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Abstract

Background. Youth with Down syndrome are characterized by deficits in balance/postural stability. One way to palliate balance deficits among this population is through exercise interventions. However, to our knowledge, the effects of exercise interventions designed to improve the balance of youth with Down syndrome have never been systematically reviewed.

Purpose. The purpose of the present article was to summarize the findings from studies examining the effects of exercise interventions designed to improve balance in youth with Down syndrome.

Data Sources. A systematic literature search was performed in 10 databases (Academic Search Complete, CINAHL Plus with Full-text, Education Source, ERIC, Medline with Full-text, PsycARTICLES, Psychology and Behavioral Sciences Collection, Scopus, SocINDEX, SPORTDiscus with Full-Text) on June 12th 2017.

Study Selection. Randomized controlled trials and controlled trials examining the effects of exercise interventions designed to improve balance in youth with Down syndrome were included.

Data Extraction. Two authors selected the studies and extracted their characteristics and results. Three authors assessed risk of bias in studies using the Cochrane collaboration’s tool.

Data Synthesis. Eleven studies, published between 2010 and 2017, met our inclusion criteria. Findings show that exercise interventions are more effective than control conditions to improve the static balance of children with Down syndrome and static-dynamic balance of children and adolescents with Down syndrome. Nevertheless, findings on dynamic balance in children and static balance in adolescents are inconclusive.

Limitations. With a small number of studies and their high risk of bias, the present findings need to be interpreted with caution.

Conclusions. The reviewed exercise interventions were successful in improving the static balance of children with Down syndrome and static-dynamic balance of children-adolescents with Down syndrome.

Keywords. Down syndrome; intervention; physical activity; clinical tests; posturography; balance; postural control.
In the research literature, it is well-documented that, when compared to typically developing youth, youth with Down syndrome tend to be characterized by deficits in gross or fundamental motor skills\(^1,2\), and in particular poor balance and postural control\(^3,4\). Balance or posture is the capability to sustain one’s body or different body segments in equilibrium (in order to avoid a fall) and requires the integration of several sensory, motor, and biomechanical inputs. This capability can be examined in static (the body remains motionless) or dynamic (the body can react to perturbations or is in movement) conditions, as well as in both conditions\(^5\). In order to challenge the balance/postural control system in either static or dynamic conditions, youths’ ability or strategies to maintain their body in a state of equilibrium is often assessed by disturbing the visual (eyes opened, eyes closed) and/or plantar cutaneous sensitiveness inputs (hard floor, foam floor), as well as the position of the leg and feet (i.e., one leg or double leg: feet apart, feet together, and semi- or full-tandem)\(^6\). According to Lauteslager, Vermeer, and Holders\(^7\), the postural balance deficit displayed by youth with Down syndrome could be explained by disturbances in the regulation system of balance or postural control. Indeed, youth with Down syndrome tend to exhibit a reduced postural tone (hypotonia) that negatively affects muscular co-activation and balance reactions, and relates to deficits in proprioceptive feedback and to hypermobility or joint laxity\(^8\).

Balance/postural control is fundamental to the ability to safely accomplish movements or motor tasks characterizing daily life\(^8\). As such, these postural and balance deficits represent a serious functional limitation for this population. Among youth with Down syndrome, these balance/postural deficits may even heighten motor delays or impairments\(^1,2,10\), increase risks of body instability, falls and fall-related injuries\(^8\), and lead to activity limitations or participation restriction. Therefore, the improvement of balance and postural control among youth with Down syndrome represents a key issue.

In youth with a typical development, exercise interventions represent an effective way to improve balance/postural control\(^11,12\). Such interventions involve activities soliciting the neuromuscular components of the balance/postural control necessary to maintain one’s body’s in equilibrium in response to external forces or unexpected stimulus or perturbations\(^13\). It can also take several forms, encompassing balance exercises (i.e., exercises soliciting balance/posture ability while disturbing visual, vestibular and/or somatosensory inputs), virtual reality exercises, computerized balance exercises, “well being” or three-dimensional physical activities (e.g., Tai Chi Chuan, Qigong, yoga), muscle strength activities, vibration platform exercises (i.e., whole-body vibration), domestic and/or general physical activities (e.g., walking, cycling, stair climbing), sport activities, as well as combinations of the above interventions\(^8,13\). The rationale behind the use of exercise interventions to improve balance/postural control is that these types of activities induce functional and structural adaptations of the balance/postural control system that will increase balance/postural performance and strategies\(^8\). For example, since lower-limb strength is related to the ability to maintain the balance of the whole body, exercise interventions focusing on ankle strength tend to result in improvements in the standing balance of participants when compared to control groups\(^8\).

