; Mostofsky et al. 2006) and can even have impaired basic motor control (Adrien et al. 1993; Jansiewicz et al. 2006). These motor abnormalities have been categorized as “associated symptoms” (as opposed to principal symptoms) (Ming et al. 2007).

Motor performance is not part of the diagnostic criteria for ASD, but motor deficits are common in this population (Fournier et al. 2010). In a study involving the analysis of first gait at a young age in 376 children and associations with the severity or symptoms of ASD, Reindal et al. (2019) found that children with this condition required a significantly longer time to acquire the skill of walking compared to children without this disorder. Moreover, the gait pattern in this population is described as “altered” during foot contact with the ground and is characterized by asymmetry (Gong et al. 2020).

A study involving 22 children with ASD compared to 21 controls matched for age and IQ performance evaluated with regards to postural orientation and balance processes found a significant increase in mutual information during dynamic stances, implying deficits in the
postural balance process. This mutual information was normally reduced during dynamic stances in comparison to static stances, as body sway is restricted to one dimension and one type of joint movement is emphasized over another. In contrast, the children with ASD showed increased levels of shared information between ankle and hip movement during dynamic stances compared to static stances. The findings suggest that failures to decouple ankle dorsi-/plantar-flexion and hip abduction/adduction may contribute to postural disruptions during dynamic stances in ASD (Wang et al. 2016).

Individuals with autism seek to establish a routine by praxis to adjust their behavior. One of the characteristic manifestations of the disorder is behavioral deficit, with repetitive, stereotyped movements, which may be milder or more severe depending on the degree of the spectrum.

According to Tani et al. (2010) cited by Soares and Cavalcante Neto (2015), interactions between an individual and the environment are of the utmost importance to perfecting motor skills. Basic motor skills are developed beginning in childhood and enable the control of one’s body in different activities. Ferreira and Thompson (2002) cited by Fernandes (2008) state that autistic individuals have difficulty understanding the globality of their bodies when considered in segments and difficulty understanding their bodies in movement. Thus, when the parts of the body are not perceived and the functions of each part are unknown, poorly adapted movements, actions and gestures arise. This disorder in the structuring of the body also exerts a negative impact on the development of static balance, right-left orientation and the notion of reversibility, which are basic functions necessary to the acquisition of autonomy and cognitive learning. The body may be a source of anguish and panic to autistic children, especially if these children are not well stimulated and understood. It is therefore necessary for them to become a center of security and stability. Thus, one of the ways to assist in the treatment of autism is through the body, seeking to establish a relationship between the psychological and the organic. Through sensorial-motor experiences, such children can improve their relationship with the world, which is initially impossible due to the difficulty in entering into contact with others whether through touch or eye contact.

The literature describes several abnormalities in ASD. Although these aspects have not been fully clarified, children with ASD develop impaired structural and functional behaviors in the early stages of childhood development, leading to altered postural control (Freitag et al. 2007;
Minshew et al. 1997), gait abnormalities (Rinehart et al. 2006), bilateral coordination deficiencies (Marsh et al. 2013) as well as spatial errors (incorrect positioning of the body and improper use of part of the body as a tool to reduce discomfort) and temporal errors (poor movement time, longer time to initiate a movement) during imitation/practice tasks (Gizzonio et al. 2015; Salowitz et al. 2013).

This study is justified by the need to determine cognitive parameters and motor delays in the gait of autistic children, considering the gap in the literature on the correlation of these variables. As a novel situation with important impacts for individuals with ASD, we believe that the results of this investigation can serve as the basis for future intervention studies that could contribute to the development of more effective therapeutic strategies for this population.

Therefore, the objectives of the present study were to compare the performance of children with ASD and those with typical development in terms of static balance, functional balance and functional mobility considering spatiotemporal and angular measures of movements during the execution of functional tests. A further aim was to identify whether the severity of the neurodevelopmental disorder, mental maturity and right-left orientation are correlated with the functional measures studied.

