Literature Review

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Postural balance in children and adolescents with Autism Spectrum Disorder: a systematic review

Equilíbrio corporal em crianças e adolescentes com Transtorno do Espectro do Autismo: revisão sistemática

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ABSTRACT

Purpose: A literature review on the findings of ocular and cervical vestibular evoked myogenic potentials (oVEMP and cVEMP), Video Head Impulse Test (vHIT) and dynamic posturography in children and adolescents with Autism Spectrum Disorder (ASD) compared to typical individuals was carried out in order to analyze the postural balance of this population. **Research strategy:** Review registered in PROSPERO under number CRD42024460328. Original studies published in peer-reviewed journals; involving only human beings; with the aim of assessing the vestibular system in children and adolescents with ASD compared to neurotypical individuals, from zero to seventeen years and eleven months were considered eligible. **Selection criteria:** PubMed, Lilacs, Web of Science, Embase, Scopus, CINAHL, PEDro and OTseeker databases were consulted. Methodological quality was assessed using the Joanna Briggs Institute checklist and studies were analyzed and selected using Endnote and Rayyan software. **Results:** Twenty-seven studies were included in this review, all of which used posturography. No studies with cVEMP, oVEMP or vHIT that matched eligibility were identified. Children and adolescents with ASD had greater postural instability, particularly with eyes closed, compared to neurotypical individuals, regardless of age group. Data suggest impaired sensory information integration in these individuals, but the review did not find any studies that specifically assessed the vestibular system in order to rule out any dysfunction in this system. **Conclusion:** Posturography showed that individuals with ASD have more postural instability. However, the assessment of postural balance in this population should be conducted using a broader battery of tests.

Keywords: Autism Spectrum Disorder; Postural balance; Vestibular function; Child; Adolescent; Systematic review.

RESUMO

Objetivo: Revisar a literatura acerca dos achados dos potenciais evocados miogênicos vestibulares oculares e cervicais (oVEMP e cVEMP), Teste de Impulso Cefálico por Vídeo (vHIT) e posturografia dinâmica em crianças e adolescentes com Transtorno do Espectro do Autismo (TEA) em comparação com indivíduos típicos, para analisar o equilíbrio postural desta população. **Estratégia de pesquisa:** Revisão registrada no PROSPERO sob número CRD42024460328. Estudos originais publicados em periódicos revisados por pares; que envolvessem apenas seres humanos; com o objetivo de avaliar o sistema vestibular na população de crianças e adolescentes com TEA em comparação com indivíduos neurotípicos, de zero a dezessete anos e onze meses foram considerados elegíveis. **Critérios de seleção:** Foram pesquisadas as bases de dados PubMed, Lilacs, Web of Science, Embase, Scopus, CINAHL, PEDro e OTseeker. A qualidade metodológica foi avaliada com o checklist do Joanna Briggs Institute e os estudos foram analisados e selecionados com os softwares Endnote e Rayyan. **Resultados:** Foram incluídos 27 estudos na presente revisão, sendo que todos utilizaram posturografia. Não foram encontrados estudos que utilizassem cVEMP, oVEMP e vHIT elegíveis. Crianças e adolescentes com TEA apresentaram maior instabilidade postural, principalmente com olhos fechados, em comparação a indivíduos neurotípicos, independente da faixa etária. Os dados sugerem alteração na integração da informação sensorial nestes indivíduos, contudo, a revisão não encontrou estudos que avaliassem especificamente o sistema vestibular para descartar disfunções neste sistema. **Conclusão:** A posturografia demonstrou que indivíduos com TEA têm mais instabilidade postural. Porém, a avaliação do equilíbrio postural nesta população deve ser conduzida utilizando uma bateria de testes mais ampla.

Palavras-chave: Transtorno do Espetro do Autismo; Equilíbrio postural; Testes de função vestibular; Criança; Adolescente; Revisão sistemática.

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INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder, characterized by repetitive behavior patterns and deficits in communication and interaction[1]. Regarding prevalence, the World Health Organization[2] states that one in every 100 children in the world is on the autism spectrum. Furthermore, a study conducted by the Centers for Disease Control and Prevention shows that one in every thirty-six eight-year-old children in the United States has the disorder[3].

Regarding comorbidities, there is evidence that ASD is related to sleep disorders, headaches/migraines, atypical gait, developmental coordination disorder, reduced postural stability, oculomotor dysfunctions and balance deficits[1,4-6]. However, little is known about the interference of possible vestibular changes in such comorbidities, as research on vestibular function in children with neurodevelopmental disorders is scarce, lacks methodological quality or does not use an extensive battery of tests, including recent assessment techniques[7].

It is known that the vestibular system interacts with the visual and somatosensory systems, thus resulting in postural balance[8]. Dynamic posturography, Video Head Impulse Test (vHIT), and both ocular and cervical Vestibular Evoked Myogenic Potentials (oVEMP and cVEMP) are recommended for assessing postural balance in this population due to their independence from the patient's direct response, enhancing result reliability.

Computerized Dynamic Posturography aims to evaluate the active and passive regulation of balance in different conditions, in a qualitative and quantitative way. A force platform is used to measure postural oscillation under the center of pressure (CoP), statically and dynamically. The data provided by the platform on the CoP, the medio-lateral and anteroposterior stabilogram, and the statokinesiogram are recorded[9].