To our knowledge, the effects of exercise interventions designed to improve the balance of children and adolescents with Down syndrome have never been systematically reviewed and summarized. However, such a synthesis is important to inform scholars, physical therapists, and adapted physical educators about evidence-based practices in order to support the design of effective programs aimed at improving balance and postural control among youth with Down syndrome. The purpose of the present article is to systematically review the effects of exercise interventions (controlled trial [CT] or randomized controlled trial [RCT]) specifically designed to improve balance and/or postural stability (i.e., static, dynamic, and/or static-dynamic) in children and adolescents with Down syndrome aged 5 to 22. The effects of these exercise interventions should be compared with control groups comprising youth with Down syndrome.

**Method**

**Data Sources and Search**

A systematic electronic search was conducted simultaneously in seven databases provided by EBSCO (Academic Search Complete, CINAHL Plus with Full-Text, Education Source, ERIC, Medline with Full-Text, Psychology and Behavioral Sciences Collection, and SocINDEX) and separately in
PsycARTICLES (including PsycINFO), Scopus, and SPORTDiscus with Full-Text. The electronic search was conducted on June 12th, 2017, and no year restriction was imposed.

The identification of studies of interest was performed using four groups (Gr.) of search terms: (Gr. 1) “Down syndrome”; AND (Gr. 2) balance OR “postural control*” OR “postural sway” OR “postural stabili*” OR “postural instabilit*” OR “postural performance*” OR “postural perturbation*” OR “postural strateg*” OR posture*; AND (Gr. 3) clinic* OR effect* OR enhanc* OR evaluation OR exercis* OR experiment* OR improv* OR intervention* OR “physical activit*” OR “physical therap*” OR physiotherap* OR pilot OR program* OR psychomot* OR random* OR rehabilitation OR sport* OR therap* OR trainin* OR treatment OR trial*; AND (Gr. 4) child* OR adolescen* OR student* OR youth*. These grouping combinations were researched in the title-abstract-keywords of the studies published by the journals indexed in the databases. Finally, the reference lists of the studies of interest were also examined to find additional relevant studies.

Study Selection

Types of studies. Only studies using a prospective randomized controlled trial (RCT) or a controlled trial (CT) design were included in this review. Case studies and non-original studies (e.g., reviews, theoretical papers) were excluded.

Type of participants. Participants had to exhibit Down syndrome and be of school age, which we defined as 5 to 22 years old. Therefore, samples with a lower (e.g., 2-4.9 years) or higher (> 22 years) age range were excluded. Additionally, studies of mixed-age samples (i.e., adolescents and adults) were considered to be eligible if the sample mean age was lower than 18 with an age range of 5-22 years old or if results were provided separately for participants younger than 22 years old.

Type of interventions. Interventions had to focus on exercise, and be specifically designed to improve balance in youth with Down syndrome. Therefore, studies using exercise interventions not designed to improve balance among youth with Down syndrome were excluded. Finally, these interventions could take place in any environment (i.e., school, home, community, institution, etc.) and their effects should be compared with control groups comprising youth with Down syndrome.

Type of outcomes. The studies had to report intervention effects on outcomes related to balance and/or postural stability (i.e., static, dynamic, and/or static-dynamic) assessed using either a clinical test or by posturography.

Type of publications. Only articles in-press or published in English in a peer-reviewed journal were considered to be relevant. Additionally, when the same sample was used in different publications, only one publication (the first) of an intervention study was included.

The eligibility of studies was assessed by the first two authors following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement (PRISMA)14. First, the two authors independently assessed the titles and abstracts of the articles. Second, they independently assessed the full text of the studies retained in the previous step. Finally, their results were discussed to reach a consensus in cases of discrepancies.

