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The impact of exercise interventions on postural control in individuals with Down syndrome: a systematic review and meta-analysis

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Abstract

Background Individuals with Down syndrome have severe difficulties maintaining proper postural control when standing upright. Therefore, the goal of the present review and meta-analysis was to examine the effects of exercise interventions on improving postural control in individuals with Down syndrome.

Methods This systematic review was reported following the PRISMA guidelines; while Cochrane guidelines were adopted for methodological guidance. Reports were searched in PubMed, Science Direct, Physiotherapy Evidence Database scale (PEDro), EMBASE, Web of Science (WOS), Scopus and Google Scholar from 2000 to January 2025. Randomized clinical trials and quasi-experimental studies were assessed in English. Review, meta-analysis, and descriptive studies were excluded from the study. Two researchers screened and evaluated data based on PEO criteria and the quality of studies was assessed using the PEDro scale.

Results Among between 374 studies, Six articles were included in the present review and meta-analysis. Four studies showed that exercise interventions improve postural control in individuals with Down syndrome. However, the results of 2 studies indicated that exercise interventions do not improve postural control in these individuals. Ultimately, after analyzing the studies, the statistical results showed a significant difference between the intervention group and the control group ($p=0.001$), indicating the effectiveness of exercise interventions and subsequent improvement in postural control in individuals with Down syndrome. According to PEDro scale, four studies were low quality, and two were high quality. Also, applying GRADE criteria, there is a "Low" certainty of evidence observed. The mean effect size of the exercises in the 6 included studies in the present review was 0.67, indicating a small effect size.

Conclusions The exercise interventions improve postural control in individuals with Down syndrome. In addition, Due to the small sample size and the small number of studies included, to deal with the risk of bias in the studies, a new randomized controlled trial with a stronger methodology and large sample size comparing exercises and other strategies or different types of exercises is recommended.

Keywords Exercise interventions, Postural control, Down syndrome, Postural sway

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Background

Down syndrome is a congenital disorder that occurs as a result of a chromosomal abnormality and manifests with specific clinical features [1]. Down syndrome is common in all populations, races, and ethnicities. The Centers for Disease Control reports that Down syndrome is the most common chromosomal disorder, with an incidence of 1 in 700 births [2, 3]. A study in Europe showed that the prevalence of Down syndrome in Europe has been increasing from 1990 to 2019, and advanced maternal age during pregnancy has been one of the determining factors for the occurrence of this syndrome [4]. Children and young people with Down syndrome experience lower levels of cardiovascular and respiratory fitness compared to their peers without Down syndrome, which can have a negative impact on their health and quality of life [5]. Research shows that children with intellectual disabilities do not participate in movements, games, and sports on their own and do not achieve proportional growth. Motor dysfunction in individuals with Down syndrome includes slower reaction and movement, balance disorders, posture, and simultaneous contraction of agonist and antagonist muscles [6]. Delay in motor development in individuals with Down syndrome is associated with general muscle hypotonia and ligament laxity, which are characteristics of this condition [7]. Balance is an important factor that affects the safety skills and independence of children with Down syndrome, and the most challenging task for these individuals is to achieve it. Gross motor skills in these individuals are consistently lower compared to normal children, and they show the most difference in the balance variable compared to normal individuals [8].

Postural control involves actively orienting the body and its parts in space and in relation to each other [9]. Healthy individuals control their vertical posture through small oscillatory movements, known as postural sway, created in different parts of the body. Maintaining controlled posture in a stable position requires the body's center of mass to be balanced within the supportive framework of the feet. Compared to typical individuals, individuals with Down syndrome exhibit greater oscillations in static posture, indicating instability in postural control [9]. The instability in individuals with Down syndrome is attributed to inherent skeletal and muscular characteristics, lax ligaments, and reduced passive stiffness around the joints [10]. Children with Down syndrome have severe difficulties in maintaining proper posture and balance when standing upright [11]. Postural control and balance are considered essential for carrying out daily activities such as getting up from a chair, walking, boarding a bus, and performing tasks, and activities. On the other hand, the ability to maintain body balance plays a significant and determining role in engaging in sports activities and effectively executing complex skills [12].