Video Head Impulse Test is a quick, practical, non-invasive test that provides objective data that can be used to evaluate the superior and inferior vestibular nerve and the semicircular canals (anterior, posterior and lateral), through the vestibulo-ocular reflex (VOR). Therefore, it is useful for detecting possible dysfunctions in this region[8,10-12], presenting advantages over the rotating chair and to caloric tests when evaluating children, as it does not require darkness that induces fear or provokes dizziness[13].

Both oVEMP and cVEMP are electrophysiological assessments of a medium-latency evoked myogenic potential generated from extraocular or cervical muscles, in response to high-intensity sounds. The exam aims to evaluate the response of the vestibular nerve, the saccule, and the utricle, and is also used to assess the integrity of these vestibular system structures[14,15]. Therefore it can be used to study some mechanisms of ASD that are still unclear[16,17]. Evaluations with VEMP are especially relevant because they are non-invasive procedures that are easy to perform, an important criterion for its use in the pediatric ASD population, while also granting access to brain dynamics on millisecond timescales.

Therefore, taking into account recent advances in neuroscience regarding diagnostic and intervention methods in ASD[17], it is reinforced that, for these individuals to reach their potential, greater awareness of this topic is necessary to promote better clinical management of this group of individuals and improve their quality of life, considering that the vestibular system appears to have a significant influence on cognitive functions, especially visuospatial skills (visuospatial memory, navigation, mental rotation and mental representation of space three-dimensional), attention and executive functions[5,18,19].

PURPOSE

To systematically review the findings of oVEMP, cVEMP, vHIT and dynamic posturography in children and adolescents with Autism Spectrum Disorder in comparison with typical individuals of the same age group, aiming to analyze the postural balance of this population.

The search questions were: (1) What are the values of latency, amplitude and asymmetry index of the oVEMP and cVEMP in children and adolescents with ASD compared to typical individuals of the same age group? (2) What are the gain and saccade parameters of the vHIT in children and adolescents with ASD compared to typical individuals of the same age group? (3) What are the results of tests carried out with Dynamic Posturography in children and adolescents with ASD compared to typical individuals in the same age group?

RESEARCH STRATEGIES

This is a systematic review designed in accordance with the Methodological Guidelines for the Development of Systematic Reviews published by the Brazilian Ministry of Health[20] and registered on the PROSPERO platform under number CRD42024460328[21]. The searches were carried out systematically in the electronic databases: PubMed, Lilacs, Web of Science, Embase, Scopus, CINAHL, PEDro and OTseeker, on September 28, 2023.

First, a research question was formulated based on the Population (P), Exposure (E), Comparison (C) and Outcome (O) (PECO) components. Descriptors for: children and adolescents (P); autism spectrum disorders (E); and vestibular system, posturography, VEMP and vHIT (O) were considered for searches.

Based on PECO components criteria, descriptors were searched for in English in the Medical Subject Headings (MeSH) metadata system. In addition to MeSH terms, synonymous text words and other MeSH suggested terms were applied in order to achieve broad search results. Selected descriptors can be seen in supplementary material.

Selection criteria

Eligibility criteria were established based on the PECO acronym items mentioned above, with the addition of the Study Type (S) item. Therefore, as inclusion criteria we considered original studies (cross-sectional studies, case-control studies, cohort studies and clinical trials, with only their baseline assessment being analyzed, not taking into account post-intervention data or correlations to any outcome) (S) published in peer-reviewed journals; that involved only human beings; with the purpose of evaluating the vestibular system (O) in the child and adolescent (P) population with ASD (E) compared to neurotypical individuals, from zero to seventeen years and

eleven months, without language restrictions and without publication time limits.

Studies that did not evaluate the vestibular system in children and/or adolescents with ASD were excluded; bibliographic review studies, letters to the editor, case studies, studies that were not directly linked to the topic or that did not compare the findings with typical individuals of the same age group.

The flow of the eligibility analysis process, as indicated in Figure 1, followed the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analyses Statement - PRISMA[22]. Of the 6,545 studies, 1,864 were found in Scopus, 1,223 in Embase, 2,028 in PubMed, 1,000 in Web of Science, twenty-three in Lilacs and 407 in CINAHL, none in PEDro, and none in OTseeker.

To align the selection process of eligible studies, a pilot analysis was carried out with the first 1,000 articles, where 939 were excluded and seventeen were included in the blind peer review. The remaining forty-four studies were sent for analysis by a third evaluator, due to disagreements between the two evaluators regarding their inclusion, as some abstracts and titles were not clear regarding the objective of the study. After analysis by the third evaluator, of the forty-four conflicting studies, nine were included and thirty-five excluded. Therefore, the pilot analysis resulted in twenty-six articles included and 974 articles excluded for the full text analysis stage.

Subsequently, the two evaluators analyzed the remaining studies and the total blinded pairwise analysis resulted in forty-six studies included, with twenty studies added to the twenty-six selected in the pilot analysis, 4,288 studies excluded and another eighty-four studies sent to a third evaluator. An assessment of inter-rater agreement was conducted using Cohen's Kappa statistic and interpreted as follows: ≤ 0 indicates absence of agreement, 0.01-0.20 suggests none to slight agreement, 0.21-0.40 implies fair agreement, 0.41-0.60 indicates moderate agreement, 0.61-0.80 suggests substantial agreement, and 0.81-1.00 denotes almost perfect agreement[23]. The result of the agreement was 0.51 (95% CI 0.42 to 0.60), indicating moderate agreement. After evaluation by the third reviewer, thirty-three studies were included and fifty-one were excluded. In the end, seventy-nine studies were included for the full text analysis stage and 4,339 were excluded.