2 METHODS

The present study was conducted in accordance with the guidelines for research involving human subjects stipulated in Resolution 466 issued in October 1996 and updated in 2012 by the Brazilian National Board of Health. This study received approval from the Human Research Ethics Committee of Universidade Evangélica de Goiás (UniEVANGÉLICA), Anápolis, state of Goiás, Brazil, on April 11, 2021 (certificate number: 4.585.636).

2.1 RECRUITMENT AND PARTICIPANTS

A convenience sample was formed involving 21 male and female children with chronological age from six years to nine years and 11 months. Ten children were recruited from the Associação de Pais e Amigos Excepcionais de Anápolis (APAE) [Association of Parents and Friends of Exceptional Children of Anápolis], which signed a statement of co-participation, with a diagnosis of autism spectrum disorder according to the criteria of the DSM-V issued by a
physician (as recorded on the patient records of the APAE). Eleven children with typical
development (TD) were also recruited through informal invitation.

All guardians received clarifications regarding the objectives and procedures of the study,
followed by the reading of the statement of informed consent. The guardians agreed to the
participation of their children by signing the statement. The children also signed (manually or
digitally) a term of assent.

2.2 ELIGIBILITY CRITERIA

The inclusion criteria were a) a diagnosis of ASD issued by a pediatric neurologist or
child psychiatrist; b) capacity to understand the procedures involved in the study and have a
satisfactory level of cooperation; c) age between six years and nine years 11 months; d) signed
statement of informed consent by a legal guardian; and e) signed term of assent by the child
agreeing to participate.

The exclusion criteria were a) having been submitted to orthopedic surgical procedures
in the 12 months prior to the onset of the evaluations; b) orthopedic deformities of the upper or
lower limbs or spinal column with an indication for surgery; c) associated neurological disorder
with absence of independent gait; d) age outside the target range established for the study; e)
unconfirmed diagnosis of ASD; and f) uncorrected visual impairment.

2.3 MEASURES

The evaluations were conducted only after approval from the UniEVANGÉLICA Human
Research Ethics Committee. Figure 1 displays the flowchart of the study.
The parents/guardians completed the identification chart with the following data: name of the participant, sex, age, date of birth, height, weight, body mass index, literacy and schooling. The parents/guardians also answered the Brazilian version of the Childhood Autism Rating Scale (CARS-BR), which assesses behavior in 14 domains generally affected by autism plus a category on the general impression of autism to determine the child’s level of the spectrum. The children were individually submitted to evaluations conducted in two steps with an average of 20 minutes for each evaluation.

Columbia Mental Maturity Scale (CMMS-3) – used to assess general reasoning capacity. The scale was administered by a psychologist (researcher of the present study). The individual record form was completed with data from the participant to identify the age group and level to be administered. The child received an explanation of the test and was instructed to point to a figure that she/he thought did not belong among a set of figures. A practice trial was used with three examples. After understanding of the test was ensured, the children performed the task until reaching the defined level.

The Piaget-Head battery was used to determine the degree of development of left-right orientation. A rapport was established with the children to ensure better understanding of the
instructions. Explanations were given with examples of the test. If necessary to ensure understanding, the psychologist showed the child how the movement should be performed a maximum of two times.

Spatiotemporal gait variables were evaluated during the Walk Test. The children were instructed to walk normally, without running, along a track, turn around a cone, walk back and turn around, ending in the original standing position. The test was performed under two conditions – in shoes and barefoot. The test was first performed twice to familiarize the child with the sequence – once accompanied by the researcher and the second time alone to verify that the child had understood the task.

Functional mobility was evaluated using the Timed Up and Go (TUG) test, which was performed with the child wearing an inertial sensor (G-sensor, BTS Bioengineering) (Figure 2). The children were instructed to walk at a safe, self-selected pace. The test was performed in shoes and barefoot. Three trials were performed under each condition – two for familiarization and the third was the trial used in the analysis.

Figure 2: Montage using G-sensor, BTS Bioengineering.

Source: Figure produced by the author.