The World Health Organization (2020) recommends that children should engage in at least 60 min of moderate to vigorous physical activity per day [13]. Unfortunately, meeting the recommended level of physical activity can be challenging for children with disabilities. Additionally, adhering to the recommended daily moderate to vigorous physical activity can be even more challenging for children with Down syndrome, as they are at a higher risk of physical inactivity and obesity, so strategies are needed to improve both the quantity and quality of their physical activity [14]. A recent study has shown that increasing levels of physical activity leads to significant improvements in musculoskeletal and cardiovascular health, as well as mental and brain health among children, adolescents, and adults with disabilities. Similar results have been found for individuals with Down syndrome as well [15]. These findings strongly suggest that individuals with Down syndrome should start or continue regular exercise and sports programs in order to benefit from the potential impacts of exercise and physical activity on their health and maintaining proper body posture.

Therefore, improving postural control in individuals with Down syndrome and encouraging them to physical activity and exercise programs has always been an important issue for trainers and physiotherapists. As the positive effects of exercise and physical activity on the lives of individuals with disabilities, especially those with intellectual disabilities and Down syndrome, have been extensively studied. Additionally, postural control in these individuals has been positively affected by exercise interventions. Most studies on individuals with Down syndrome have investigated the effect of exercise interventions on the balance variable, and few studies have directly evaluated the impact of exercise interventions on the postural control variable. Therefore, identifying the best type of intervention to improve the postural control of these individuals can be very important in preventing falls and improving postural independence. According to the searches, no systematic review and meta-analysis studies investigated the effect of exercise interventions specifically and separately on the postural control variable alone in individuals with Down syndrome. in research conducted in these areas, the need for a study concurrently examining the impact of exercise on the postural control variable was felt. The researchers in this study aim to investigate all interventions and exercise programs that have had an impact on the postural control variable in individuals with Down syndrome, in order to guide individuals and sports trainers in recognizing and designing the best exercise programs for improving the health and lifestyle of individuals with Down syndrome.

Methods

Search strategy

This review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses(PRISMA) [16]. Cochrane guideline for systematic reviews and meta-analysis [17] was followed as methodological guidance. The present study was prospectively registered in thein the PROSPERO database of prospectively registered systematic reviews (CRD42024550515). In this study, a comprehensive review was conducted on the effects of exercise interventions on postural control in individuals with Down syndrome through searching PubMed, Science Direct, PEDro, EMBASE, Web of Science, Scopus and Google Scholar using the following keywords:

Group 1: "sport interventions" OR "exercise" OR "sport program" OR "motor interventions" OR "sport training" OR "physical education program" OR "exercise protocol" OR "training protocol" OR "exercise intervention" OR "intervention program" AND Group 2: "control posture" OR "postural control" OR "postural stability" OR "posturography" OR "body sway" OR "control stance of body" OR "postural adaptation" OR "postural performance" OR "postural sway" OR "postural strategy" OR "postural perturbation" AND Group 3: "down syndrome" OR "down's syndrome" OR "trisomy 21" OR "mongolism" OR "trisomy 18" OR "chromosomal disorder" OR "xyy trisomy" OR "trisomy 13". The search was conducted from the year 2000 to January 2025.

All terms were searched without any research limitations, and in some cases were combined with each other. In addition, a manual search and a full review of article sources were conducted to find articles that were not found through systematic search. The English language was used in this search. After collecting search results, the titles and abstracts of articles were first reviewed. If the articles met the inclusion and exclusion criteria, their results were used in the present review, otherwise, they were excluded. The structure and framework of the review and meta-analysis study were based on PEO strategy (Table 1).

Table 1 PEO design

Components	Description
(P)	Individuals with Down Syndrome ranging from age 2 to 65 years.
(E)	Sports (exercise) interventions such as balance exercises, core stability, virtual reality, suspension training, dancing, Swiss ball, etc.,
(O)	Laboratory tests (Biodex and force plate, etc.) and field tests (BESS and CTSIB, etc.)

P: Population. E: Exposure. O: Outcomes

Inclusion and exclusion criteria

In the first stage, screening of titles and abstracts of studies focusing on the effect of exercise interventions on postural control in individuals with Down syndrome was conducted in English. The second stage involved screening the full text based on Inclusion criteria and the specific target population. Screening of all texts was done by two researchers. Another senior researcher checked the final list of selected articles to ensure that all articles aligned with the study objectives. The inclusion criteria included individuals with Down syndrome without other disabilities, postural control variable, implementation of exercise interventions, original research articles, experimental, quasi-experimental, and randomized clinical trials, articles in English, and studies that were published in full text. The exclusion criteria included articles that were only published as summaries in congresses and seminars, as well as case reports, pilot studies, and reviews. Following the search process, the studies were exported to the EndNote Reference Library (Version 20; Clarivate Analytics, Thomson Reuters Corporation, Philadelphia, Pennsylvania) software, and any duplicate entries were eliminated. Subsequently, two authors (H.Z. and M.Y.) independently reviewed all titles and abstracts resulting from the search process. Any discrepancies were resolved through consensus.