In order to identify studies that might have been out of the searched databases and to screen recent publications to verify the need for an update search, a grey literature search was carried out on October 29, 2024. A total of 1172 studies were identified and analyzed by two reviewers using Endnote

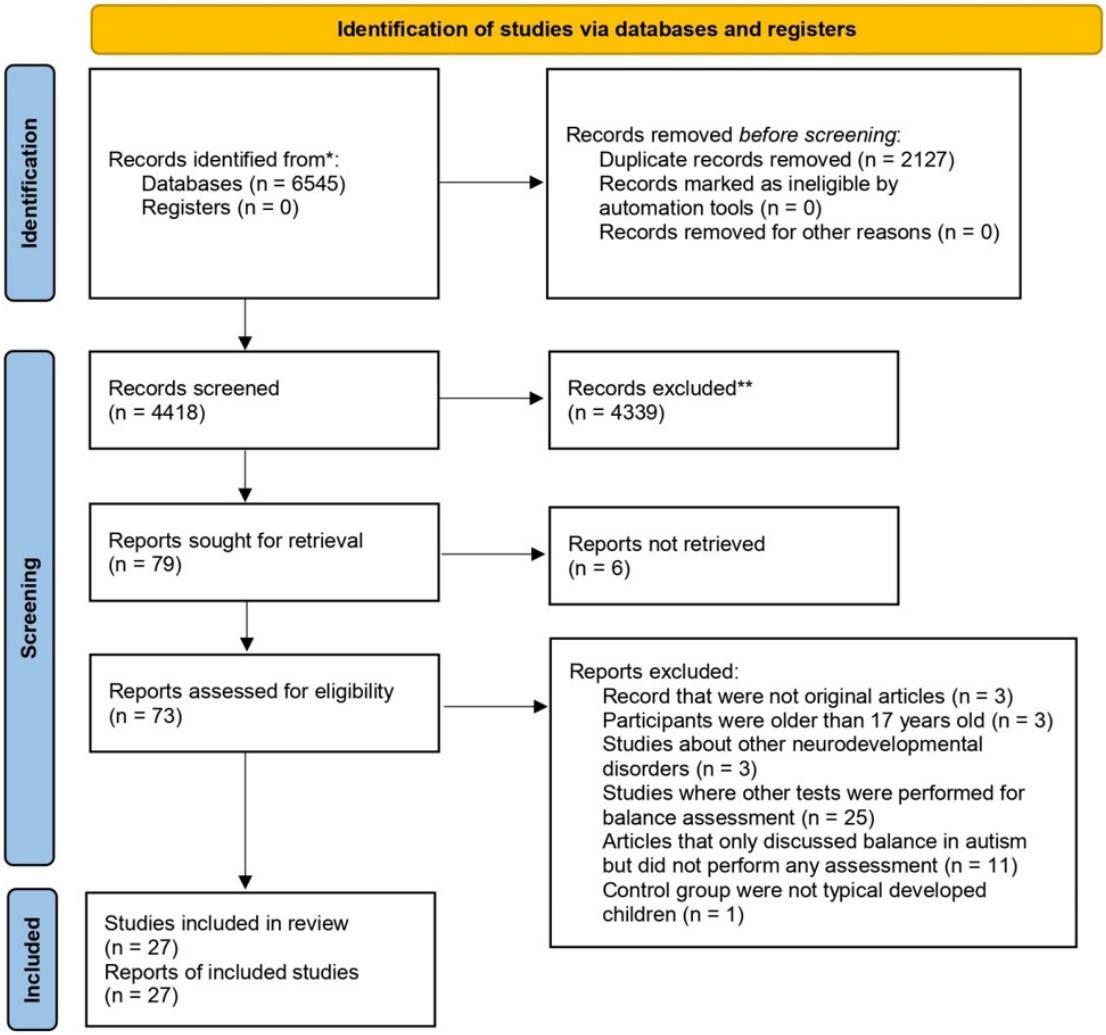

Figure 1. Eligibility analysis process flow diagram

software. However, no new studies were found that met the eligibility criteria. All identified studies that met elegibility criteria were already included in the review.

Data analysis

When carrying out the initial search, the studies were added to the EndNote software (version 19) to eliminate duplications and, subsequently, added to the Rayyan software to read and analyze titles and abstracts, which were carried out independently by two investigators, with studies selected based on the established inclusion and exclusion criteria. When a summary was not available, or the necessary information was not evident, the entire article was read. In studies where there was divergence in the initial assessment, a third researcher evaluated and held a meeting to discuss the divergent information and define a consensus. After reading the abstracts or full texts, all selected articles were read in full and those that met the selection criteria were included in the study analysis stages.

Data analysis involved qualitative methods to determine if the studies addressed the research question. Relevant data were extracted to systematize outcomes, including author details, publication year, language, country, sample size, age, study design, vestibular assessment method, and exam results. Following data synthesis, findings were presented descriptively.