For the assessment of static balance, the children were instructed to stand on two force plates remaining as still as possible with arms alongside the body and head in the vertical position. A 30-second reading was made under each condition: eyes open and closed without somatosensorial perturbation (no mat) and with somatosensorial perturbation (foam rubber mat).

Functional balance was assessed using the Pediatric Balance Scale, which consists of 14 tasks that resemble different activities of daily living. The participants were instructed and encouraged to perform the movements.
2.4 DATA ANALYSIS

The Kolmogorov-Smirnov test revealed that the data were parametric. Continuous variables were expressed as mean and standard deviation. Categorical variables were expressed as absolute and relative (percentage) frequencies. Comparisons between the ASD group and TD group (control) were performed using the unpaired t-test. Pearson’s correlation coefficients (r) were calculated to determine correlations between the psychological tests and functional tests of mobility and balance for which differences between groups were found. A p-value < 0.05 was considered indicative of statistical significance.

3 RESULTS

Forty-eight children were contacted for the present study – 35 with autism and 13 with TD. The children with a diagnosis of ASD were screened at the Associação de Pais e Amigos dos Excepcionais de Anápolis (APAE) [Association of Parents and Friends of Exceptional Children of Anápolis] between April 12, 2021 and April 2, 2022. Twenty-one children met the eligibility criteria and participated in the study. The experimental group (children with a diagnosis of ASD) was composed of 10 children and the control group (children with TD) was composed of 11 children. The children in both groups completed all evaluation procedures. Table 1 displays the anthropometric and clinical characteristics of the sample.

Table 1: Legend: Anthropometric and clinical characteristics of study groups. CARS-BR: Brazilian version of Childhood Autism Rating Scale. CMMS-3: Columbia Mental Maturity Scale 3. # data expressed as mean and standard deviation. ## data expressed as absolute and relative frequency

<table>
<thead>
<tr>
<th></th>
<th>Children with Autism Spectrum Disorder</th>
<th>Children with Typical Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 10</td>
<td>n = 11</td>
</tr>
<tr>
<td>Age (years)*</td>
<td>7.3 ± 1.0</td>
<td>7.5 ± 1.1</td>
</tr>
<tr>
<td>Sex (female / male)**</td>
<td>1 (10%) / 9 (90%)</td>
<td>4 (36.3%) / 7 (63.4%)</td>
</tr>
<tr>
<td>Literate (yes / no)**</td>
<td>6 (60%) / 4 (40%)</td>
<td>9 (81.9%) / 2 (18.1%)</td>
</tr>
<tr>
<td>CARS-BR (mild / moderate / severe)**</td>
<td>3 (30%) / 4 (40%) / 3 (30%)</td>
<td>----</td>
</tr>
<tr>
<td>CMMS-3*</td>
<td>60.7 ± 35.3*</td>
<td>93.8 ± 10.4</td>
</tr>
<tr>
<td>Piaget-Head battery*</td>
<td>36.6 ± 33.3*</td>
<td>80.7 ± 15.4</td>
</tr>
</tbody>
</table>

Source: produced by the author.

3.1 OUTCOMES

*Pediatric balance scale*. The statistical analysis demonstrated impaired functional balance in the ASD group (51.5 ± 7.1) compared to the control group (55.8 ± 0.4), with a
difference between means of $4.318 \pm 2.164$ ($p < 0.001$). Figure 3 displays the mean and standard deviation values for the Pediatric Balance Test in the two groups.

![Figure 3: ASD: autism spectrum disorder; TD: typical development. * $p < 0.05$ unpaired t-test.](image)

Stabilometry. No differences between groups were found regarding total displacement of the center of pressure, mean velocity, mediolateral sway or anteroposterior sway with eyes open or eyes closed in the readings performed with and without the foam rubber surface ($p > 0.05$ for all analyses). Table 2 displays the mean and standard deviation values for the stabilometric variables in the two groups.