Quality assessment

The quality of the methods in the relevant studies was assessed using the Physiotherapy Evidence Database scale (PEDro scale) [18], which consists of 11 items measuring various criteria including (1) specification of the eligibility criteria for participation; (2) random allocation of participants; (3) concealed allocation; (4) similarity between groups in relevant variables at pre-test; (5) blinding of participants; (6) blinding of the investigators administering the program; (7) blinding of the assessors measuring the dependent variables; (8) proportion of participants having at least one dependent variable measured; (9) compliance of participants with the intervention; (10) statistical comparisons between groups; and (11) point measures and measures of variability provided for at least one dependent variable. Each criterion that was satisfied received a score of 1, and the total score was calculated by summing up the results from items 2 to 11 [18, 19]. Studies with a total score of 5 or less were considered to have 'low' quality, while those with a score of 6 or more were considered to have 'high' quality [19].

Risk of bias

We used Cochrane risk of bias (RoB 2) to assess the risk of bias in randomized trials [20]. To assess the risk of bias, two authors independently evaluated all the included studies and recorded supporting data to judge the chance of bias in each domain (low, Some concerns, or high). They talked about any disagreements and archived final choices. We reported the risk of bias judgments for each domain in each included study in risk of bias summary figures. Judgments for each domain overall included studies were detailed in risk of bias graphs. Risk of bias will be categorized as 'low risk,' 'high risk,' or 'Some concerns,' which is described in the Cochrane Handbook for Systematic Reviews of Interventions [20].

Certainty of evidence

Two authors evaluated the certainty of the evidence for each meta-analysis utilizing the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system [21]. We reduced the confidence in the evidence when the subsequent concerns were identified: (1) Risk of bias (over 75% of studies were not classified as low risk of bias); (2) Inconsistency (I2 statistic exceeding 50%); (3) Imprecision (if the upper or lower limit of the confidence interval crosses 0.5 of the effect size in either direction, the confidence interval is broad and the effect estimate is imprecise); (4) Indirectness (studies involving indirect comparisons); and (5) Publication bias (asymmetry observed in the funnel plot) [21, 22].

Statistical analyses

The study utilized the Comprehensive Meta-analysis (CMA) software Version 3 to pool quantitative data using random effects models with 95% confidence intervals (CIs) for statistical meta-analysis. Heterogeneity was assessed using the I^2 index, with thresholds of 25%, 50%, and 75% indicating low, moderate, and high levels of heterogeneity, respectively. Hedges' g effect size was calculated to measure the effects of training (effect size [ESs]) [23]. Threshold values for assessing magnitudes of ES were <0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2-2.0, large; 2.0–4.0, very large; and >4.0, nearly perfect [24]. An alpha level of 0.05 was defined for the statistical significance of all the tests. Publication bias was assessed using a symmetrical inverted funnel plot and the Begg rank correlation test [25].

Results

Study selection

Figure 1 illustrates the process of study selection. A total of 374 articles were initially identified, with 221 abstracts selected for review after removing duplicate titles. Following abstract review, 142 articles were excluded, leaving 79 articles for full-text review. Following full-text review, 73 articles were excluded, resulting in 6 articles being included in the study. Table 2 presents a summary of the findings from these articles.

Quality assessment

Quality assessment of the included studies revealed that four were rated as low quality (score less than five on the PEDro scale) and two were rated as high quality (score of six on the PEDro scale) [19]. This information is detailed in Table 3.

Exercise intervention (type and duration)

The duration of the exercise interventions varied between 5 and 12 weeks. Only two studies implemented exercise interventions for 12 weeks [26, 27]. The remaining four studies used a duration of 5 to 8 weeks for conducting exercise interventions [28–30]. Additionally, there were 144 participants (25 females and 53 males) [26, 28, 30]. Three studies did not specify the gender of the participants [27, 29, 31]. These studies included 73 participants in the experimental and 71 participants in the control group. The exercise interventions used in the studies included core stability exercises, Thai Elephant-Assisted Therapy, isokinetic strength exercises, virtual reality games, trampoline exercises, and combined balance and resistance exercises.

The control group did not receive any intervention in four studies [28–31]. However, the control group received standard physical therapy exercises in two studies [26, 27].

