Systematic Review

The Urgent Need for Neuroscience Research to Consider Culture when Assessing the Development of Gait in Autistic Children: A Scoping Review

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Abstract

Background: Over the last decade, there has been a steady increase in the number of children diagnosed with autism spectrum disorder (ASD) on a global scale, impacting all racial and cultural groups. This increase in the diagnostic rate has prompted investigation into a myriad of factors that may serve as early signs of ASD. One of these factors includes the biomechanics of gait, or the manner of walking. Although ASD is a spectrum, many autistic children experience differences in gross motor function, including gait. It has been documented that gait is also impacted by racial and cultural background. Given that ASD is equally prevalent across all cultural backgrounds, it is urgent that studies assessing gait in autistic children consider the impact of cultural factors on children’s development of gait. The purpose of the present scoping review was to assess whether recent empirical research studies focusing on gait in autistic children have taken culture into account.

Methods: To do so, we conducted a scoping review following PRISMA guidelines using a keyword searching with the terms autism, OR autism spectrum disorder, OR ASD, OR autism, AND gait OR walking in the following databases: CINAHL, ERIC (EBSCO), Medline, ProQuest Nursing & Allied Health Source, PsycINFO, PubMed, and Scopus. Articles were considered for review if they met all six of the following inclusionary criteria: (1) included participants with a diagnosis of autism spectrum disorder (ASD), (2) directly measured gait or walking, (3) the article was a primary study, (4) the article was written in English, (5) participants included children up to age 18, and (6) the article was published between 2014 and 2022. Results: A total of 43 articles met eligibility criteria but none of the articles took culture into account in the data analysis process. Conclusions: There is an urgent need for neuroscience research to consider cultural factors when assessing gait characteristics of autistic children. This would allow for more culturally responsive and equitable assessment and intervention planning for all autistic children.

Keywords: culture; gait; autism; biomechanics; children

1. Introduction

Autism spectrum disorder (ASD) has steadily been on the rise, now impacting 1 in 100 children worldwide [1]. ASD is a neurodevelopmental disorder, with specific autistic characteristics presenting themselves uniquely in every autistic child. Although autism is a spectrum, many autistic children present with differences in social communication, restrictive and repetitive behaviors/interests, sensory processing, as well as gross motor skills, in comparison to neurotypical peers [2–4]. Given the steady rise in autism prevalence, investigations have been undertaken to identify early signs of autism in order to provide early assessment and intervention, which has the potential to result in increased quality of life for all autistic children.

Differences in the development of motor skills may serve as an early diagnostic indicator for ASD [5]. For example, early signs of gross motor delays and poor postural control have been posited to indicate neurodevelopmental disruption in children with ASD [6–11]. Poor postural control in infants can lead to delays in crawling and later walking, as postural stability is essential to maintain an upright balance over one’s base of support [12]. Importantly, these motor differences emerge before a child with ASD says their first words [7], which are usually parents’ primary area of reported concern [13]. In fact, parents who are first concerned with motor difficulties, rather than language, seek professional help, and subsequently, an ASD diagnosis, sooner [14].

With the early diagnostic value of gross motor skills in mind, many recent studies have been devoted to assessing the biomechanics of gait, or the manner of walking, in autistic children. Traditionally, the terms “kinematics” and “kinetics” have been used to study and describe gait patterns. Kinematics refers to the study of motion, including considerations of space and time. The kinematic analysis of gait describes the linear and angular displacements, such as stride or step length, step width, velocity, and acceleration of motion. Kinetic parameters focus on forces in the production of movement in the gait cycle.
Gait variations between autistic children and neurotypical peers have been previously explored utilizing both kinematic and kinetic parameters. Some notable differences have been observed in the gait patterns of autistic children. The most prevalent findings in these studies are increased step width and, debatably, a decrease in both step length and stride length. While some studies have [15] found longer stance phases and shorter stride lengths, others [16] found that stride length in children with ASD is higher at a given cadence compared with neurotypical controls. The same pattern of findings have been shown when kinematic parameter cadence was assessed. While some studies found kinematic parameter cadence to be higher in autistic children [17], other studies [18] reported it to be lower in the ASD group, whereas others found no significant difference between ASD and neurotypical groups [19,20].