<table>
<thead>
<tr>
<th></th>
<th>Children with Autism Spectrum Disorder n = 10</th>
<th>Children with Typical Development n = 11</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without foam mat</td>
<td>With foam mat</td>
</tr>
<tr>
<td>Displacement of center of pressure (mm)</td>
<td>Eyes open $579.0 \pm 134.5$ Eyes closed $725.8 \pm 232.3$</td>
<td>Eyes open $36.3 \pm 12.3$ Eyes closed $776.2 \pm 177.6$</td>
</tr>
<tr>
<td>Mean velocity (mm/s)</td>
<td>19.3 $\pm$ 4.4 Eyes open $24.8 \pm 9.5$ Eyes closed $23.7 \pm 7.6$</td>
<td>17.7 $\pm$ 5.9 Eyes open $18.2 \pm 5.5$ Eyes closed $18.1 \pm 5.8$</td>
</tr>
<tr>
<td>Mediolateral sway (mm)</td>
<td>36.3 $\pm$ 12.3 Eyes open $57.4 \pm 34.5$ Eyes closed $55.7 \pm 25.3$</td>
<td>28.2 $\pm$ 10.9 Eyes open $31.3 \pm 12.9$ Eyes closed $39.3 \pm 13.9$</td>
</tr>
<tr>
<td>Anteroposterior sway (mm)</td>
<td>10.9 $\pm$ 6.4 Eyes open $12.0 \pm 4.5$ Eyes closed $15.5 \pm 10.1$</td>
<td>8.5 $\pm$ 4.8 Eyes open $9.0 \pm 2.9$ Eyes closed $10.5 \pm 6.6$</td>
</tr>
</tbody>
</table>

Source: Produced by the author.

Timed Up and Go. Significant differences between groups were only found for the following spatiotemporal variables: duration of the going phase when performed barefoot (mean difference between groups: $0.67 \pm 0.49$ s, $p = 0.001$); duration of the standing to sitting phase...
performed barefoot (mean difference between groups: 0.17 ± 0.26 s, p <0.001) and in shoes (mean difference between groups: 0.73 ± 0.57 s, p <0.001); and the angular spatial variable peak trunk flexion in the sitting to standing phase when performed barefoot (mean difference between groups: 18.8 ± 6.8°, p = 0.018). The ASD group required more time in these phases and had a larger peak trunk flexion angle compared to the TD group. No significant differences between groups were found for the other variables analyzed during the TUG test (p >0.05 for all analyses). Table 3 displays the mean and standard deviation values of the variables measured during the execution of the TUG test in both groups and under both conditions (barefoot and in shoes).

Table 3: Mean and Standard Deviation Values of Variables Analyzed during Timed Up and Go Test in Group with ASD and Group with Typical Development. * unpaired t-test p < 0.05.