Data Extraction and Risk of Bias Assessment

Data Extraction. As illustrated in Tables 1 to 4, the following categories of information were independently extracted by the first two authors for each of the included studies: (a) country and geographic region as defined by the World Health Organization (see http://www.who.int/aboutregions/en/); (b) design; (c) recruitment setting; (d) sample age category; (e) intellectual disability level; (f) characteristics of the exercise intervention and control groups; (g) characteristics of the exercise intervention program; (h) description of the control condition; (i) characteristics of balance measures; and (j) within and between-group differences in balance measures.

Risk of Bias Assessment. The first two authors independently assessed the risk of bias in studies using the Cochrane collaboration’s tool15. This six-item scale measures the following criteria16: (1) random sequence generation (selection bias); (2) allocation concealment (selection bias); (3) blinding of participants and personnel (performance bias); (4) blinding of outcome assessment (detection bias); (5) incomplete outcome data (attrition bias); and (6) selective reporting (attrition bias). Each item is graded using the following categories: “low risk of bias”, “high risk of bias” and “unclear risk of bias”. These
Selection of the Studies
As reported in Figure 1, 659 articles were identified, and this number fell to 353 when duplicates were removed. Analysis of titles and abstracts showed that 331 articles did not meet the inclusion criteria, leading to their exclusion. The full text of the 22 remaining articles was screened, leading to the exclusion of 11 publications (see the online supplement for the full references of these studies) that did not meet the inclusion criteria (see Figure 1 for reasons). A total of 11 studies, published between 2010 and 2017, met our inclusion criteria. Almost three quarters of these studies (8/11) focused on children with Down syndrome. The remaining ones (3/11) focused on adolescents with Down syndrome. These studies are described in Table 1.

Characteristics of the Reviewed Studies
Sample Characteristics and Design. As illustrated in Table 1, eight of the studies (73%) were conducted in the Eastern Mediterranean region, two in Europe and one in South-East Asia. Seven of these studies (64%) were RCT. A total of 281 youth with Down syndrome participated in these studies, including 189 children ($M_{total} = 11.8$, range = 8 to 16; 75% boys), and 92 adolescents ($M_{total} = 15.3$, range = 11 to 20; 60.6% boys). Children were mainly recruited in outpatient clinics and schools, whereas adolescents were mainly recruited in schools and institutions. Most studies (4/8 for children and 2/3 for adolescents) reported the intellectual disability level of the participants (Table 1).

Exercise Interventions and Control Condition. As shown in Table 2, studies of children with Down syndrome examined balance (backward walking training, Hopscoth local game), computerized balance training using visual feedback (Wii Fit balance game training), strengthening (core stability exercises, isokinetic training), vibration platform (whole body vibration), or combined (Stretching, strength, and balance exercises) exercise interventions. Studies of adolescents assessed balance, vibration platform, or combined exercise interventions (Table 3). Exercise interventions lasted between 6 and 24 weeks ($M_{weeks} = 10.7$, $SD_{weeks} = 6$). Additionally, only one study of children relied on a follow-up period of 10 weeks. Finally, in studies of children and adolescents, training sessions were held two or three times per week ($M_{times} = 2.7$, $SD_{times} = 0.5$), and lasted between 20 and 90 minutes per session. Only two studies described who delivered the intervention, and none mentioned the intervention setting, whether the intervention was adapted during trial, or whether strategies were used to ensure the conformity of the intervention. In half of the studies of children (4/8), the control group followed a conventional/designed physical therapy program, whereas in studies of adolescents, the control condition was only detailed in one study (i.e., regular school activities).

Balance Measures. For children (Table 2), five out of the eight studies assessed dynamic balance, one assessed static balance, one assessed both static and dynamic balance, and one assessed static-dynamic balance. For adolescents (Table 3), out of the three studies, two assessed static balance, and one assessed static-dynamic balance.

Studies conducted among children and adolescents with Down syndrome assessed static balance using either posturography apparatus (pressure platform) or clinical tests such as the original or modified version of the Stork Test. Those measuring dynamic balance used either a posturography apparatus (Biodex Balance System) or clinical balance tests, such as the Heel-to-Toe Dynamic Balance Test and the Timed Up and Go Test. Finally, studies examining static-dynamic balance used the balance subscale of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP).