Velocity, joint motion, angles, and range of motion also have been explored when assessing gait in autistic walkers. Although many studies have not found any significant difference in velocities between ASD and comparison groups [16,20,21], one study reported that it was significantly reduced in the ASD group [18]. Several studies have investigated joint motion and angles at specific points in the gait cycle. Nobile et al. [22] reported increased ankle dorsiflexion at toe-off. Vilensky et al. [15] found no significant differences at toe-off but reduced dorsiflexion at heel strike in children with ASD. Therefore, it is currently difficult to discern whether significant changes occur at the ankle joint during the gait cycle in autistic children. Two studies have shown that autistic children have a reduced range of motion with a decreased flexion-extension at the knee during toe-off [15,22], but there was no consensus at the hip joint. Nobile et al. [22] showed that autistic children have a reduced hip range of motion, but Vilensky et al. [15] showed an increase in hip flexion in autistic children. Thus, overall, findings in kinematic parameters over the gait cycle in autistic children have not been conclusive, with much variability, as is expected given that autism is a spectrum.

Only a few studies have investigated kinetic parameters in ASD, demonstrating several parameters to differ between autistic children and their neurotypical peers. Ambrosini et al. [23] reported relatively typical ground reaction forces in autistic children but a reduced secondary vertical peak, which refers to the ground reaction force in the terminal stance phase. Calhoun et al. [17] found that autistic children have reduced peak plantar flexion moments at the ankle. All other ankle kinetic parameters seemed to be within the typical range. No changes were noted in knee joint kinetics, but a significant alteration was found in hip joint kinematics, with the ASD group displaying decreased peak hip flexor moments and increased hip flexion angles. This may imply weakness in the hip flexor muscles, as they are unable to generate the same amount of force as those that neurotypical controls can, and the increased angles suggest a weakness or lack of control in the hip flexor muscles. These results strongly indicate that further investigation of muscle activity in autistic children, as compared with that in neurotypical children, is necessary.

To further complicate interpretations of the variability of kinematic and kinetic findings in autistic gait, the aforementioned gait studies have been conducted with predominately Western and White individuals, even though cultural and racial background have been shown to impact gait patterns [24–27]. This issue is not only present in the literature assessing gait differences in autistic individuals, but it is present globally, indicating that, in general, much less is known about gait of non-White and non-Western individuals [27]. We take culture to broadly mean the customs, practices, and background of individuals belonging to a specific social group [28]. The few studies that have been conducted with non-White and non-Western individuals do demonstrate that culture and other sociocultural factors impact gait. For example, cultural differences have been shown to impact stride length [24,29], walking speed [27,29] and in general, childrearing practices impact walking milestones and gait patterns [26]. Despite these clearly observed cultural differences, gait parameters obtained from White and Western populations are used globally to make clinical judgments and recommendations.

To understand the early neurobiological factors that impact how gait develops in autistic walkers, and, ultimately, in order to make services more equitable and culturally relevant, it is necessary to undertake gait research on autistic children from diverse cultural backgrounds. The purpose of the present study was to review the recent literature investigating gait patterns of autistic children and whether any studies have considered cultural factors, and to describe how culture was assessed in studies that took culture into account. We assessed each eligible article for cultural factors, which have been broadly defined to mean the customs, practices, and background of individuals belonging to a specific social group, including ethnicity and socioeconomic status [28].

2. Materials and Methods

Identification and selection of research articles for the present review were conducted following the Arksey and O’Malley framework [30] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [31] between October and November 2022. A keyword search with the terms autism, OR autism spectrum disorder, OR ASD, OR autistic, AND gait OR walking was used to search the following databases: CINAHL, ERIC (EBSCO), Medline, ProQuest Nursing & Allied Health Source, PsychInfo, PubMed, and Scopus. Articles were considered for review if they met all six of the following inclusionary criteria: (1) included participants with a diagnosis of autism spectrum disorder (ASD), (2) directly measured gait or walking, (3) the article was a primary study, (4) the article was written in English, (5) participants included children up to age 18,
Articles were removed because they did not meet the aforementioned inclusionary criteria. One article was not able to be retrieved for full text examination, an additional article was removed upon full text examination because it did not meet the age range criteria, and another paper was removed because it was a conference proceeding. Thus, a total of 43 articles were reviewed for the present study. Please refer to Fig. 1 for the article selection process.