<table>
<thead>
<tr>
<th>Spatiotemporal variables</th>
<th>Children with Autism Spectrum Disorder n = 10</th>
<th>Children with Typical Development n = 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of test (s)</td>
<td>Barefoot (9.7 ± 2.6)</td>
<td>Barefoot (8.8 ± 1.5)</td>
</tr>
<tr>
<td></td>
<td>Shod (10.3 ± 1.6)</td>
<td>Shod (9.2 ± 1.0)</td>
</tr>
<tr>
<td>Duration of sit-to-stand phase (s)</td>
<td>Barefoot (1.2 ± 0.4)</td>
<td>Barefoot (1.0 ± 0.2)</td>
</tr>
<tr>
<td></td>
<td>Shod (1.0 ± 0.1)</td>
<td>Shod (1.1 ± 0.2)</td>
</tr>
<tr>
<td>Duration of going phase (s)</td>
<td>Barefoot (2.9 ± 1.5*)</td>
<td>Barefoot (2.2 ± 0.5)</td>
</tr>
<tr>
<td></td>
<td>Shod (2.8 ± 0.6)</td>
<td>Shod (2.4 ± 0.4)</td>
</tr>
<tr>
<td>Duration of mid turn phase (s)</td>
<td>Barefoot (1.8 ± 0.7)</td>
<td>Barefoot (1.9 ± 0.3)</td>
</tr>
<tr>
<td></td>
<td>Shod (2.1 ± 0.8)</td>
<td>Shod (1.6 ± 0.4)</td>
</tr>
<tr>
<td>Duration of returning phase (s)</td>
<td>Barefoot (2.1 ± 0.5)</td>
<td>Barefoot (2.0 ± 0.5)</td>
</tr>
<tr>
<td></td>
<td>Shod (2.4 ± 1.0)</td>
<td>Shod (2.1 ± 0.4)</td>
</tr>
<tr>
<td>Duration of final turn phase (s)</td>
<td>Barefoot (1.1 ± 0.4)</td>
<td>Barefoot (1.1 ± 0.4)</td>
</tr>
<tr>
<td></td>
<td>Shod (1.2 ± 0.3)</td>
<td>Shod (1.2 ± 0.3)</td>
</tr>
<tr>
<td>Duration of stand-to-sit phase (s)</td>
<td>Barefoot (1.1 ± 0.8*)</td>
<td>Barefoot (0.9 ± 0.2)</td>
</tr>
<tr>
<td></td>
<td>Shod (1.8 ± 1.6*)</td>
<td>Shod (0.8 ± 0.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angular variables</th>
<th>Children with Autism Spectrum Disorder n = 10</th>
<th>Children with Typical Development n = 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit-to-stand – Peak trunk flexion (°)</td>
<td>Barefoot (52.1 ± 20.6*)</td>
<td>Barefoot (33.2 ± 9.1)</td>
</tr>
<tr>
<td></td>
<td>Shod (38.4 ± 14.8)</td>
<td>Shod (38.4 ± 13.1)</td>
</tr>
<tr>
<td>Sit-to-stand – Peak trunk extension (°)</td>
<td>Barefoot (23.4 ± 15.8)</td>
<td>Barefoot (17.3 ± 9.9)</td>
</tr>
<tr>
<td></td>
<td>Shod (10.7 ± 9.2)</td>
<td>Shod (20.4 ± 11.7)</td>
</tr>
<tr>
<td>Stand-to-sit – Peak trunk flexion (°)</td>
<td>Barefoot (44.0 ± 14.0)</td>
<td>Barefoot (27.7 ± 12.8)</td>
</tr>
<tr>
<td></td>
<td>Shod (39.8 ± 16.5)</td>
<td>Shod (32.6 ± 12.6)</td>
</tr>
<tr>
<td>Stand-to-sit – Peak trunk extension (°)</td>
<td>Barefoot (19.3 ± 11.9)</td>
<td>Barefoot (10.0 ± 9.2)</td>
</tr>
<tr>
<td></td>
<td>Shod (19.1 ± 15.0)</td>
<td>Shod (13.1 ± 11.1)</td>
</tr>
</tbody>
</table>

Source: Produced by the author.

**Walk Test.** The ASD group had a worse performance on the Walk Test compared to the TD group. The children with ASD had higher means than the control group for the time required to execute the test barefoot (mean difference between groups: 9.6 ± 4.0 s, p = 0.041) and in shoes (mean difference between groups: 11.9 ± 4.6, p = 0.00) as well as speed during the test performed barefoot (mean difference between groups: 0.58 ± 0.37 m/s, p = 0.001) and in shoes (mean difference between groups: 0.61 ± 0.39 m/s, p = 0.001). Differences in means were also found for stride length and percentage of the step of each lower limb during a stride (measure used to analyze symmetry). No significant difference between groups was found regarding cadence when the test was performed barefoot (p = 0.96) or in shoes (p = 0.24). Table 4 displays the results of the variables analyzed during the Walk Test in the two groups.
Table 4: Mean and Standard Deviation Values of Variables Analyzed during Walk Test in Group with ASD and Group with Typical Development. * unpaired t-test p < 0.05.