Postural control evaluation

In the assessment of postural control in these 6 studies, all laboratory tests were used (Biodex and force plate) while Clinical tests such as CTSIB and BESS were not used.

Risk of bias

Two researchers checked the details of each study's risk of bias. Risk of bias: each study was reported by reaching a consensus between two authors. Figures 2 and 3, presents the outcomes of the Evidence Project risk of bias tool. Three studies had a high [29–31], Two had a Some concerns [27, 28], and one had a low [26] risk of bias.

Certainty of evidence

Applying GRADE criteria, Table 4 shows "Low" certainty of evidence.

Data synthesis

Six studies were conducted to assess the impact of exercise intervention on postural control in 144 individuals with Down syndrome. With an I^2 index of 28.36%, indicating low heterogeneity, a random effect model was utilized. The findings revealed a positive effect of exercise intervention on postural control in individuals with Down syndrome, with a Hedges' g effect size [ES] of -0.65 and a 95% confidence interval [CI] of -0.89 to -0.41 (Z =

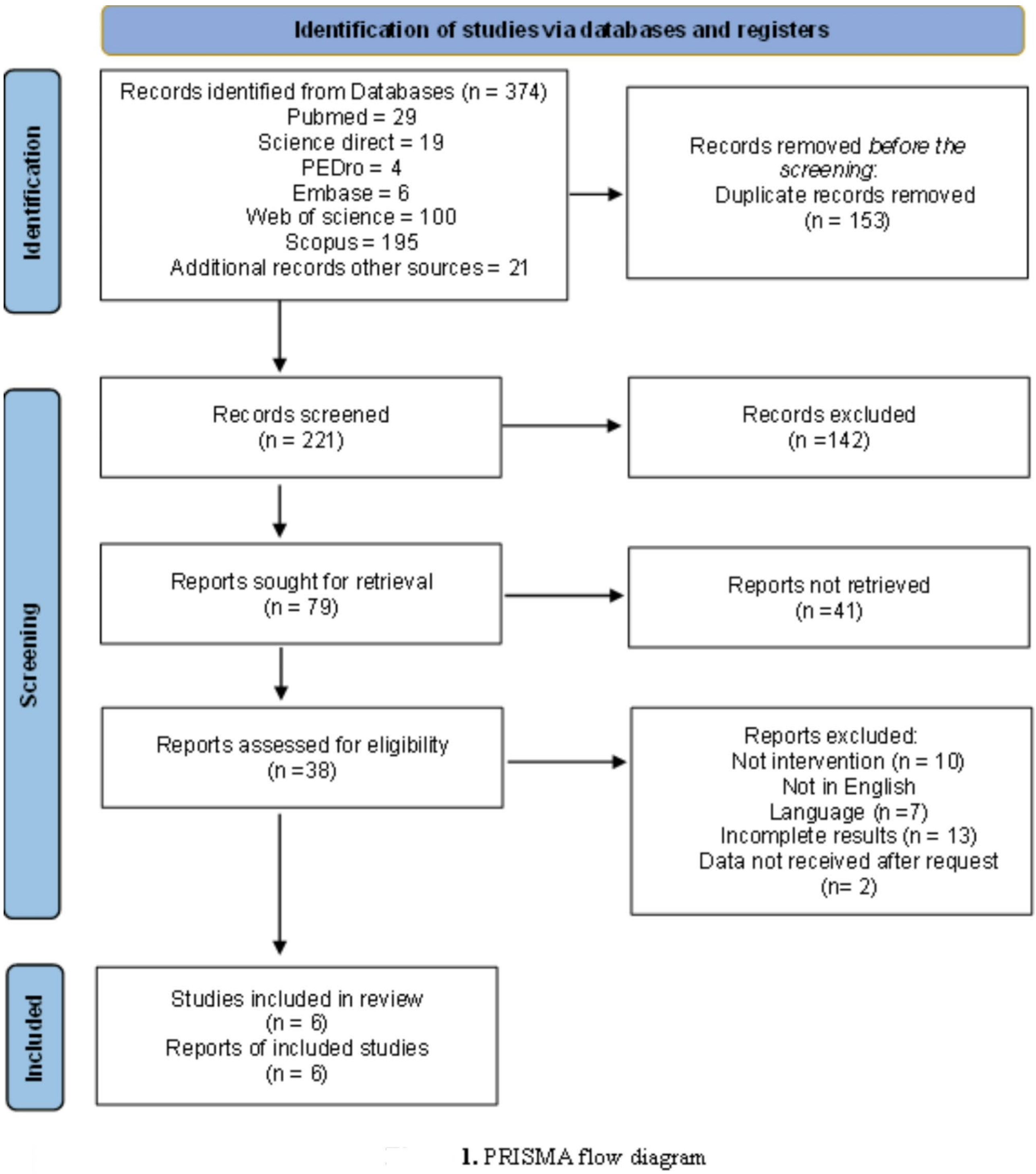

Fig. 1 PRISMA flow diagram

-5.36; $P = 0.001$) (Fig. 4). Therefore, according to the effect size observed, core stability and Isokinetic training, compared to other exercise interventions, can have a more positive effect on postural control in individuals with Down syndrome.

In the funnel plot, the similarity of the studies on each side of the Hedge's g average index does not indicate the presence of publication bias. Additionally, the Begg rank correlation test yielded a p-value of 0.42, suggesting that there is no significant publication bias in the six studies analyzed and no publication bias overall (Fig. 5).

Table 2 Summary of studies conducted on the effect of exercise interventions on postural control in participants with down syndrome

Researcher	Intervention	Sample size	Age range (year)	Study variable	Assessment tool	Result
Aly SM and Abonour (2016) [28]	Core stability exercise (Eight Ws/ three ss/w)	30 Ss (21 Bs, 9 Gs) EX = 15 (11 Bs, 4 Gs) CO = 15(10 Bs, 5 Gs)	EX (8.11 ± 1.26) CO (8.34 ± 1.07)	postural stability	Biodex Balance System	A significant effect with Eight Ws of central stability exercises on improving the stability of children with DS
Satiansuk-pong et al. (2016) [29]	Thai Elephant-Assisted Therapy (Eight Ws/ two ss/w)	16 Ss EX = 8 CO = 8	EX = 11.18 ± 2.13 and CO = 9.59 ± 2.74 years	postural control	the postural control record form	No improvement in the postural control. participants with DS have a wide range of performance in postural control, causes difficulty in obtaining statistically different results between groups, especially when the sample size is small.
