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Exercise-based Interventions Aimed at Improving Balance Among Children and Adolescents with Autism Spectrum Disorder: A Meta-analysis

Abstract

Children with Autism Spectrum Disorder (ASD) often have deficits in motor skills, especially balance. This article presents a meta-analytic review of 15 intervention studies that aimed to improve balance in children and adolescents with ASD. Across these studies, there were 195 participants with ASD for whom pre-intervention and post-intervention balance scores were available. We measured the standardized mean difference (Hedges' g) between their pre-intervention and post-intervention balance scores and found a large, positive effect from these balance interventions (standardized mean difference- 1.82 (95% CI [1.34, 2.29])). Various balance intervention procedures were shown to be very efficacious for children and adolescents with ASD. Clearly, balance is a motor skill that is very susceptible to intervention efforts. We also provided recommendations to researchers regarding what information to include when conducting intervention studies.

Key words: children and adolescents with autism spectrum disorder, balance, intervention study, meta-analysis

Introduction

Autism Spectrum Disorder (ASD) is a an early-onset neurodevelopmental condition characterized by social and communication deficits and repetitive sensory-motor behaviors; it is associated with a strong genetic component and other causes (Lord et al., 2018). Current studies have estimated the prevalence of ASD at around 1 in 59 children, with males four times more likely than females to be diagnosed with ASD (Baio et al., 2018). Besides deficits in communication and social skills, individuals with ASD often have motor skill deficits in both fine motor skills (Choi et al., 2018) and gross motor skills (Staples & Reid, 2010). Up to 83% of children with ASD have difficulties performing age-appropriate motor skills (Ruggeri et al., 2019). Deficits in motor skills are, in turn, related to problems in adaptive behavior and everyday functioning (Jasmin et al., 2009; MacDonald et al., 2013; Mazefsky et al., 2008; Stone et al., 1999). However, not all motor skills are equally affected by ASD. For example, some studies revealed that static balance is more significantly impaired than other motor skills (Ament et al., 2015; Whyatt & Craig, 2012), suggesting that there is a specificity of motor impairments in ASD that particularly affect balance. Studies on balance control in ASD are interesting from a cognitive science perspective, as they suggest that balance requires a complex interplay of information processing, motor planning and timing, and sequencing of motor muscles (Stins & Emck, 2018). Given the importance of balance to everyday functioning, it is not surprising that many ASD studies have addressed balance. For example, balance was examined in relation to core autistic symptoms such as repetitive behaviors (Radonovich et al., 2013) and the effects of visual feedback on balance (Somogyi et al., 2016). A plethora of studies compared balance between persons with ASD and typically developing persons (Berkeley et al., 2001; Minshew et al., 2004a; Vernazza-Martin et al., 2005). Persons with ASD have shown such reduced postural control that many never

reach an adult level of postural control (Memari et al., 2014; Minshew et al., 2004b). Given the frequency and severity of motor coordination deficits, including deficits in balance, some authors believe that these deficits should be classified as core deficits in ASD (Ben-Sasson et al., 2009). Thus, ASD treatment should consider motor performance interventions aimed at improving motor coordination, including gait and balance (Fournier et al., 2010).

Although numerous studies have addressed balance, defining balance has not been a simple task; there is no universally accepted definition of the balance construct (Pollock et al., 2000). As noted above, balance is a complex motor skill, also referred to as postural control, which can be operationalized as a mechanism by which the human body prevents itself from falling (Ragnarsdóttir, 1996). Balance is closely related to the inertial forces that act on the body and the inertial characteristics of body segments (Winter, 1995). Balance control requires maintenance of one's center of mass over their base of support (Graham et al., 2015). Balance is usually classified as either static or dynamic. Static balance, as the name implies, requires maintaining equilibrium for a stationary body position, while dynamic balance requires maintaining equilibrium during motion (Davlin, 2004). There have been many methods of assessing balance, with the researcher's goals having determined its measurement across different studies and no single measure having emerged, making the selection of an appropriate balance assessment procedure difficult (Rudolf et al., 2020). Static balance is usually measured by asking participants to stand on a force platform on one leg or by measuring the length of time participants can maintain an equilibrium position (Ricotti, 2011); dynamic balance can be measured in a multitude of ways, but it is typically measured through tasks such as requiring participants to walk on a balance beam (Cinelli & Depaepe, 1984).