Table 1 summarizes the findings. Of the 43 articles that met eligibility criteria, one was published in 2014, two were published in 2015, two were published in 2016, seven were published in 2017, seven were published in 2018, two were published in 2019, seven were published in 2020, nine were published in 2021, and six were published in 2022. The eligible articles included children ranging from toddlers at 19 months to 17-year-olds, with the majority of the articles focused on school-age children.

Of the 43 articles, none took into account culture when assessing gait in autistic children. For the purposes of this scoping review, any report of the participants’ race, ethnicity, socioeconomic status, country of origin, or cultural identity that was factored into the data analysis would have been coded as taking culture into consideration. Even with this broad estimate of culture, not one single study included in this scoping review considered culture in its analytical interpretations. One study [39] collected information on children’s socioeconomic status, this information was not taken into account during the data analysis process. Participant socioeconomic status was not reported in any other article.

4. Discussion
The goal of the present review was to assess whether studies investigating gait differences in autistic children took culture into account given that gait is impacted by cultural factors. We specifically targeted articles published after 2013 following the change in diagnostic criteria of autism spectrum disorder. A review of 43 recently published articles revealed that culture has not been considered in autism gait studies. It is clear from this review that studies assessing gait in ASD must consider the impact of cultural factors.

With the increasing prevalence of autism globally, neuroscientific research exploring the underlying neurobiological differences in the development of autistic characteristics, such as gross motor skills, is crucial to better understand, diagnose and serve autistic individuals. Although a body of scientific literature has indicated that the study of gait in autistic walkers may objectively quantify gross motor differences and could potentially lead to methods of earlier diagnosis, it is urgent for these studies to report the participants’ cultural background such as race, ethnicity, socioeconomic status, country of origin, and cultural identity to ensure that the results can be generalized across all autistic individuals. In fact, there was a complete lack of information regarding participant characteristics in the 43 articles that were reviewed for the present scoping review.
Most studies only reported age and sex information. We would further like to propose the need for more information to be included in future publications regarding autism diagnostic criteria. Many studies included in the present review did not report how the participants obtained the ASD diagnosis. This lack of information paired with the fact that most gait studies have been conducted with White and Western individuals, could lead to misinterpretations of the findings, and could delay the advancement of scientifically sound diagnostic tools and services to autistic individuals.

Given the potential promise of using walking gait to further our understanding of ASD and its neural underpinnings, we would like to propose that future studies take culture into consideration. We outline several ways in which culture can be incorporated into future studies. First, the inclusion of autistic researchers across a variety of backgrou-
Table 1. Summary of included studies (n = 43).