In studies using posturography, estimates of balance were based on stability index scores (overall, anterior-posterior, and medio-lateral), the path length covered by the vertical projection of the center of gravity, the time spent by the vertical projection of the general center of gravity within a 13 mm radius circle, the velocity of the center of pressure, and the root-mean-square error of the center of pressure. For the clinical tests, estimates of balance were standing time, time taken to perform the test, number of steps, and a score obtained with the BOTMP.
Effects of Exercise Interventions

Children samples. The detailed results from the studies conducted among children are presented in Table 4. All of the studies showed that the exercise intervention groups have significant higher post-test static, dynamic and static-dynamic balance values than the control groups (Table 4). Additionally, findings showed that all of these studies reported a statistically significant improvement (from pre to post test) in static\textsuperscript{22,23}, dynamic\textsuperscript{17,19,21,23}, and static-dynamic\textsuperscript{16} balance in the exercise intervention groups. Finally, three of the eight studies reported a statistically significant improvement (from pre to post test) in dynamic balance for the control groups as well\textsuperscript{17,19,20}.

Adolescent Samples. As shown in Table 4, none of the RCT studies found or reported post-test differences in static balance\textsuperscript{25,26} between groups, but one study reported that the intervention group reported a significantly higher pre-post change values in static-dynamic balance than the control group\textsuperscript{24}. Additionally, findings showed that two of the studies focusing on adolescents reported a statistically significant improvement (from pre to post test) in static balance\textsuperscript{25,26} in the exercise intervention groups. Finally, none of these studies reported a statistically significant improvement (from pre to post test) in static balance for the control groups\textsuperscript{25,26}.

Risk of Bias of the Reviewed Studies

Figure 2 presents the quality assessment of the reviewed studies. This systematic review indicates, for both types of samples (children and adolescent), a high risk of bias related to allocation concealment (selection bias), performance (blinding of participants and personnel) and detection bias (outcome assessment), with unclear risk of bias in random sequence generation, attrition (incomplete outcome data), and reporting bias.

Discussion

The purpose of the present article was to conduct a systematic review of the effects of exercise interventions specifically designed to improve balance in children and adolescents with Down syndrome. All of the reviewed studies focusing on children with Down syndrome showed that the post-effects of exercise interventions on static, dynamic and static-dynamic balance were significantly higher than control groups. Additionally, they showed, in contrast to control groups, that exercise interventions with a duration of 6-24 weeks significantly improved (from pre to post test) the static\textsuperscript{22,23} and static-dynamic\textsuperscript{16} balance of children with Down syndrome. Despite the exercise intervention groups\textsuperscript{17,21,23} being effective in improving dynamic balance from pre to post test, similar effects were also observed for dynamic balance in the control groups\textsuperscript{17,19,20}.

None of the reviewed studies\textsuperscript{25,26} focusing on adolescents with Down syndrome showed or reported that the post-effects of exercise interventions on static balance were significantly different from those found with control conditions. Nevertheless, these studies showed, in contrast to control groups, that exercise interventions with a duration of 12-20 weeks significantly improved (from pre to post test) the static\textsuperscript{25,26} balance of adolescents with Down syndrome. Finally, one study reported that pre-post change values in static-dynamic balance were significantly higher in the exercise intervention group than in the control group.