Two reviewers independently assessed the methodological quality of the included studies, considering established items such as selection, measurement and confounding. In cases of disagreement, a third researcher served as judge to resolve them. The methodological analysis, in relation to the assessment of the risk of bias, was carried out using the Critical Appraisal Checklist for Analytical Cross-Sectional Studies scale[24]. Although seven studies were case-control[25-31] and one a non-randomized clinical trial[32], we chose to evaluate all studies as being cross-sectional, since our objective was to analyze only baseline data from children and adolescents with ASD, not taking into account intervention effects or association with any outcome.

RESULTS

Twenty-seven studies were included in the present review after full text analysis, all of which evaluated individuals with posturography. Studies involving the cVEMP, oVEMP and vHIT procedures that met the eligibility criteria were not found. The characterization of the sample and the main findings of the examination can be seen in Table 1.

Regarding sample size, studies varied between five[32,39] and ninety-one[43] subjects in groups diagnosed with ASD. The age of participants in the ASD groups varied between four[39] and twenty years old[43]. The studies were only included in this review if there was an independent analysis of age subgroups, and only the results regarding the ages of interest were extracted for the review, and only data from ages zero to seventeen years and eleven months were considered. It was also observed that, with the exception of three[32,39,43], the other studies described the gender of the participants, however, it is worth noting that all studies mentioned a higher percentage of boys in the samples.

The results of the assessment of the methodological quality of the included studies are presented in Figure 2, created with

Author (year)	Questions							
	1	2	3	4	5	6	7	8
Abdel Ghafar et al (2022)	Y	Y	Y	Y	Y	Y	U	Y
Bojanek et al (2020)	U	N	Y	Y	Y	U	U	Y
Bucci et al (2013)	N	N	Y	Y	U	N	U	Y
Bucci et al (2017)	U	N	Y	Y	N	N	U	Y
Bucci et al (2018)	U	Y	Y	Y	U	U	U	Y
Chen and Tsai (2015)	Y	Y	Y	Y	U	U	U	Y
Gepner et al (1995)	U	N	Y	Y	U	U	U	Y
Gepner and Mestre (2002)	U	Y	Y	Y	N	N	U	U
Goulème et al (2017)	N	Y	Y	Y	U	U	U	Y
Graham et al (2014)	Y	Y	Y	Y	Y	Y	U	Y
Kohen-Raz et al (1992)	U	N	Y	Y	U	N	U	Y
Li et al (2019)	N	N	Y	Y	U	U	U	Y
Li et al (2020)	Y	N	U	Y	U	U	U	Y
Lidstone et al (2020)	Y	Y	U	Y	Y	Y	U	Y
Mache et al (2016)	Y	Y	Y	Y	Y	Y	U	Y
Memari et al (2013)	Y	Y	Y	Y	N	N	U	Y
Memari et al (2014)	Y	Y	Y	Y	U	U	U	Y
Miller et al (2019)	N	N	Y	Y	U	U	U	U
Molloy et al (2003)	N	N	U	Y	U	U	U	Y
Reinert et al (2014)	Y	Y	U	Y	N	N	U	Y
Shabana et al (2012)	U	Y	U	Y	N	N	U	Y
Somogyi et al (2016)	Y	Y	Y	Y	Y	Y	U	Y
Stania et al (2023)	Y	Y	U	Y	U	U	U	Y
Stins et al (2015)	U	Y	Y	Y	N	N	U	Y
Travers et al (2018)	N	Y	N	Y	Y	N	U	Y
Wang et al (2016)	Y	Y	Y	Y	U	N	U	Y
Zoccanté et al (2021)	Y	Y	Y	Y	N	N	U	Y

Figure 2. Methodological quality analysis with the Critical Appraisal Checklist for Analytical Cross-Sectional Studies

Subtitle: Y = yes; N = no; U = undefined; 1 = Were the criteria for inclusion in the sample clearly defined?; 2 = Were the study subjects and the setting described in detail?; 3 = Was the exposure measured in a valid and reliable way?; 4 = Were objective, standard criteria used for measurement of the condition?; 5 = Were confounding factors identified?; 6 = Were strategies to deal with confounding factors stated?; 7 = Were the outcomes measured in a valid and reliable way?; 8 = Was appropriate statistical analysis used?