<table>
<thead>
<tr>
<th></th>
<th>Children with Autism Spectrum Disorder n = 10</th>
<th>Children with Typical Development n = 11</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Barefoot</td>
<td>Shod</td>
</tr>
<tr>
<td><strong>Duration of gait cycle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of test (s)</td>
<td>34.2 ± 11.7*</td>
<td>33.8 ± 14.4*</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>121.1 ± 13.7</td>
<td>121.8 ± 16.5</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>1.0 ± 0.3*</td>
<td>1.0 ± 0.3*</td>
</tr>
<tr>
<td><strong>Stride length (m)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left lower limb</td>
<td>1.0 ± 0.2*</td>
<td>1.0 ± 0.1*</td>
</tr>
<tr>
<td>Right lower limb</td>
<td>1.0 ± 0.3*</td>
<td>1.0 ± 0.1*</td>
</tr>
<tr>
<td><strong>Step length during stride (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left lower limb</td>
<td>49.9 ± 5.7</td>
<td>48.8 ± 1.1*</td>
</tr>
<tr>
<td>Right lower limb</td>
<td>52.8 ± 4.7*</td>
<td>51.1 ± 1.1*</td>
</tr>
</tbody>
</table>

Source: Produced by the author.

Correlation analysis. The CARS-BR score was moderately correlated with the results of the Pediatric Balance Scale and duration of the Walk Test performed barefoot. The CMMS-3 demonstrated a moderate positive correlation with the Pediatric Balance Scale and a strong negative correlation with the duration of the Walk Test performed barefoot and in shoes. Moderate correlations were found between these functional variables and right-left orientation (Piaget-Head battery). Table 5 presents the results of the correlation analysis between the psychological tests and functional tests of mobility and balance.

Table 5: Pearson’s Correlation Coefficients between Psychological Tests and Functional Tests of Mobility and Balance in Sample with Autism Spectrum Disorder.

<table>
<thead>
<tr>
<th></th>
<th>Childhood Autism Rating Scale</th>
<th>Columbia Mental Maturity Scale 3</th>
<th>Piaget-Head Battery – Right-Left Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatric Balance Scale</td>
<td>r = -0.39; p = 0.07</td>
<td>r = 0.35; p = 0.11</td>
<td>r = 0.38; p = 0.08</td>
</tr>
<tr>
<td>Walk Test: duration of test barefoot</td>
<td>r = 0.28; p = 0.20</td>
<td>r = -0.78; p &lt; 0.001</td>
<td>r = -0.30; p = 0.18</td>
</tr>
<tr>
<td>Walk Test: duration of test in shoes</td>
<td>r = 0.44; p = 0.042</td>
<td>r = -0.81; p &lt; 0.001</td>
<td>r = 0.39; p = 0.07</td>
</tr>
<tr>
<td>Walk Test: velocity barefoot</td>
<td>r = -0.23; p = 0.29</td>
<td>r = 0.25; p = 0.25</td>
<td>r = -0.05; p = 0.81</td>
</tr>
<tr>
<td>Walk Test: velocity in shoes</td>
<td>r = -0.27; p = 0.22</td>
<td>r = 0.28; p = 0.21</td>
<td>r = -0.01; p = 0.94</td>
</tr>
</tbody>
</table>

Source: Produced by the author.

4 DISCUSSION

In psychology, human development is normally described in terms of motor, language, cognitive and social domains. Autism spectrum disorder (ASD) is currently one of the most widely studied neurodevelopment conditions in the field of child and adolescent health due mainly to its impact on functioning. Motor difficulties in this population are not restricted to the
acquisition of independent gait (Reindal et al., 2020) and constitute a major limiting factor in the performance of activities of daily living.

Considering the increasing prevalence of ASD and its impact on physical rehabilitation centers throughout the world, the aim of the present study was to analyze balance and gait using scientifically validated instruments that enable a better understanding of motor control during functional activities, such as the TUG test and Walk Test and perform a comparative analysis considering the performance of children with typical development in an attempt to determine deficient aspects of motor control in children with ASD. If motor performance in this population was indeed altered, a further aim was to investigate correlations between the motor abnormalities identified and the severity of ASD as well as mental maturity and right-left orientation.