From a clinical point of view, both clinical and posturographic tests showed a significant and positive effect of exercise interventions on the balance/posture of youth with Down syndrome. However, only a few studies measured balance/posture changes when visual\textsuperscript{16,24-26} and/or plantar cutaneous sensitiveness\textsuperscript{26} inputs were disturbed. This represents a gap in research as it is well known that variations of sensory information impact balance/posture capability as the brain must adjust and rearrange the inputs sent by other sources of sensory information.\textsuperscript{31} For example, the foam surface disturbs balance/postural control by producing a balance perturbation in multiple directions\textsuperscript{32,33}. When used in a static balance condition, it modifies the biomechanics of the foot, which results in a change in the distribution of the plantar pressure and an augmentation of the ankle muscles’ activation linked to the location of the foot’s center of pressure\textsuperscript{32,34-36}. However, the maturation of the cortical and central processes involved in balance/postural control takes place during childhood. Consequently, the balance/postural control does not reach adult levels until the age of 13-14 years\textsuperscript{37}. Similarly, vision plays a predominant role in adolescents’ control of orientation and body stabilization. Youth use different balance/postural strategies and are not capable of
reaching postural performance levels comparable to those observed in adults. The explanation is that youth are not yet able to use the available plantar cutaneous sensitiveness information to improve their balance/postural control due to a maturation difference compared to adults. This suggests that the mechanisms underlying balance/postural control are still maturing during adolescence, which might constitute a transient period for pondering and adequately using the proprioceptive inputs in sensory integration of balance control. The observed findings suggest that, after exercise interventions, children and adolescents with Down syndrome were better able to compensate for the insufficiency of visual or plantar cutaneous sensitiveness inputs in balance/postural control. This is a key point since it has been proposed that the proprioception of youth with Down syndrome does not adequately compensate for the lack of visual information in static postural control when compared to typically developing youth, suggesting that there is an important sensorial component in maintaining balance/postural stability. Indeed, it is well known that when vision is removed during the maintenance of a normal quiet stance, a sensorial reweighting occurs and somatosensory inputs (proprioception) are tuned up in order to compensate and maintain balance/postural stability. Finally, the results of one study also suggest that both the tactile sensitivity and ability to detect plantar pressure distributions can improve for youth with Down syndrome after exercise interventions. Additionally, even though different types of exercise interventions (i.e., balance, strengthening, vibration platform, or multiple components) and types of balance of measures (clinical test or posturography) were used in these studies, the results appear to hold irrespective of these differences. The findings suggest that, because of the exercise intervention, children and adolescents with Down syndrome experienced an increase in their ability to maintain balance/postural stability under different balance/postural stances challenging their balance/postural control. Interestingly, the results also suggest that a control condition consisting of a conventional physical therapy program also represents an effective means to improve dynamic balance among children with Down syndrome. These results are consistent with the research literature related to the effects of different types of exercise, physical and sport interventions on the balance/postural function. It has been reported that, compared to other types of exercise, specific balance exercise interventions induce balance/postural adaptations because they are directly related to the neurophysiological organization of balance/postural control. Strength exercises and techniques that stimulate the neuromuscular system (whole-body vibration training) also improve balance since lower limbs muscles are involved in balance/postural control, with the ankle level explicitly related to the inverted pendulum regulation. Finally, multicomponent exercises seem to be efficient to improve balance/posture, especially if specific balance exercises are included in the multicomponent training program.

Directions for Future Studies to Inform Exercise Intervention

Although encouraging, the conclusions from this systematic review should be interpreted with caution given the following limitations.

First, the effects of the exercise interventions on the static and static-dynamic balance of children with Down syndrome were examined in a very limited number of studies. Likewise, only a few studies considered the effects of exercise interventions on any form of balance among adolescents with Down syndrome. In addition, most of the studies assessed balance capacities while adopting a double leg stance with opened eyes. Therefore, it is currently unclear whether the exercise interventions are truly effective at improving (a) the static or static-dynamic balance of children with Down syndrome; (b) the balance of adolescents with Down syndrome; and (c) balance while standing on one leg or when visual cues or plantar cutaneous sensitivity are disturbed.

Second, each study included only one type of exercise intervention. Therefore, the type of exercise intervention that is most effective at improving balance among youth with Down syndrome remains unknown. This issue should be examined more thoroughly in future studies aiming to compare distinct intervention programs so that educators can make informed decisions to expend their limited resources on the most effective types of exercise intervention.

Third, the duration of the exercise interventions was generally short (two-thirds of the studies were of 6 or 8 weeks), and may not have been long enough to induce balance changes in youth with Down
syndrome. Therefore, more research is warranted to clarify the required duration. Furthermore, no study has examined the impact of the frequency and duration of the exercise sessions to identify the most effective combination for the improvement of balance among youth with Down syndrome. Evidence regarding the maintenance of the balance training effects also remains unclear and needs to be more thoroughly examined in future studies.

Fourth, most of the reviewed studies did not report sufficient information about the nature of the exercise interventions, such as their settings, the facilitator (i.e., person who delivers the intervention), the adaptation of the intervention during trial, and the strategies used to maintain intervention conformity. Thus, it is presently impossible to conclude which configurations of exercise intervention characteristics and contextual features are fundamental for successful outcomes. Furthermore, without the publication of such information, educators and therapists are unable to implement the evidence-base into best practice.

Fifth, most of the RCTs suffered from major weaknesses in concealed allocation; blinding of participants, investigators, and assessors; and compliance with assigned intervention. Therefore, future studies examining the effects of exercise interventions on the balance of youth with Down syndrome should improve the quality of their methodology and reporting regarding these specific criteria if the research field is to improve practice, and thus outcomes, for this population.