Table 1. Characterization of the studies samples and their main findings

Authors, year (Country)	Sample	Assessment(s)	Main results of the assessment(s)
Abdel Ghafar et al.[33], 2022 (Saudi Arabia)	ASD: 38 individuals, average of 9.57 (±2.08) years (25 MG and 13 FG) TD: 36 individuals, average of 10.84 (±2.91) years (21 MG and 15 FG)	Posturography with stable and unstable platform, with OE and CE	ASD group showed a significant increase in postural sway in all conditions tested, especially in conditions in which visual and somatosensory inputs were compromised.
Bojanek et al.[34], 2020 (USA)	ASD: 17 individuals, average of 13.67 (±3.00) years (15 MG and 2 FG) TD: 20 individuals, average of 12.48 (±4.17) years (16 MG and 2 FG)	Posturography with a stable platform. Static posture tasks, dynamic posture and stepping tasks.	ASD group showed worse performance in medial lateral displacement. There was no statistically significant difference in the other tasks with posturography.
Bucci et al.[35], 2013 (France)	ASD: 7 individuals, average of 6 (±0.8) years (5 MG and 2 FG) TD: 7 individuals, average of 6 (±1.7) years (5 MG and 2 FG)	Posturography with a stable platform. Tests: visual fixation tasks, saccades and pursuit eye movements.	ASD group had greater instability in all conditions tested. Stability did not improve during saccades or pursuit eye movements.
Bucci et al.[36], 2017 (France)	ASD: 23 individuals, average of 10.3 (±0.4) years TD: 23 individuals, average of 10.2 (±0.3) years Percentage of each unspecified gender	Posturography with stable and unstable platform, with OE and CE	The ASD group showed lower postural control than the TD group, which worsens in a dynamic environment and when visual information is absent.
Bucci et al.[37], 2018 (France)	ASD: 26 individuals, average of 9.4 (±0.1) years TD: 26 individuals, average of 9.5 (±0.4) years Percentage of each unspecified gender	Posturography with a stable platform, standing and sitting. Visual tasks: Visually guided saccades, memory-guided saccades and fixation.	For the fixation task, the ASD group showed worse eye movement performance in the standing condition compared to the sitting condition, while this difference was not found in the TD group.
Chen and Tsai[38], 2015 (China)	ASD: 16 individuals, average of 11.04(±1.275) years (11 MG and 5 FG) TD: 16 individuals, average of 10.96(±1.166) years (11 MG and 5 FG)	Posturography with stable platform and manual support, with OE and CE.	Effect of absence of vision was more prominent in children with ASD. Larger average oscillation on the ML axis. Furthermore, the results showed a significant improvement in postural sway with the aid of touching the support.
Gepner et al.[39], 1995 (France)	ASD: 5 individuals, average of 6 (±1.2) years (3 MG and 2 FG) TD: 12 individuals, average of 5.6 (±0.8) years (8 MG and 4 FG)	Posturography with stable platform, with OE and CE	Postural instability was greater in the ASD group with both CE and OE. Furthermore, the moving visual stimulus did not cause postural differences in the ASD group, unlike what occurred in the TD group.
Gepner and Mestre[40], 2002 (France)	ASD: 3 individuals, average of 9.5 (±1.1) years (1 MG and 2 FG) AS: 3 individuals, average 7.5 (±2.1) years (all MG) TD: 9 individuals, average of 8.2 (±2.9) years (5 MG and 4 FG)	Posturography with a stable platform. Test with CE and OE with static visual stimulation and dynamic stimuli.	Overall postural instability was significantly reduced in the ASD group compared to the TD group.
Goulème et al.[41], 2017 (France)	ASD: 30 individuals, average of 12.1 (±2.9) years (26 MG and 4 FG) TD: 30 individuals, average of 11.08 (±0.5) years (26 MG and 4 FG)	Posturography with stable and unstable platforms, in three viewing conditions (OE, CE and disturbed vision). Furthermore, sensory integration was analyzed.	Significantly greater instability in all conditions tested in the ASD group.
Graham et al.[42], 2014 (USA)	ASD: 26 individuals, average of 13.0 (±3.2) years (22 MG and 4 FG) TD: 18 individuals, average of 13.4 (±1.9) years (16 MG and 2 FG)	Posturography with a stable platform. Tests: (1) OE, and bipedal support; (2) CE and bipedal support; (3) OE, and single leg support; and (4) CE and single-leg support.	Children with ASD showed greater postural instability in all conditions, with worse performance in the CE condition and single-leg support.
Kohen-Raz et al.[43] 1992 (Israel, USA and France)	ASD: 91 individuals, ages between 6 and 20 years (65 MG and 26 FG) TD: 166 individuals, ages between 4 and 11 years old (percentage of genders not specified)	Posturography with stable platform and OE	Stability limit lower than the TD group, worse performance in tests in the age group of 10 to 13 years in the ASD group.
Li et al.[44], 2019 (USA)	ASD: 11 individuals, average of 8.8 (±2.3) years (10 MG and 1 FG) TD: 11 individuals, average of 8.7 (±2.3) years (9 MG and 2 FG)	Posturography with stable and unstable platforms, with OE and CE.	Greater displacement on an unstable surface, with CE in the ASD group.
Li et al.[45], 2020 (USA)	ASD: 25 individuals, average of 6.9 (±1.8) years (11 MG and 14 FG) TD: 25, average of 7.2 (±2.0) years (15 MG and 10 FG)	Posturography with stable and unstable platforms, with OE and CE.	Significantly greater displacement in the AP and ML axes, in addition to a greater total area of displacement in the ASD group, in all tests.
Lidstone et al.[46], 2020 (USA)	ASD: 23 individuals, average of 12.4 (±2.8) years (19 MG and 4 FG) TD: 22 with TD, average of 11.7 (±2.7) years (14 MG and 8 FG)	Posturography with a stable platform, with OE, without dynamic visual stimulation.	Significantly greater displacement in the AP and ML axes, in addition to a greater total area of displacement in the ASD group, in all tests.

Subtitle: ASD = Autism Spectrum Disorder group; TD = Typical development group; MG = male gender; FG = female gender; OE = open eyes; CE = closed eyes; USA = United States of America; CoP = Center of pressure

Table 1. Continued...