Among the many studies of intervention programs/training protocols aimed at improving balance in individuals with ASD, there have been interventions that can be classified as exercise or sport-based, such as taekwondo, skating, karate, aquatic exercise (Ansari et al., 2020; Casey et al., 2015; Cheldavi et al., 2014; Kim et al., 2016), videogame-based interventions (Fang et al., 2018; Travers et al., 2018), and sensory-based interventions (Case-Smith et al., 2014; Pfeiffer et al., 2011). Some interventions have used new neuroscience technology such as transcranial direct current stimulation to improve balance in children with ASD (Mahmoodifar & Sotoodeh, 2019). Among these various ASD interventions that have targeted balance, exercise-based interventions have been most common; and previous studies have shown their positive effects on the motor skills of children with ASD, including bilateral coordination, running speed, agility, and balance (Yin & Yin, 2019). Thus, various different physical exercises have often been prescribed to improve postural control and reduce the risk of injury in this population (Bressel et al., 2007).

Although several prior reviews have attempted to describe interventions for improving physical fitness and motor skills in children with ASD (Ruggeri et al., 2019; Yin & Yin, 2019), past review efforts considered motor performance generally and did not focus specifically on balance. Also, while reviews of individual studies have shown positive exercise effects, there has been no meta-analytic review to numerically assess the specific efficacy of exercise-based or sports-based interventions on balance among children and adolescents with ASD. Exercise-based interventions are defined as those in which children make voluntary movements to exercise their muscles against an external force (Howe et al., 2011). Our goals in the present study were: (a) to review and evaluate, through meta-analysis, exercise-based intervention studies specifically aiming to improve balance in children with ASD; and (b) to provide recommendations for future research in this area.

Method

Literature Search

For this review, we searched the literature for studies in which motor balance (static, dynamic, or both) was an outcome measure and participants were children and adolescents (aged 0–18 years) with ASD. We searched SCOPUS, PubMed and Web of Science databases for studies containing the terms "autism," "autism spectrum disorder/s," "balance," "intervention/s," "training/s," and "postural control." Within the articles we initially located, we then further examined referenced articles in those studies to locate any additional relevant studies that we might have first missed. A similar review methodology was previously used by Memisevic and Djordjevic (2018). We did not include abstracts, conference proceedings, dissertations, and publications without full text in English, and we did not collect data on other intervention outcomes (e.g., social skills, other motor skills, repetitive behavior). Finally, we did not include single participant case studies. A flowchart of this review methodology is presented in Figure 1.

[Insert **Figure 1**. *Study Selection Flow Chart about here.]*

Study Inclusion Criteria

To be selected for this review, research studies needed to fulfil the following criteria:

(a) The intervention was exercise- or sports-based;

(b) The protocol was explained in detail (number of participants, methodology description, intervention duration and intensity, etc.);

(c) Participants were children and adolescents (0-18 years of age) with a diagnosis of ASD;

(d) Balance (static balance and/or dynamic balance) was an outcome measure;

(e) There were pre- and post-intervention measures/scores on balance or effect size values for mean differences between pre- and post-test scores;

(f) The study was published between January 2010 – January 2021 in a peer-reviewed journal in English.

Our systematic search produced 15 studies that fulfilled the above-mentioned criteria (Akyol & Pektas, 2018; Ansari et al., 2020; Arzoglou et al., 2013; Cai et al., 2020; El Shemy & El-Sayed, 2018; Huseyin, 2019; Kim et al., 2016; Lourenço et al., 2015a, 2015b; Najafabadi et al., 2018; Pan et al., 2016; Rafie et al., 2017; Sarabzadeh et al., 2019; Wuang et al., 2010; Zamani et al., 2017); and the first and second authors of this paper agreed on the selection of 12 of these 15 studies (80%) with disagreements for three studies. In one of these, the authors reported post-intervention mean scores (and standard deviations) and compared the intervention group with a control group that did not receive the treatment (Zamani et al., 2017). We reached agreement to include that study, as the scores of the control and intervention groups were not statistically different at pre-test. A second disagreement was related to a study in which the investigators did not report mean scores (and standard deviations) but only the effect size and standardized mean difference (Rafie et al., 2017). We agreed to include this study because it provided sufficient information for the purposes of this meta-analysis. A third disagreement involved a study that reported median values and interquartile range on the balance measure (El Shemy & El-Sayed, 2018). We agreed to include that study as well, because found an approximate way to transform these scores into means (and standard deviations) (Wan et al., 2014). A summary of the selected studies is shown in Table 1.