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Total participants; ASD participants, ASD participants assigned male at birth</th>
<th>Age range of ASD participants</th>
<th>ASD Diagnostic Criteria</th>
<th>Culture considered?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accardo and Barrow, 2015 [32]</td>
<td>n = 61; ASD = 61, male = 54</td>
<td>19–36 mos.</td>
<td>DSM-IV</td>
<td>No</td>
</tr>
<tr>
<td>Arık, Aksoy, Aysev and Akçakin, 2018 [33]</td>
<td>n = 79; ASD = 79, male = 66</td>
<td>2–16 yrs.</td>
<td>DSM-IV</td>
<td>No</td>
</tr>
<tr>
<td>Armitano-Lago, Bennett and Haegele, 2021 [34]</td>
<td>n = 34; ASD = 17, male = 12</td>
<td>13.5–16.5 yrs.</td>
<td>DSM-IV</td>
<td>No</td>
</tr>
<tr>
<td>Bennett and Haegele, 2021 [35]</td>
<td>n = 34; ASD = 17, male = 12</td>
<td>13.2–16.2 yrs.</td>
<td>Documentation confirming diagnosis</td>
<td>No</td>
</tr>
<tr>
<td>Bennett, Ringleb, Bobzien and Haegele, 2022 [36]</td>
<td>n = 34; ASD = 17, male = 12</td>
<td>13.2–16.2 yrs.</td>
<td>Documentation confirming diagnosis</td>
<td>No</td>
</tr>
<tr>
<td>Bennett, Ringleb, Bobzien and Haegele, 2021 [37]</td>
<td>n = 34; ASD = 17, male = 12</td>
<td>13.2–16.2 yrs.</td>
<td>Documentation confirming diagnosis</td>
<td>No</td>
</tr>
<tr>
<td>Bennett, Jones, Valenzuela and Haegele, 2021 [38]</td>
<td>n = 20; ASD = 10, male = 10</td>
<td>13.2–16.2 yrs.</td>
<td>Documentation confirming diagnosis</td>
<td>No</td>
</tr>
<tr>
<td>Biffi et al., 2018 [39]</td>
<td>n = 31; ASD = 15, male = 14</td>
<td>8.24–11.38 yrs.</td>
<td>Confirmed with ADOS</td>
<td>No</td>
</tr>
<tr>
<td>Eggleston et al., 2020 [40]</td>
<td>n = 21; ASD = 11, male = N/A</td>
<td>5–12 yrs.</td>
<td>DSM-IV</td>
<td>No</td>
</tr>
<tr>
<td>Eggleston et al., 2018 [41]</td>
<td>n = 10; ASD = 10, male = 10</td>
<td>7.2–15 yrs.</td>
<td>Verbally confirmed by parent</td>
<td>No</td>
</tr>
<tr>
<td>Eggleston et al., 2018 [42]</td>
<td>n = 8; ASD = 8, male = 8</td>
<td>7.1–16.1 yrs.</td>
<td>Parent-confirmed diagnosis from a psychiatrist or psychologist</td>
<td>No</td>
</tr>
<tr>
<td>Eggleston, Harry and Dufek, 2018 [43]</td>
<td>n = 18; ASD = 9, male = 7</td>
<td>6.7–11.3 yrs.</td>
<td>Verbally confirmed by parent</td>
<td>No</td>
</tr>
<tr>
<td>Eggleston, Harry, Hickman and Dufek, 2017 [44]</td>
<td>n = 10; ASD = 10, male = 6</td>
<td>5–12 yrs.</td>
<td>Verbally confirmed by parent</td>
<td>No</td>
</tr>
<tr>
<td>El Shemy and El-Sayed, 2018 [45]</td>
<td>n = 30; ASD = 30, male = 22</td>
<td>8.65–9.99 yrs.</td>
<td>CARS</td>
<td>No</td>
</tr>
<tr>
<td>Golden and Getchell, 2017 [46]</td>
<td>n = 17; ASD = 9, male = 9</td>
<td>8–11 yrs.</td>
<td>Previous diagnosis from psychologist and/or physician</td>
<td>No</td>
</tr>
<tr>
<td>Gong et al., 2020 [47]</td>
<td>n = 86; ASD = 58, male = 52</td>
<td>4.21–6.86 yrs.</td>
<td>Confirmed with AQ-CHILD and SRS-2</td>
<td>No</td>
</tr>
<tr>
<td>Hasan, Jailani and Tahir, 2017 [49]</td>
<td>n = 60; ASD = 30, male = 23</td>
<td>6.47–10.79 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Hasan, Jailani, Tahir and Desa, 2018 [50]</td>
<td>n = 60; ASD = 30, male = 23</td>
<td>6.47–10.79 yrs.</td>
<td>Clinically diagnosed, none specified</td>
<td>No</td>
</tr>
<tr>
<td>Hasan, Jailani, Tahir and Ilias, 2017 [51]</td>
<td>n = 35; ASD = 15, male = 11</td>
<td>7.61–11.73 yrs.</td>
<td>Previous diagnosis</td>
<td>No</td>
</tr>
<tr>
<td>Hasan, Jailani, Tahir and Sahak, 2017 [52]</td>
<td>n = 60; ASD = 30, male = N/A</td>
<td>4–12 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Jafarnezhadgero et al., 2021 [53]</td>
<td>n = 30; ASD = 15, male = 15</td>
<td>8.3–9.7 yrs.</td>
<td>Parent or teacher report</td>
<td>No</td>
</tr>
<tr>
<td>Li, Koldenhoven, Liu and Venuti, 2021 [54]</td>
<td>n = 29; ASD = 29, male = N/A</td>
<td>6–14 yrs.</td>
<td>DSM-5</td>
<td>No</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Total participants; ASD participants, ASD participants assigned male at birth</td>
<td>Age range of ASD participants</td>
<td>ASD Diagnostic Criteria</td>
<td>Culture considered?</td>
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<td>------------------------------------------------</td>
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</tr>
<tr>
<td>Lim, O’Sullivan, Choi and Kim, 2016 [55]</td>
<td>n = 30; ASD =15, male = 13</td>
<td>8.4–14 yrs.</td>
<td>DSM-IV</td>
<td>No</td>
</tr>
<tr>
<td>Manfredi, Riefoli, Coviello and Dibello, 2022 [56]</td>
<td>n = 22; ASD = 22, male = 12</td>
<td>5.6–12.6 yrs.</td>
<td>DSM-5</td>
<td>No</td>
</tr>
<tr>
<td>Manicolo et al., 2019 [57]</td>
<td>n = 68; ASD = 32, male = 27</td>
<td>5.2–12.8 yrs.</td>
<td>ICD-10</td>
<td>No</td>
</tr>
<tr>
<td>Mason, Padilla and Travers, 2022 [58]</td>
<td>n = 27; ASD = 9, male = 8</td>
<td>11–12.4 yrs.</td>
<td>Previous clinical diagnosis</td>
<td>Confirmed with ADOS-2</td>
</tr>
<tr>
<td>Mohd Nor, Jailani and Tahir, 2020 [59]</td>
<td>n = 60; ASD = 30, male = N/A</td>
<td>6–13 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Mohd Nor et al., 2016 [60]</td>
<td>n = 18; ASD = 8, male = N/A</td>
<td>6–13 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Olivas, Chavez and Eggleston, 2022 [61]</td>
<td>n = 9; ASD = 9, male = 8</td>
<td>9.6–15.8 yrs.</td>
<td>Clinical diagnosis verbally confirmed by parent</td>
<td>No</td>
</tr>
<tr>
<td>Olivas et al., 2022 [62]</td>
<td>n = 14; ASD = 14, male = 12</td>
<td>8–17 yrs.</td>
<td>Documentation from medical professionals or school IEP</td>
<td>No</td>
</tr>
<tr>
<td>Pauk, Zawadzka, Wasilewska and Godlewski, 2017 [63]</td>
<td>n = 58; ASD = 28, male = 17</td>
<td>5.1–9.8 yrs.</td>
<td>CARS</td>
<td>No</td>
</tr>
<tr>
<td>Pradhan, Chester and Padhiai, 2022 [64]</td>
<td>n = 40; ASD = 19, male = 16</td>
<td>7.6–13.4 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Sengupta et al., 2021 [65]</td>
<td>n = 1; ASD =1, male = N/A</td>
<td>10 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Shetreat-Klein, Shinnar and Rapin, 2014 [66]</td>
<td>n = 76; ASD = 38, male = 28</td>
<td>1.83–10.76 yrs.</td>
<td>DSM-JV</td>
<td>No</td>
</tr>
<tr>
<td>Souza et al., 2020 [67]</td>
<td>n = 6; ASD = 6, male = 2</td>
<td>3–17 yrs.</td>
<td>CARS</td>
<td>No</td>
</tr>
<tr>
<td>Steiner and Kertesz, 2015 [68]</td>
<td>n = 26; ASD = 26, male = 12</td>
<td>10–13 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Telang, Naqvi, Dhankar and Jungade, 2021 [69]</td>
<td>n = 20; ASD =20, male = N/A</td>
<td>4–10 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Valagussa et al., 2020 [70]</td>
<td>n = 69; ASD = 69, male = 56</td>
<td>14.1 (±3.6 yrs.)</td>
<td>DSM-5</td>
<td>No</td>
</tr>
<tr>
<td>Wilder et al., 2020 [71]</td>
<td>n = 3; ASD =3, male = 3</td>
<td>4–6 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Wilson et al., 2020 [72]</td>
<td>n = 191; ASD = 21, male = 71%</td>
<td>30 mos.–11 yrs.</td>
<td>ADOS-2</td>
<td>No</td>
</tr>
<tr>
<td>Zakaria, Jailani and Tahir, 2021 [73]</td>
<td>n = 53; ASD = 23, male = 21</td>
<td>8–8.8 yrs.</td>
<td>None specified</td>
<td>No</td>
</tr>
<tr>
<td>Zakaria et al., 2017 [74]</td>
<td>n = 40; ASD = 10, male = N/A</td>
<td>8.40 (1.90) yrs.</td>
<td>Previous clinical diagnosis</td>
<td>No</td>
</tr>
</tbody>
</table>