Authors, year (Country)	Sample	Assessment(s)	Main results of the assessment(s)
Mache and Todd[47], 2016 (USA)	ASD: 11 individuals, average of 113.5 (±30.0) months (10 MG and 1 FG) TD: 11 individuals, average of 112.2 (±28.9) months (9 MG and 2 FG)	Posturography with stable and unstable platforms, with OE and fixed gaze on visual stimulus.	There was greater displacement in the ASD group on both platforms, with worse results on the unstable platform.
Memari et al.[26], 2013 (Iran)	ASD: 21 individuals, average 11.5 (±1.6) years old, all MG TD: 30 individuals, average 11.6 (±1.9) years, all MG	Posturography with stable force platform and OE.	ASD group presented worse results for all analyses, with greater instability in the AP direction.
Memari et al.[27], 2014 (Iran)	ASD: 19 individuals, average 11.9 (±1.6) years old, all MG TD: 28 individuals, mean 11.8 (±1.7) years old, all MG	Posturography with a stable platform and OE, with visual stimulation, performing a cognitive task associated with vision and hearing	The ASD group showed greater instability in all conditions tested, with greater postural oscillation in the task of chasing the moving visual stimulus.
Miller et al.[29], 2019 (USA)	ASD: 10 individuals, average 13 (±2.54) years (9 MG, 1 FG) TD: 8 individuals, average of 10.2 (±3.41) years (4 MG 1 FG)	Posturography with a stable platform using a belt, with moving images.	ASD group showed higher speed values and lower acceleration in the ML direction, which indicates slower and less precise movements to adjust the CoP.
Molloy et al.[25], 2003 (USA)	ASD: 8 individuals, average of 124.8 (±26.3) months, all MG TD: 8 individuals, average of 126.5 (±25.7) months, all MG	Posturography with stable and unstable platforms with OE and CE.	Worse performance was observed with CE on both platforms in the ASD group.
Reinert et al.[32], 2015 (USA)	ASD: 5 individuals, average of 9.2 (±0.45) years TD: 5 individuals, average of 7.4 (±2.06) years The percentage of each gender was not specified.	Posturography with stable and unstable platforms with OE and CE.	ASD group with more instability, highlighting greater difficulty on the unstable platform and CE, and greater displacement in the AP direction in all tests.
Shabana et al.[48], 2012 (Egypt)	ASD: 20 individuals, average 8.95 (±2.98) years (13 MG and 7 FG) TD: 15 individuals, average of 9 (±1.6) years (9 MG and 6 FG)	Posturography with stable and unstable platforms, with OE and CE and fixed and moving visual stimuli.	There was a significant impairment in postural balance control in the ASD group, even in conditions with fewer stimuli.
Somogyi et al.[49], 2016 (Hungary)	ASD: 18 individuals, average of 94 (±18.5) months (14 MG and 4 FG) TD: 12 individuals, average of 96 (±9.6) months (8 MG and 4 FG)	Posturography with stable platform and OE, with and without visual stimulation.	Postural stability was lower in children with ASD, on the stable platform with OE, without visual stimulation. With visual stimulation there was an improvement in performance, but it was still inferior.
Stania et al.[31], 2023 (Poland)	ASD: 16 individuals, average of 8.13 (±1.54) years (11 MG and 5 FG) TD: 16 individuals, average of 7.93 (±0.88) years (9 MG and 7 FG)	Posturography with stable and unstable platforms with OE.	There was greater AP displacement on the stable and unstable platforms in the ASD group.
Stins et al.[50], 2015 (Netherlands)	ASD: 9 individuals, average of 10.8 (±1.2) years (8 MG and 1 FG) TD: 9 individuals, average of 10.8 (±1.2) years (8 MG and 1 FG)	Posturography with stable and unstable platforms, OE and CE, with associated cognitive task.	The ASD group performed worse in conditions with CE and also in conditions in which they needed to perform a cognitive task, with OE and CE.
Travers et al.[28], 2018 (USA)	ASD: 21 individuals, average of 9.63 (±2.09) years (18 MG and 3 FG) TD: 16 individuals, average of 9.64 (±2.78) years (14 MG and 2 FG)	Posturography with stable and unstable platforms with OE	There was greater displacement in the ASD group in both conditions, with worse performance on unstable surfaces.
Wang et al.[51], 2016 (USA)	ASD: 22 individuals, average of 12.72 (±3.64) years (19 MG and 3 FG) TD: 21 individuals, average of 11.67 (±4.53) years (18 MG and 3 FG)	Posturography with stable and unstable platforms, with OE and CE.	ASD Group presented worse performance in all conditions, especially with unstable platform
Zoccanté et al.[30], 2021 (Italy)	ASD: 20 individuals, average of 10.7 (±2.0) years (16 MG 4 FG) TD: 23 individuals, average 12.3 years (±2.6) (10 MG 13 FG)	Posturography. Patients were subjected to 7 different sensory situations to identify sensory integration.	Worse performance on an unstable platform with CE and on an unstable platform with moving visual stimuli in the ASD group.

Subtitle: ASD = Autism Spectrum Disorder group; TD = Typical development group; MG = male gender; FG = female gender; OE = open eyes; CE = closed eyes; USA = United States of America; CoP = Center of pressure

Microsoft Office Word 2019 and edited with digital software Canva. Regarding the reliability of the outcome assessment tests (in this case, tests to assess postural balance in patients with ASD), although standardized tests were used, none of the studies specified whether the investigators had received prior training or were experienced with the procedures.