[Insert **Table 1** about here.]

Participants in Selected Studies

Summing the participant sample sizes in these studies, 195 children and adolescents with ASD (aged 3-17 years of age) comprised this meta-analytic review. Gender information was given in 10 studies (155 participants; 120 boys and 35 girls). In four studies (totaling 40 participants), investigators did not state the participants' gender. In four studies, the authors reported that the diagnosis of ASD was made according to DSM (American Psychiatric Association, Diagnostic and Statistical Manual) criteria – DSM-IV (Arzoglou et al., 2013), DSM-IV-TR (Najafabadi et al., 2018; Pan et al., 2016), and DSM-5 (Ansari et al., 2020), while in the remainder, no diagnostic method was specified. Co-existing diagnosis were reported only in one study (Pan et al., 2016), in which three participants also had Attention Deficit Hyperactivity Disorder. On the other hand, some authors made clear what were the exclusionary criteria within their studies. These were the absence of serious medical conditions, such as orthopedic or any acute conditions (Najafabadi et al., 2018), absence of auditory, visual, or respiratory deficits, or fixed deformities of the extremities (El Shemy & El-Sayed, 2018), absence of mental retardation and malnutrition (Sarabzadeh et al., 2019), orthopedic or sensory problems (Arzoglou et al., 2013), existing health problems (Akyol & Pektas, 2018), co-morbid psychiatric disorders, a complex neurological disorder (e.g., epilepsy, phenylketonuria, fragile X syndrome, tuberous sclerosis), visual and auditory disorders, a medical history of head trauma (Cai et al., 2020), uncontrolled seizure, severe self-injurious behavior, congenital hip dislocation, and severe sensory impairments (Wuang et al., 2012), obvious physical or developmental impairments (Rafie et al., 2017), motor and physical disabilities (Zamani et al., 2017), and complex neurologic disorder (e.g. epilepsy, phenylketonuria, fragile X syndrome, and tuberous

sclerosis) (Ansari et al., 2020). Three studies (Ansari et al., 2020; Najafabadi et al., 2018; Sarabzadeh et al., 2019) assessed ASD symptom severity with the Gilliam Autism Rating Scale-2nd Edition (Gilliam, 2006), three studies (Cai et al., 2020; El Shemy & El-Sayed, 2018; Rafie et al., 2017) used the Childhood Autism Rating Scale (Schopler et al., 1988), two studies (Cai et al., 2020; Pan et al., 2016) used the Social Responsiveness Scale -2nd Edition (Constantino & Gruber, 2012), and one study (Zamani et al., 2017) used the Autism Spectrum Screening Questionnaire (Ehlers & Gillberg, 1993). The remaining studies did not assess ASD symptom severity with any scale. Although the exact level of the participants' intellectual functioning was not reported in any of the studies, two reviewed studies (Rafie et al., 2017; Sarabzadeh et al., 2019) indicated that exclusion criteria included the presence of intellectual disability and one study reported that its participants had borderline intellectual ability.

Four studies described participants as having mild or mild/moderate autistic symptoms (Ansari et al., 2020; El Shemy & El-Sayed, 2018; Lourenço et al., 2015a; Rafie et al., 2017), while the remainder did not describe ASD severity in their participants. However, no studies described participants with severe autism features, and two studies required their participants to understand and follow verbal instructions (Arzoglou et al., 2013; Kim et al., 2016).

Types of Intervention

Two studies used trampoline training in their intervention (Lourenço et al., 2015a, 2015b), one study used the Sports, Play, and Active Recreation for the KIDS (SPARK) program (Najafabadi et al., 2018), one used a physical therapy program (El Shemy & El-Sayed, 2018), one used Tai Chi Chuan (Sarabzadeh et al., 2019), one used traditional Greek dance (Arzoglou et al., 2013), one used gymnastics training combined with music (Akyol & Pektas, 2018), one used gymnastic exercises (Zamani et al., 2017), one used table tennis exercise (Pan et al., 2016), one

used a mini-basketball training program (Cai et al., 2020), one used sport training (Huseyin, 2019), one used a simulated developmental horse-riding program (Wuang et al., 2012), one used an exercise intervention (Rafie et al., 2017), one used Taekwondo (Kim et al., 2016), and one used both aquatic exercise and kata techniques (Ansari et al., 2020). In Table 2. we present the intervention activities and the duration of the intervention program.

[Insert **Table 2** about here.]