Note. ASD, Autism spectrum disorder; m, Male; N/A, Not available; mos., Months; yrs., Years; DSM, Diagnostic and Statistical Manual of Mental Disorders; ADOS, Autism Diagnostic Observation Schedule; CARS, Childhood Autism Rating Scale; SRS, Social Responsiveness Scale; AQ-Child, Autism Spectrum Quotient: Children’s Version; ICD, International Classification of Diseases; IEP, Individualized Education Program.
nds as collaborators on research teams could help identify potential areas of research bias as the study methods are in the development stage and in the interpretation of the results. This community-based participatory research approach is gaining momentum in health-based research, with the ultimate goal of improving the science of addressing health disparities in socially disadvantaged population groups [75–78]. Second, active recruitment of autistic participants across a broad range of cultural, racial, and socioeconomic backgrounds could also help to disentangle which aspects of gait are unique to ASD irrespective of cultural, racial, or socioeconomic status. Cultural factors do impact every aspect of ASD, from the referral and diagnostic process to the way that the child is accepted and integrated into the overall society [79]. Perhaps autistic children with more involved needs, such as intellectual needs, may be approached differently within different cultures, which could have further implications for how they in turn adopt cultural norms, such as walking gait. In fact, a relationship between intellectual functioning and motor skills has been documented, such that individuals with lower intellectual functioning often demonstrate poorer motor performance [80–82] and given that autism is a spectrum disorder, some autistic children also have an intellectual disability. In fact, one-third of autistic children also have intellectual disability [83]. Third, a way to help increase the diversity of participants is to ensure that researchers undertaking these studies come from a variety of backgrounds and experiences and that all researchers undergo cultural humility training. This would allow the researchers to establish trusting relationships with all participants from all backgrounds. Ultimately, for neuroscientific researchers to more accurately study gait in autistic individuals, cultural factors must be taken into consideration in future research.