Another point to be highlighted concerns the assessment of biases by research authors, with twenty-two out of the twenty-seven selected in the present review not specifying whether confounding biases were identified in the samples and the strategies used to resolve them if identified. Of these, ten considered some confounding factors as exclusion criteria, but did not consider others equally important, such as the use of medications or the presence of comorbidities that could affect postural balance[25,27,29,31,37-39,41,44,45]. Of the twelve remaining studies, seven do not mention the observation of possible confounding

bias at any stage of their research[26,30,32,36,40,48,50], three assessed a broader age range and did not correct statistical analyzes to reduce age bias[35,43,51], and two explained the identified biases, but these were not corrected, and the authors chose to keep the participants in the final sample[28,34].

It was also observed that fifteen articles did not provide relevant data about the population, or the inclusion and exclusion criteria were not clearly defined. Of these, fourteen did not detail the inclusion and exclusion criteria, and eight also did not characterize the sample[25,29,34-36,39,43,44], while six reported the demographic data of the participants, of interest to the research[28,37,40,41,48,50]. The remaining article stipulated inclusion and exclusion criteria, but did not provide sufficient information about the sample[45].

A topic highlighted by the analysis of methodological quality was the issue of the participants' ASD diagnosis. Four articles do not mention which diagnostic method was used for the patients[32,45,46,48], one article only mentions that it used a scale to verify the diagnosis after inclusion[28], and two cite widely used scales[25,31], however, it is worth highlighting that the most current edition of the Classification International Disease Association (ICD-11), is based on the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V-TR)[1] to classify ASD, therefore, these materials are considered to be the gold standard for diagnosis[52].

Finally, the majority of articles used adequate statistical analysis, however two studies did not mention the software or the analyzes performed[29,40] and another three did not mention adjustments for age, with a very heterogeneous sample in relation to this variable[35,43,51].

DISCUSSION

This study reviewed oVEMP, cVEMP, vHIT, and dynamic posturography findings in ASD children versus typical peers to analyze their postural balance. No eligible studies on oVEMP, cVEMP, or vHIT were found. However, posturography revealed greater instability in ASD individuals across stable and unstable platforms, irrespective of age.

Regarding the characteristics of the sample, the articles analyzed presented a greater number of boys with ASD. This finding is in line with data from epidemiological samples, which indicate that the prevalence of the disorder in males and females is 3:1[1]. It is not yet clear what factors justify this predisposition, however, there are concerns about the findings of ASD in girls[1] and, in addition, recent neuroimaging studies mention hormonal and genetic differences between the genders that appear to act as a protective factor in females, however, more studies are needed to confirm this hypothesis[53].

Another fact about the samples, frequently mentioned, concerns the association between age and postural instability, with this correlation tending to be negative in typical development, that is, the younger the age, the greater the instability. This can be attributed to the physiology of postural balance, which necessitates the integration of visual, vestibular, and proprioceptive systems to generate a motor response that counteracts gravitational force, enabling individuals to maintain an upright position[54,55]. In typical development, there's a variation in the maturation timing of the pathways governing each of these systems. Until about age eight, children rely on visual and proprioceptive cues for effective postural control, as the vestibular system and sensory integration capabilities aren't fully matured, a process that may extend until age fifteen[56].

However, the studies included in the present review demonstrate that children and adolescents with ASD have greater postural instability regardless of age. Four studies[26,33,48,51] conducted statistical analyses involving age and posturography data. They concluded that postural instability did not differ across age groups; individuals with ASD exhibited significantly greater postural instability compared to controls, irrespective of age. This suggests a potential association between the diagnosis and postural balance dysfunction. Furthermore, two other studies[42,43] identified that the older group with ASD presented greater instability than the younger group, contrary to what is observed in groups of typical development, concluding that age does not seem to contribute to balance as much as it does for peers in the control groups. The authors note that despite the sample's inherent heterogeneity due to the disorder's spectrum, all participants exhibited poorer results in the postural assessment.

Regarding differences between groups in posturography results, fifteen out of the twenty-seven included articles mentioned increased postural instability in conditions with eyes closed[25,27,30,32,33,35,36,38,39,41,42,44,45,48,50] and one mentioned increased stability with visual feedback[49]. As mentioned previously, visual dependence is characteristic of children aged eight or less, due to the immaturity of the vestibular system and sensory integration mechanisms. However, most articles that analyzed this difference between groups contained individuals aged over eight in their samples. Furthermore, five of these studies[27,33,36,38,41] performed statistical evaluations to verify the difference between the performance of the groups in posturography with eyes open and closed and identified that groups with ASD have greater instability with eyes closed, regardless of other demographic variables. Furthermore, it was observed in the study by Abdel Ghafar et al. (2022) that there was no statistical difference between the groups aged six to nine years and ten to fourteen years in the tests with eyes closed, which continued to demonstrate greater instability, contrary to what occurred in the group with typical development, whose stability increased significantly in the group from ten to fourteen years old[33]. The finding corroborates research[57] that included adults with ASD in the analysis and found that they depended on eye fixation to maintain posture, opposite to what occurred with adults without ASD. These data allow us to infer that in this population visual dependence does not seem to be associated with age, but rather with the disorder.