Outcome Measures

For outcome measures, eight of the analyzed studies used Balance/Body Coordination scores from the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP; (Bruininks, 1978; Bruininks & Bruininks, 2005)). More specifically, three studies (Najafabadi et al., 2018; Rafie et al., 2017; Wuang et al., 2010), used the original BOTMP (Bruininks, 1978), while five studies (El Shemy & El-Sayed, 2018; Lourenço et al., 2015a, 2015b; Pan et al., 2016; Zamani et al., 2017) used the revised edition of the test (BOTMP-2; (Bruininks & Bruininks, 2005)). The BOTMP and BOTMP-2 are standardized, norm-referenced measures of fine and gross motor skills of children and youth. Interrater reliability for the BOTMP has been found to be between .63 and .97, while the internal consistency has ranged from .38 to .92 (Bruininks, 1978). Interrater reliability for the BOTMP-2 is >.90 for all subtests, except Fine Motor Precision (r= .86). Internal consistency has ranged from .60 to .92. (Bruininks & Bruininks, 2005). The other six studies all used different balance measures. One reviewed study (Sarabzadeh et al., 2019) used Balance scores from the Movement Assessment Batery for Children- 2nd Edition (MABC-2; (Henderson et al., 2007)). The MABC-2 is designed to identify and describe impairments in the motor performance of children and adolescents aged 3 - 16 years of age, inclusively. Interrater

reliability for MABC-2 has ranged from .49 to .70 for three-year-olds and .92 to 1 for adolescents (Brown & Lalor, 2009), while the internal consistency has been reported to be .90 (Wuang et al., 2012). Another study in this review (Arzoglou et al., 2013), used the Korperkoordinationstest fur Kinder (KTK; (Kiphard & Schilling, 2007). The KTK aims to assess neuromotor coordination with four subtests, one of which is balance when walking backwards, often used as an outcome measure of balance. Authors of this reviewed study only reported the reliability of this test (r=.90) and stated that it is one of the most reliable measures of neuromuscular coordination in both typical populations and in people with disabilities. In the reviewed study by Akyol and Pektaş (2018), the authors used the Flamingo Balance Test, a part of Eurofit Motor Fitness Tests, as a measure of balance (Eurofit, 1988). In this test, a child is required to stand on one leg on a metal beam for as long as possible, and the number of times the child is unable to hold balance for one minute is recorded. The test-retest reliability has ranged from .40 to .80 (Monyeki et al., 2005). In another reviewed study, (Cai et al., 2020) used a balance beam test from China's national physical fitness measurement. Reported reliability of this test depends on the age of the participant and, for the balance test, reliability has ranged from .33 in 3-year-olds to .68 in 5.5-year-olds (Fang & Ho, 2020). In the reviewed study by Ansari et al. (2020), the authors used two balance measures for both static and dynamic balance. For static balance, they used the Modified Stork Test (Johnson & Nelson, 1979), requiring participants to stand on a dominant leg; and they used the Heel-to-Toe walking test (Henderson & Sugden, 1992) to measure dynamic balance. These authors did not report any psychometric properties of the tests they used; however the literature indicates that psychometric properties of these instruments are satisfactory (Atwater et al., 1990; Gard & Rösblad, 2009; Smits-Engelsman et al., 2011). In another reviewed study (Huseyin, 2019) two balance measures (for static and

dynamic balance) were drawn from the Basic Sport Skills Assessment. The author (Huseyin, 2019) did not report the reference for this test and its psychometric properties, and we could not find any references regarding this test. Finally, in the reviewed study by Kim et al. (2016), investigators used several measures of static and dynamic balance (eyes open, eyes closed, firm surface, unstable surface) from the NeuroCom Balance Master. For purposes of our meta-analysis, we used mean static balance scores and mean dynamic balance scores.

In four studies (Ansari et al., 2020; Huseyin, 2019; Kim et al., 2016; Najafabadi et al., 2018), the authors reported both, static and dynamic balance scores, while in the rest of the studies only one measure of balance was reported. Of note, in the study by Ansari et al. (2020) there were two intervention groups. Thus, in the 15 reviewed intervention studies analyzed in this paper, there were 21 different reported measures of balance.