Sixth, despite the fact that most of the reviewed studies relied on RCT, the total number of studies was limited, which diminish the strength of our conclusions. Furthermore, the fact that most of these studies were conducted in the Eastern Mediterranean region limit the generalizability of our findings to other geographic regions.

Finally, further rigorous studies are required to generate a more complete view on the topic. In particular, the present review remains limited by its focus on a small number of studies characterized by a generally high risk of bias, notably the presence of selective reporting bias (for instance, only one study has provided analyses about the pre-post change in balance). As such, the true magnitude and generalizability of the effects of these exercise interventions remain unclear, despite being promising. With additional studies having less risk of bias, and larger samples it will be interesting to update this review and to perform quantitative analyses of effect sizes controlling for risk of biases.

**Conclusion**

In sum, the present results show that the reviewed exercise interventions are more effective than control conditions to improve static and static-dynamic balance of children with Down syndrome. Additionally, findings among adolescents with Down syndrome suggest that exercise interventions are more effective than control conditions to improve static-dynamic balance. Nevertheless, findings on dynamic balance in children and static balance in adolescents are inconclusive. Given the limited number of studies, and their high risk of bias, the present findings need to be interpreted with caution. Therefore, the effect of exercise interventions on balance outcomes needs to be more rigorously and systematically examined in the future. Finally, our review highlights that more detailed exercise interventions and reporting practices are needed to support professionals in the selection, development, and implementation of interventions to enhance the physical health of youth with Down syndrome.

**References**


Figure 1. Results of Search Based on the PRISMA Statement.14
<table>
<thead>
<tr>
<th>Studies</th>
<th>Samples</th>
<th>Random sequence generation (selection bias)</th>
<th>Allocation concealment (selection bias)</th>
<th>Masking of participants and personnel (performance bias)</th>
<th>Masking of outcome assessment (detection bias)</th>
<th>Incomplete outcome data (attrition bias)</th>
<th>Selective reporting (reporting bias)</th>
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<td>+</td>
<td>+</td>
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<td>-</td>
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Note. CHILD = children; ADOS = adolescents  
- Low risk of bias  
- High risk of bias  
? Unclear risk of bias

Figure 2. Quality Assessment of the Reviewed Studies
## Table 1

*Characteristics of Children’s and Adolescents’ Studies Included in the Systematic Review*

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Design</th>
<th>Recruitment setting</th>
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<th>Control group</th>
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<th>Age range</th>
<th>Mean age</th>
<th>Sample size (N)</th>
<th>% of boys</th>
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<td>15 53 8-10 8.9</td>
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<td>Eid et al.</td>
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<td>16 56 9-12 10.1</td>
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<td>Fard et al.</td>
<td>Iran</td>
<td>CT</td>
<td>Special school</td>
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<td>Ghaeemi et al.</td>
<td>Iran</td>
<td>RCT</td>
<td>Rehabilitation center</td>
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<td>Mehralitabar et al.</td>
<td>Iran</td>
<td>CT</td>
<td>Exceptional child care center</td>
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<td>Mild-Sev</td>
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<td>Schools</td>
<td>ADOS</td>
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<td>12 67 11-14 13.5</td>
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<td>Jankowicz-Szymanska et al.</td>
<td>Poland</td>
<td>RCT</td>
<td>Special education and care center</td>
<td>ADOS</td>
<td>Mild</td>
<td>20 NM 16-18 NM</td>
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<td>Villaroya et al.</td>
<td>Spain</td>
<td>RCT</td>
<td>Schools and institutions</td>
<td>ADOS</td>
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<td>16 NM 11-20 15.9</td>
<td>13 NM 11-20 15.6</td>
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</table>