In a detailed analysis of the results, we highlight some aspects that proved clinically relevant in the sample studied. For several variables of motor control, such as static balance, no significant differences were found between the ASD and TD groups. The main abnormalities found in the ASD group were identified during functional activities, such as the Pediatric Balance Scale, TUG test and Walk Test. The analysis of spatiotemporal and angular variables during the execution of the TUG test and Walk Test revealed deficits mainly in specific phases of the tests that involved the need for cognitive functions and behavioral skills or variables that require body organization, adjustments and symmetry, such as stride length and the percentage of the step of each lower limb during a stride.

In the general context, the majority of motor abnormalities described in the literature suggest that children and adolescents with ASD have deficient postural control with impaired abilities related to balance, coordination and movement velocity. The first scientific reports described the gait of children with ASD as “awkward” or “disorganized” (Fournier et al. 2010). The increase in knowledge regarding the dysfunctional aspects involved in this neurodevelopmental disorder resulted in hypotheses that could explain the motor abnormalities often observed in this population. One hypothesis relates altered gait and balance to a sensory integration disorder associated with abnormalities of the tonic labyrinthine reflex (Shetreat-Klein et al., 2014). Other authors describe the involvement of the frontostriatal circuits and cerebellar regions, which play an important role in the processing of information from the vestibular system and balance control (Esposito et al., 2011; Nobile et al., 2011; Rinehart et al., 2006). Dysfunctional patterns of these structures result in impairments regarding body stability, head
stability during movement and global motricity. These structures also participate in cognitive functions and communication. One example is the participation of cerebellar processing in proprioception and fine motor control as well as attention, decision making, language and affective regulation (Jaber, 2017; Nayate et al., 2005).

These aspects underscore the need for a more comprehensive understanding of abnormal motor control in children with ASD. Motor control is often analyzed and discussed exclusively considering purely motor aspects (Gowen & Hamilton, 2013; Mohd Nordin et al., 2021; Posar & Visconti, 2022), such as strength, flexibility, velocity and dysfunctions in areas exclusively responsible for the control of the execution of a movement.

Fuentes (2014) state that neuropsychology crosses several intersections with motor behavior, as most inferences regarding mental functions are based on fundamentally motor actions, such as speech, writing and drawing. Moreover, neurobiological bases have strong anatomic interconnections. For instance, the dorsolateral prefrontal circuit is linked to executive functions that correspond to a set of complex abilities that organize procedures to ensure a good performance in daily tasks, especially more complex activities that require choosing procedures, the hierarchization of steps and the administration of information.

The neurofunctional motor abnormalities found in this population are apparently closely related to aspects of the cognitive functions and behavioral skills of movement. Thus, the incidence of abnormal motor skills is not necessarily related to the severity of the developmental disorder, but rather the cognitive skills (e.g., executive functions) necessary to execute each motor component of a function efficiently (Bertilsson et al., 2018).

The participants with ASD in the present study had similar stabilometric variables as those found in the group of children with typical development. This was the only motor outcome that did not involve the execution of a motor function, requiring the participant to only remain still. Our intention is not to describe the maintenance of quiet standing as a simple skill related to postural control, but to draw attention to the fact that this activity does not place large demands on cognitive functions and behavioral skills for its efficient execution compared to other motor functions that involve steps and sequences (Bertilsson et al., 2018).

In contrast, the analysis of functional balance using the Pediatric Balance Scale, which comprises 14 tasks resembling activities of daily living, revealed a mean difference between groups of 4.3 (± 2.1) points. The performance of the children with ASD can be considered
expressive for a sample of children who theoretically do not have any neuromotor lesions. Moderate correlations were found between functional balance and both the severity of the disorder and mental maturity, whereas no correlation was found with right-left orientation. These results suggest a relationship between functional performance and aspects of cognitive functions and behavioral skills in the present sample.

According to Fuentes [org] (2014), there is strong evidence that individuals with ASD have difficulties regarding cognitive flexibility. Such individuals exhibit rigid thought and difficulties assessing new strategies when changes occur in the course of actions/thoughts in accordance with the demands of the environment.