Research Methodology

We used a modified version of the Quality Assessment Tool for Quantitative Studies (Thomas et al., 2004) to evaluate the quality of the methodology in these selected studies. This instrument has been said to have adequate content and construct validity (Jackson et al., 2005). Using this tool, we evaluated the studies in this review in relation to (a) Selection bias, (b) Study design, (c) Confounders, (d) Blinding, (e) Data collection methods and (f) General impression. Given that the first two authors performed previous analyses (independent literature search, article comparison, removal of duplicates, and review of articles), our third and fourth authors independently assessed each reviewed study with the Quality Assessment Tool for Quantitative Studies Dictionary and graded each of the domains above with 1 (strong), 2 (moderate), or 3 (weak). Domain scores were then averaged to provide a summary score for each study. Based on their summary score, studies were then assigned an overall quality rating of strong (1.00–1.50),

moderate (1.51–2.50) or weak (2.51–3.00) (Armijo-Olivo et al., 2012). Joint agreement between these two authors on these scores is evident in Table 3. Based on these assessments, seven studies were assessed as good quality and eight studies as moderate quality. It is important to note that only four studies used random allocation of participants into the intervention and control groups (Ansari et al., 2020; El Shemy & El-Sayed, 2018; Najafabadi et al., 2018; Pan et al., 2016).

[Insert **Table 3** about here.]

Statistical Analysis

As noted, pre-intervention and post-intervention scores (means and standard deviations) were provided in 12 studies for the participants included in the interventions. One study reported median and inter-quartile range for pre-intervention and post-intervention balance scores (El Shemy & El-Sayed, 2018). The scores obtained in this study were converted to mean scores (and standard deviations) according to the method described by Wan et al. (Wan et al., 2014). One study reported Cohen's *d* effect size (Cohen, 2013) and mean differences from pre-intervention to post-intervention scores without providing information for pre-intervention and post-intervention mean (and standard deviation) balance scores (Rafie et al.,2017). Lastly, one study, provided post-intervention balance mean scores (and standard deviations) for the intervention and control group as the groups did not differ prior to intervention (Zamani et al., 2017).

We calculated a standardized mean difference using Hedges' g effect size with 95% CI to assess the magnitude of change across all studies from pre-intervention to post-intervention balance scores. Hedge's g measures the effect size for the difference between two means (Rosenthal et al., 1994). Hedge's g provides an estimate of effect size similar to Cohen's d but it

is less reactive to small sample sizes (Hedges & Olkin, 2014). We also performed a Q test and an I^2 test of heterogeneity. All statistical analysis were performed with the computer program MedCalc for Windows, version 19 (MedCalc, 2020).

Results

According to the Q test and I^2 test we conducted, the reviewed studies were very heterogeneous (Q=98.1, df=20, p<.001; I^2=79.6% 95% CI [69.5, 86.4]). This heterogeneity result was expected, as the reviewed studies employed various methodologies and different outcome measures. Given that these studies were heterogeneous, we reported total random effects as they are more appropriate than the fixed-effects model in most cases, especially when researchers want to make general conclusions about the researched topic (Field, 2001). Total random and fixed effects were calculated from 21 tests. The mean standardized difference was 1.82 (95% CI [1.34, 2.29]). The standardized mean difference score for each study is presented in Table 4.

[Insert **Table 4** about here.]

The forest plot of effect sizes is presented in Figure 2.

[Insert **Figure 2.** *Standardized Mean Difference of Balance Scores from Pre-intervention to Post-intervention for Reviewed Studies.* about here]

All the reviewed studies in this paper showed a large, positive intervention effect on these participants' balance with a mean standardized pre- post-test difference of 1.82. The mean

standardized difference of the effect was medium to large in all studies and ranged from 0.37 (Kim et al., 2016) to 4.72 (Ansari et al., 2020). In total, the 95% CI included zero effect in four intervention studies (Cai et al., 2020; Kim et al., 2016; Najafabadi et al., 2018). In a study by Kim et al. (2016), the 95% CI included zero effect for both static and dynamic balance, while in a study by Najafabadi et al. (2018), the 95% CI zero effect was present for static balance only.

Discussion

Our goal in the present meta-analytic review was to examine the effects of exercise- and sports-based intervention studies on improving balance among children and adolescents with ASD. Balance has been the intervention target in efforts to assist children with other developmental disabilities as well. Exercise-based training has had a positive effect on balance in children with intellectual disability (Giagazoglou et al., 2013), children with Attention-deficit Hyperactivity Disorder or ADHD (Smith et al., 2011), children with hearing-impairment (Lewis et al., 1985), and children with cerebral palsy (Dewar et al., 2015).