*Note. ADOS = adolescents; CT = controlled trial; CHILD = children; DS = Down syndrome; ID = intellectual disability; Mod = moderate; NM = not mentioned; RCT = randomized control trial; Sev = severe.*
### Table 2
Description of Intervention Program, Control Condition, and Balance Measures in Children’s Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention program</th>
<th>Setting (delivery)</th>
<th>Adaptation (fidelity)</th>
<th>Total duration</th>
<th>Follow-up</th>
<th>Session duration in minutes (frequency per weeks)</th>
<th>Types of control condition</th>
<th>Balance measures</th>
<th>Types</th>
<th>Assessment method</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdel Rahman</td>
<td>Wii Fit balance game training</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>6 weeks</td>
<td>-</td>
<td>60(2)</td>
<td>Conventional physical therapy program</td>
<td>Static balance (OLS: EC-EO), dynamic balance</td>
<td>BOTMP (balance subtest)</td>
<td>Static-dynamic balance score</td>
<td></td>
</tr>
<tr>
<td>Aly &amp; Abonour</td>
<td>Core stability exercises</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>8 weeks</td>
<td>-</td>
<td>45-60(3)</td>
<td>Conventional physical therapy program</td>
<td>Dynamic balance (DLS: EO)</td>
<td>Biodex Balance System</td>
<td>Overall, A-P, and M-L stability index scores</td>
<td></td>
</tr>
<tr>
<td>Amini et al.</td>
<td>Backward walking training</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>8 weeks</td>
<td>10 weeks</td>
<td>35(2)</td>
<td>No participation in regular physical activities</td>
<td>Dynamic balance (DLS: EO)</td>
<td>Biodex Balance System</td>
<td>Overall, A-P, and M-L stability index scores</td>
<td></td>
</tr>
<tr>
<td>Eid</td>
<td>Physical therapy + whole-body vibration</td>
<td>NM(PHT)</td>
<td>NM(NM)</td>
<td>24 weeks</td>
<td>-</td>
<td>80-90(3)</td>
<td>Designed physical therapy program</td>
<td>Dynamic balance (DLS: EO)</td>
<td>Biodex Balance System</td>
<td>Overall, A-P, and M-L stability index scores</td>
<td></td>
</tr>
<tr>
<td>Eid et al.</td>
<td>Physical therapy + isokinetic training</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>12 weeks</td>
<td>-</td>
<td>60(3)</td>
<td>Conventional physical therapy program</td>
<td>Dynamic balance (DLS: EO)</td>
<td>Biodex Balance System</td>
<td>Overall, A-P, and M-L stability index scores</td>
<td></td>
</tr>
<tr>
<td>Fard et al.</td>
<td>Hopscotch local game</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>8 weeks</td>
<td>-</td>
<td>50(3)</td>
<td>Engaged in normal activities</td>
<td>Dynamic balance</td>
<td>Heel-to-Toe Dynamic Balance Test</td>
<td>Number of steps</td>
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<tr>
<td>Ghaeeni et al.</td>
<td>Core stability exercises</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>8 weeks</td>
<td>-</td>
<td>45-60(3)</td>
<td>NM</td>
<td>Static balance (OLS: EO)</td>
<td>Modified Stork Test</td>
<td>STAND-T (in sec)</td>
<td></td>
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<tr>
<td>Mehralitabar et al.</td>
<td>Stretching, strength, and balance exercises</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
<td>6 weeks</td>
<td>-</td>
<td>45(3)</td>
<td>Usual daily activities</td>
<td>Static balance (OLS: EO), dynamic balance</td>
<td>Stork Test, Timed Get Up and Go Test</td>
<td>STAND-T (in sec), time taken to perform the test (in sec)</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** A-P = anterior-posterior; BOTMP = Bruininks-Oseretsky Test of Motor Proficiency; DLS = double leg stance; EC = eyes closed; EO = eyes open; M-L = medio-lateral; NM = not mentioned; OLS = one leg stance; PHT = physical therapist; STAND-T = stand time.
### Table 3
Description of Intervention Program, Control Condition, and Balance Measures in Adolescents’ Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention program</th>
<th>Types of control condition</th>
<th>Balance measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Types</td>
<td>Setting (delivery)</td>
<td>Adaptation (fidelity)</td>
</tr>
<tr>
<td>Gupta et al.²⁴</td>
<td>Strength and balance exercises</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
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<tr>
<td>Jankowicz-Szymanska et al.²⁵</td>
<td>Training program targeting balance capacities</td>
<td>NM(NM)</td>
<td>NM(NM)</td>
</tr>
<tr>
<td>Villaroya et al.²⁶</td>
<td>Whole-body vibration</td>
<td>NM(RES)</td>
<td>NM(NM)</td>
</tr>
</tbody>
</table>