Eid et al. (2017) [26]	Isokinetic training (12 Ws/two ss/w)	31 Ss (17 Ms, 14 Fs) CO = 16 (9 Ms, 7 Fs) EX = 15 (8 Ms, 7 Fs)	EX (10.26 ± 0.79) CO (10.05 ± 0.68)	postural balance	Biodex Stability System	The positive effect of the 12-week isokinetic exercise with physiotherapy on the postural control of the people with DS.
Álvareza et al. (2018) [31]	Virtual reality (Five Ws/two ss/w)	16 Ss (EX = 9) (CO = 7)	CO (8.43 ± 1.62) EX (8.30 ± 2.06)	postural control	Postural control was evaluated by the center of pressure displacement	No significant difference between the control and experimental groups in the variable postural control.
Shin YA et al. (2021) [30]	Resistance Training and Balance Training (Eight Ws/ three ss/w)	20 Ss (Fs = 5; Ms = 15) EX = 10 CO = 10	(mean age: 44.55 ± 7.25 years).	Postural Control	balance force platform	A significant improvement in the postural control variable in the experimental group, so resistance and balance training can be considered as a positive strategy for individuals with DS.
Azab et al. (2022) [27]	Trampoline-based stretch-shortening cycle exercises (12 Ws/two ss/w)	31 Ss (both sexes) EX = 16 CO = 15	CO (8.60 ± 0.98) EX (9.19 ± 0.75)	postural control	(Biodex Medical Systems, Shirley, NY, USA)	Trampoline is likely to be effective for improvement postural control in children with DS.

Ws: Weeks., ss/w: Sessions per week, Ss: Subjects., EX = experimental group., CO = control group., Bs: Boys., Gs: Girls., Ms: Males., Fs: Females., DS: Down syndrome

Discussion

This review and meta-analysis aimed to investigate the effect of exercise interventions on improving postural control in individuals with Down syndrome. The meta-analysis results showed that exercise programs and interventions significantly improved postural control in the experimental group (with intervention) compared to the control group in individuals with Down syndrome ($p = 0.001$). In Aly SM and Abonour (2016) study, core stability exercises were used to improve postural control in individuals with Down syndrome, which had the largest effect size among all included studies (ES=-1.29) [28]. While in the study by Álvareza et al. (2018) [31], virtual reality exercises (ES=-0.09), and Satiansukpong et al. (2016) [29] which used Thai elephant therapy exercises (ES = 0.06) to improve postural control in individuals with Down syndrome, the effect sizes were the smallest among the included studies. The average effect size of exercises in the 6 included studies in this review was ES= -0.65, indicating a small effect size. With all these interpretations, due to the high risk of bias and low quality in most of the reported studies, it seems better to be cautious in generalizing the results to the Down syndrome population.