Evidence of exercise benefits for physical and psychosocial gains in children with developmental disabilities dates to more than two decades ago (Dykens et al., 1998; Gabler-Halle et al., 1993). These effects were especially evident for health-related physical fitness, including cardiovascular endurance (Chanias et al., 1998). In addition, many exercise-based interventions have been found to be efficacious for improving balance in children with ASD. However, as the intervention protocols were not homogeneous and the exercises within these programs differed, it has been difficult to pinpoint “the best” intervention. In our review, Kata techniques (Ansari et al., 2020) and Tai Chi (Sarabzadeh et al., 2019) produced large, positive effects, but a Taekwondo (Kim et al., 2016) study produced a medium effect. However, benefits

of martial arts go beyond the motor skills. Studies of martial arts have generally shown its efficacy for many other developmental domains such as executive functions (Diamond & Lee, 2011). These effects of martial arts on executive functions were also evident in children with ASD (Phung & Goldberg, 2019). Martial arts have had positive effects in other domains as well, such as for self-regulation (Lakes & Hoyt, 2004), and for overall well-being (Moore et al., 2019).

Hippotherapy is a therapeutic modality with known positive effects. It has been successfully used for balance improvement in many conditions, such as intellectual disability (Giagazoglou et al., 2012), multiple sclerosis (Bronson et al., 2010), and chronic brain disorders (Sunwoo et al., 2012). In this review, a large effect was also noted for a simulated horse-riding program (Wuang et al., 2012). Previous studies have shown that riding simulators can be a useful alternative to hippotherapy in improving the balance in children with cerebral palsy (Lee et al., 2014). Riding-simulators can also be an option for children with ASD to reduce the risk of injury and also an option for some children who do not respond adequately to horses (Memishevikj & Hodzhikj, 2010).

Limitations and Directions for Further Research

A major limitation of previously conducted studies reviewed here has been their small sample sizes and relatively poor methodological quality, particularly including a failure to have randomly assigned participants to control and exercise conditions, opening the possibility that the strong positive results on motor skills and balance associated with exercise-based interventions for children with ASD may not generalize to all children with ASD. Exercise participants in past studies may have been those children with ASD who self-selected an exercise or sports-based intervention. Children or families who were less attracted to exercise interventions may not benefit to the same degree. Future research must utilize cross-over

research designs and random assignment to groups to put this caveat to rest. Of course, there are other reasons to question the generalizability of these positive impressions of exercise -based interventions in past ASD research. Most of the studies we reviewed gave limited or no information on the severity of ASD symptoms. Given that ASD is a very heterogenous disorder, the results of this meta-analysis may not be applicable to children at all severity levels. Thus, further methodological improvements in future research on balance training for children with ASD include (a) providing more detail regarding diagnostic method, (b) reporting symptom severity from a standardized scale, (c) reporting more participant characteristics in both intervention and control groups (i.e., age range, mean age [and standard deviations] and gender), (d) provide means (and standard deviations) for participants' balance scores in both experimental and control groups, and (e) provide sufficient intervention detail for others to replicate the research..

Another limitation of this review is related to publication bias. We may have encountered difficulty identifying relevant studies with null effects, due to publication bias that tends to favor articles reporting statistically significant intervention effects. This type of limitation is pertinent to most meta-analytic reviews. Also, we had to exclude some studies, as we had no way of knowing their mean pre-intervention and post-intervention balance scores.

Conclusion

In this meta-analytic review of 15 prior studies that focused particularly on balance measures and relied upon diverse types of intervention programs, we identified large positive effects of exercise-based interventions on improving balance in children and adolescents with ASD. These findings have many implications for professionals in the field, including

occupational therapists, special education teachers, physical education teachers, and physiotherapists. These professionals should be aware of the benefits of these exercises for children and adolescents with ASD and they should use these methods in their everyday practice to help them maintain a healthy lifestyle and build better social interactions (Mayrena et al., 2021). As stated earlier, balance improvements will probably generalize to other domains of a child's functioning, especially with regard to adaptive behavior.

Regarding future research in this domain, it should also be noted that we identified a number of methodological weaknesses in the studies we reviewed, and we have provided specific recommendations to address them. Small sample sizes, failure to randomly assign participants to groups, insufficient detail about diagnostic method and assessment instruments, ASD severity, intervention content, participant characteristics, and mean scores or effect sizes on outcome measures serve, collectively, to weaken the impact of this research and should be addressed by future investigators.

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