In agreement with findings described in the literature, the present results also demonstrated a correlation between spatiotemporal gait variables during the execution of the Walk Test and both the severity of the disorder and mental maturity (Gong et al., 2020; Kaur et al., 2018; Reindal et al., 2020), demonstrating that greater ASD severity and lower mental maturity are related to a more altered gait pattern. However, divergences are found in scientific data on altered gait speed and cadence in children with ASD, as some studies reported a reduction in these important variables, whereas other studies found no difference in this population when compared to children with typical development.

No consistence was found in the results of gait speed (slower in the group with ASD compared to the control group) and cadence (no difference between groups). The conflicting results reported in the literature as well as the present findings may be due to the diversity of evaluation methods used in the literature to quantify these variables, such as scales, functional tests and three-dimensional gait analysis. The major difference of the present study may have been the synchronous use of functional tests with a human movement analysis instrument, enabling a more discerning look at how the function was executed and not only the time required to execute it. As examples, we found that children with ASD performed greater peak trunk flexion compared to the children with typical development in the sitting to standing phase of the TUG test, demonstrating compensation suggestive of deficient postural control during the execution of the motor task of standing; and a reduction in stride length associated with asymmetry of the step length of each lower limb during a stride, demonstrating “disorganization” between the two sides of the body during gait executed during the Walk Test.
Lastly, although the results are interesting and promising as the basis for future investigations, the present study has limitations that should be considered, such as the small number of participants. Developing a study involving children with developmental disorders is always a challenging task. This challenge was even greater in the present case due to the occurrence of the COVID-19 pandemic, which did not permit increasing the size of the sample. We believe that the functional motor assessment model proposed could serve as the basis for the development of future studies that include other aspects considered to be of fundamental importance, such as an in-depth analysis of aspects of cognitive functions and behavioral skills (e.g., executive functions) and neurofunctional aspects (measures of cerebellar and vestibular functions).

Psychological intervention programs in the rehabilitation of children with ASD generally use applied behavior analysis (ABA) for interventions directed at the development of different skills, such as cognition, communication and socialization. ABA therapy achieves good results, as it involves the observation and assessment of a child’s behavior to enhance learning and promote both development and autonomy. However, besides behavioral therapies and interventions, studies point to the use of novel procedures involving noninvasive brain stimulation techniques, such as transcranial magnetic stimulation and transcranial direct current stimulation. Such procedures should be the focus of study, as these methods could achieve good results with regards to behavioral and cognitive improvements in individuals with ASD through the modulation of neuronal plasticity.

The understanding of the causes of functional motor abnormalities is extremely important to the development of a theoretical-scientific basis capable of guiding evidence-based clinical practice directed at neurofunctional motor training in this population.

5 CONCLUSION

Children with ASD have similar static balance as children with typical development. Abnormalities were identified during the functional tests, such as deficient balance and functional mobility in the children with ASD, especially in measures related to spatiotemporal and angular variables of movement during the execution of functional tasks. The severity of the disorder and mental maturity were correlated with variables that demonstrated motor abnormalities, such as functional balance and gait speed.
ACKNOWLEDGMENTS

The authors gratefully acknowledge financial support from the Brazilian fostering agencies Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Nível 2. 2008-2020), Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG – PD&I 07/2020/202110267000212). The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript. The study was conducted in accordance with the Declaration of Helsinki, and approved by the Human Research Ethics Committee of Universidade Evangélica de Goiás (UniEVANGÉLICA), Anápolis, state of Goiás, Brazil, on April 11, 2021 (certificate number: 4.585.636) and was conducted in accordance with the guidelines for research involving human subjects stipulated in Resolution 466 issued in October 1996 and updated in 2012 by the Brazilian National Board of Health. Written informed consent was obtained from the legal guardians of the participants and all children signed a term of assent agreeing to participate in the study. The authors are grateful to all children and parents/guardians who participated in the study and the collaborators at APAE who assisted in the screening of the participants.
REFERENCES