The findings indicate that ASD individuals show changes in postural balance regardless of age, as revealed by posturography assessments. The exam's key advantage lies in its capacity to assess sensory integration across visual, vestibular, and somatosensory systems, identifying conditions associated with increased instability[9,58]. Therefore, the observation of changes in an exam that evaluates this issue, associated with the lack of correlations with other variables that interfere in the balance of individuals with typical development, leads to the main hypothesis discussed in the studies that concerns the existence of a deficit in processing sensory information coming from each of the afferent pathways, as well as the integration between them.

Currently, the DSM-V-TR(1) establishes that atypical responses to sensory stimuli are a criterion for the diagnosis

of ASD. Hyperresponsiveness, hyporesponsiveness, or an unusual interest in environmental sensory demands fall within this criterion[1]. Regarding postural balance, there's adaptation to various sensory conditions to maintain posture. In low-light environments, where visual information is unreliable, the vestibular and proprioceptive systems compensate to maintain stability.

In this context, Gepner et al. (1995) observed a lack of response to optokinetic visual stimuli in children with ASD, contrasting with the behavior seen in typically developing children[39]. While this data shows hypo-responsivity, other studies with varied stimuli suggest hyper-responsivity, leading to increased postural adjustments in more challenging sensory tasks. The data from Goulème et al.[41] and Shabana et al.[48] who have found statistically significant instability as the sensory demand increased, that is, when the platform was unstable and the participant had to close their eyes[45].

These findings corroborate results described by Doumas et al.[59], whose main objective was to verify the role of sensory integration in the balance of young adults with ASD, and show that the difficulty seems to occur when the three systems are activated in the same proportion, suggesting a deficit in the integration of information, and not a deficit in one of the systems alone. Taken together, atypical sensory responses may have a direct impact on postural balance in individuals with ASD.

In addition to the criteria addressed in the DSM-V-TR[1], Schaaf et al[60]. emphasize that a comprehensive assessment, based on standardized and quantitative instruments, of sensory functions must be carried out to provide greater information about the sensory characteristics of ASD and, consequently, improve available interventions. In the aforementioned study, the authors identified sensory difficulties that are not mentioned or measured in manuals and diagnostic tests, which impact other functions and impair quality of life. Travers et al.[61] also draw attention to this fact, in their research to verify the relationship between scores in sensory and motor functions, and the performance in daily living skills, the results of which demonstrate that activities of daily living, such as dressing, personal hygiene and cleaning, as well as preparing meals can be challenging in children with motor and sensory difficulties, which limits the development due to lack of social experiences. The results were similar to Mache and Todd[47] who have found that individuals with ASD had poorer motor skills and it was associated with higher postural instability.

Studies with neuroimaging examinations have investigated which cortical regions can explain the deficits in sensory processing in individuals with ASD. Kilroy et al.[62] reviewed evidence revealing morphological and functional changes in the motor cortex and connection pathways between the cerebellum and various brain regions involved in sensory and motor mechanisms, including postural balance[62].

The review's limitations stem from notable heterogeneity among studies, encompassing clinical and methodological variations like study design, sample size, ASD diagnosis criteria/tools, publication year, and demographics of children and adolescents (e.g., gender, age). Despite rigorous inclusion criteria aiming to mitigate heterogeneity effects, its persistence, coupled with low methodological study quality, diminishes the reliability of evidence. Consequently, caution is advised when interpreting these findings.

The study underscores the need for future research to analyze the postural balance of children and adolescents with ASD, emphasizing specific criteria for participant selection: greater number of participants with sample calculation, confirmation of the diagnosis of ASD by a specialist using the DSM-V-TR criteria[1], as well as assessment of the level of support, provision of details about the aptitude and previous experience of posturography exam examiners, adoption of strategies to deal with factors of confusion (sample stratification or multivariate regression analysis, for example), clarity regarding the inclusion and exclusion criteria of the study group and control group, as well as provision of details about demographic data of both groups and the period in which the data collection was carried out. Furthermore, research emphasizing the evaluation of vestibular function in this population via VEMP and vHIT is underscored, comparing outcomes with neurotypical individuals. These exams offer objective data on the vestibular nerve, saccule, utricle, and semicircular canals, which posturography cannot provide[8,10-12,15], thus we recommend researchers to conduct new studies focusing on vestibular assessments to verify any impairments in this population.

The findings underscore the significance for clinicians to closely monitor postural balance changes in ASD individuals during clinical practice, given the evidence of increased instability across age groups.

CONCLUSION

Finally, the findings of this systematic review demonstrate that dynamic posturography is often chosen to assess postural balance in children and adolescents with ASD. Its results indicate that, in general, children and adolescents with ASD present greater postural instability when compared to neurotypical individuals in the same age group, especially with their eyes closed. However, due to the low quality of available evidence, it is necessary to interpret such results with caution. Furthermore, studies evaluating postural balance and vestibular function in this population should be conducted with greater methodological rigor and using a larger battery of tests such as cVEMP, oVEMP and vHIT.

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Supplementary Material

Supplementary material accompanies this paper.

Search strategy for each database

This material is available as part of the online article from: https://doi.org/10.1590/2317-6431-2024-2945en