The present scoping review is not without limitations. We considered culture very broadly, but even with this broad definition of culture, none of the 43 articles took culture into account. Further, there are sex differences in the biomechanics of gait [23] but we did not specifically assess whether these studies took these sex differences into account. Gaging by the number of ASD participants assigned male at birth, as illustrated in Table 1, it appears that the current research assessing the relationship between autism and the biomechanics of gait is male dominated. Historically, the ratio of male to females diagnosed with ASD has been reported to be 4 males to 1 female [84]; however, it has become increasingly evident that autistic characteristics differ between males and females and this ratio is in fact much lower [85]. Future work is necessary to consider sex differences in addition to cultural factors.

5. Conclusions

Motor differences in autistic children have been widely reported [3,4,86], and may point to an early diagnostic indicator of ASD [5]. In particular, poor postural control, necessary to maintain upright balance, in infants as young as 6 months of age is one of the earliest identified indicators of ASD [7]. As toddlers continue to grow and learn to walk, gait differences have also been observed in autistic children. Thus, gait differences may serve clinical utility and as an early indicator of ASD. In order to provide culturally responsive assessment and intervention services, studies assessing gait in autistic children should consider the impact of culture on gait. An urgent call to action is necessary to ensure that children from all cultural backgrounds are recruited for research studies, and that investigators consider culture in the study design, recruitment, and data analysis process. This is the first step to creating equitable ASD screening, diagnostic, and intervention tools.

Availability of Data and Materials

The dataset is available from the corresponding author on reasonable request.

Author Contributions

MB, AG, SO and ZW designed the research study. Under the supervision of MB, GI and RT performed the research and analyzed the data. MB, AG, and SO wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Appendix

One of the seven researched database searched for the present scoping review included the ERIC EBSCO host. The following steps were taken to obtain relevant articles:
Step 1: Type the keywords in the advanced search tab “Autism or ASD or autism spectrum disorder or autistic” and “gait or walking”.

Step 2: Click both tabs selecting “title” in the select field, then press “search”.

Step 3: Repeat the previous step but instead of selecting “title” for the select field, select “abstract” then press “search”.

Step 4: Following both searches, press on “search history”, click on “select/deselect all” and press “search with AND”.

Step 5: Scroll down to “source types” and press on “academic journals”.

Step 6: Once the page updates, click on the folder icon on the top right corner of the article if it is relevant to the research question.

Step 7: Once all articles that are relevant are selected into a folder, press “folder view”.

Step 8: Press “select/deselect all” then press “export”.

Step 9: Once exported, go under “save citations to a file formatted for:” and press “download CSV”.

Step 10: Press save. This will then allow us to retrieve all information regarding an article into an excel spreadsheet.

References


Pauk J, Zawadzka N, Wasilewska A, Godlewski P. Gait devia-