**Note.** A-P = anterior-posterior; BOTMP = Bruininks-Oseretsky Test of Motor Proficiency; CFS = compliant-foot-support; COG = general center of gravity; COG-radius circle = time spent by the vertical projection of the general center of gravity within a 13-mm radius circle; COP = center of pressure; COP-RMS = root mean square error of the center of pressure excursion; COP-velocity = mean velocity of the center of pressure; DLS = double leg stance; EC = eyes closed; EO = eyes open; FFS = fixed-foot-support; M-L = medio-lateral; NM = not mentioned; OLS = one leg stance; PATH-L = path length covered by the vertical projection of the COG; RES = researcher; *Only the total was considered for the present review.*
### Table 4
Results from the Children’s and Adolescents’ Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample age category</th>
<th>IG (pre- vs. post-test)</th>
<th>CG (pre- vs. post-test)</th>
<th>IG vs. CG (post-test)</th>
<th>IG vs. CG (pre-post change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdel Rahman(^\text{16})</td>
<td>CHILD</td>
<td>(\uparrow)</td>
<td>NS</td>
<td>IG &gt; CG</td>
<td>NM</td>
</tr>
<tr>
<td>Aly &amp; Abonour(^\text{17})</td>
<td>CHILD</td>
<td>(\uparrow) (all)</td>
<td>(\uparrow) (all)</td>
<td>IG &gt; CG (all)</td>
<td>NM</td>
</tr>
<tr>
<td>Amini et al.(^\text{18})</td>
<td>CHILD</td>
<td>NM</td>
<td>NM</td>
<td>IG &gt; CG (all)</td>
<td>NM</td>
</tr>
<tr>
<td>Eid(^\text{19})</td>
<td>CHILD</td>
<td>(\uparrow) (all)</td>
<td>(\uparrow) only for A-P and M-L stability index scores</td>
<td>IG &gt; CG (all)</td>
<td>NM</td>
</tr>
<tr>
<td>Eid et al.(^\text{20})</td>
<td>CHILD</td>
<td>(\uparrow) (all)</td>
<td>(\uparrow) (all)</td>
<td>IG &gt; CG (all)</td>
<td>NM</td>
</tr>
<tr>
<td>Fard et al.(^\text{21})</td>
<td>CHILD</td>
<td>(\uparrow)</td>
<td>NM</td>
<td>IG &gt; CG</td>
<td>NM</td>
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<tr>
<td>Ghaeeni et al.(^\text{22})</td>
<td>CHILD</td>
<td>(\uparrow)</td>
<td>NS</td>
<td>IG &gt; CG</td>
<td>NM</td>
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<tr>
<td>Mehralitabar et al.(^\text{23})</td>
<td>CHILD</td>
<td>(\uparrow) (all)</td>
<td>NS (all)</td>
<td>IG &gt; CG (all)</td>
<td>NM</td>
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<tr>
<td>Gupta et al.(^\text{24})</td>
<td>ADOS</td>
<td>NM</td>
<td>NM</td>
<td>NM</td>
<td>IG &gt; CG</td>
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<tr>
<td>Jankowicz-Szymanska et al.(^\text{25})</td>
<td>ADOS</td>
<td>(\uparrow) only for COG-radius circle in EC</td>
<td>NS (all)</td>
<td>NS (all)</td>
<td>NM</td>
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<tr>
<td>Villaroya et al.(^\text{26})</td>
<td>ADOS</td>
<td>(\uparrow) only for COP-RMS (M-L, EC, CFS) and COP-velocity (EC, CFS; ratio EC-CFS/EO-FFS)</td>
<td>NS (all)</td>
<td>NM</td>
<td>NM</td>
</tr>
</tbody>
</table>

**Note.** ADOS = adolescents; A-P = anterior-posterior; CFS = compliant-foot-support; CG = control group; CHILD = children; COG-radius circle = time spent by the vertical projection of the general center of gravity within a 13-mm radius circle; COP-RMS = root mean square error of the center of pressure excursion; COP-velocity = mean velocity of the center of pressure; EC = eyes closed; EO = eyes open; FFS = fixed-foot-support; IG = intervention group; M-L = medio-lateral; NM = not mentioned; NS = non-significant; \(\uparrow\) improvement.
Online Supplemental Materials for:
Effects of Exercise Interventions Designed to Improve Balance for Children and Adolescents with Down Syndrome: A Systematic Review

References of Full-Text Articles Assessed for Eligibility but Excluded from the Systematic Review