A total of 5 studies were conducted in the age range of children to adolescents. The exercise interventions used in this group included core stability exercises, Thai Elephant-Assisted Therapy, isokinetic strength exercises, virtual reality games, and trampoline exercises. After analyzing the results, it was found that all exercise interventions significantly improved postural control in individuals with Down syndrome. Only the study by Álvarez, et al. [31] and Satiansukpong, et al. [29], who used a program of virtual reality exercises and Thai Elephant-Assisted Therapy, did not have a significant effect on postural control in individuals with Down syndrome, so the effect size of these studies had the smallest effect size among studies. According to the studies reviewed, one of the possible reasons for the lack of effectiveness of these exercise interventions on the postural control variable is the duration and number of exercise sessions. The duration of the virtual reality exercise program was five weeks, twice a week, and the Thai Elephant-Assisted Therapy was eight weeks, twice a week. Other reasons include the small number of participants and the selection of the type of game in the exercise program. In the adult age group, one study was also conducted. The exercise intervention used in the study by Shin, et al. [30] was

Table 3 The results of the quality assessment of the reviewed studies

Studies	PEDro scale criteria* 1	2	3	4	5	6	7	8	9	10	11	Total score	Quality
1. Aly SM and Abonour. [28]	■	■	□	■	□	□	□	■	■	■	■	6	High
2. Satiansukpong, et al. [29]	■	□	□	■	□	□	■	■	■	■	■	6	High
3. Eid, et al. [26]	■	■	□	□	□	□	□	■	■	■	■	5	Low
4. Álvareza, et al. [31]	■	□	□	■	□	□	□	■	■	■	■	5	Low
5. Shin YA, et al. [30]	■	□	□	□	□	□	□	■	■	■	■	4	Low
6. Azab, et al. [27]	■	■	□	□	□	□	□	■	■	■	■	5	Low

*PEDro scale for measuring the quality of studies: Items 1 to 11 are mentioned in the research methodology section. The sum of items 2–11. ■ 1 point and □ 0 point

a combination of balance and resistance exercises. After Mata analyzed the results, it was found that the balance-resistance exercise program had a significant effect on postural control in adults with Down syndrome.

The formation of cortical and subcortical processes involved in postural control occurs during childhood. As a result, postural control does not reach adult levels until the age of 13–14 [32]. Similarly, vision plays a major role in stabilizing and controlling the body orientation in adolescents. Younger adults use different balance/postural strategies and are not able to reach postural performance levels comparable to adults [33]. This is because adolescents compared to adults are still unable to use sensory information from the plantar skin of their feet to improve their balance/postural control due to developmental differences. This suggests that the responsible mechanisms of postural control are still developing during adolescence, which may be a transitional period for deeper integration and use of sensory inputs in postural control [34]. Observed findings indicate that after engaging in exercise interventions, children and adolescents with Down syndrome can compensate for insufficient sensory inputs from the plantar skin in postural control. This is a key point because it has been reported that the proprioceptive senses of adolescents with Down syndrome compared to typically developing youth do not compensate enough for the lack of visual information in static postural control, indicating an important sensory component in maintaining postural control [35, 36]. In fact, it is well known that when vision is eliminated during maintaining a natural standing position, sensory reweighting occurs, and somatosensory inputs (proprioceptive) are adjusted to compensate and maintain postural control [37, 38]. The findings suggest that due to the exercise interventions, children and adolescents with Down syndrome have experienced an increased ability to maintain postural control in different situations that challenge their postural control.

Compared to the existing literature, our findings provide several new and unique insights: (1) Comprehensive analysis: Using meta-analysis, we analyzed multiple data from different studies, which allowed us to more precisely assess the overall impact of exercise interventions on postural control. This approach is different from the previous articles that examined each study separately. (2) Identifying the type of interventions: We specifically examined the type of exercise interventions (such as balance, strength and, etc.) and their effects on postural control. This distinction allows us to understand which type of intervention works best to improve postural control, and this information is valuable for practitioners and researchers in this field. (3) Meta-Analytic Evidence: Our meta-analysis statistically evaluates the effectiveness of this exercise, providing statistical insights that were

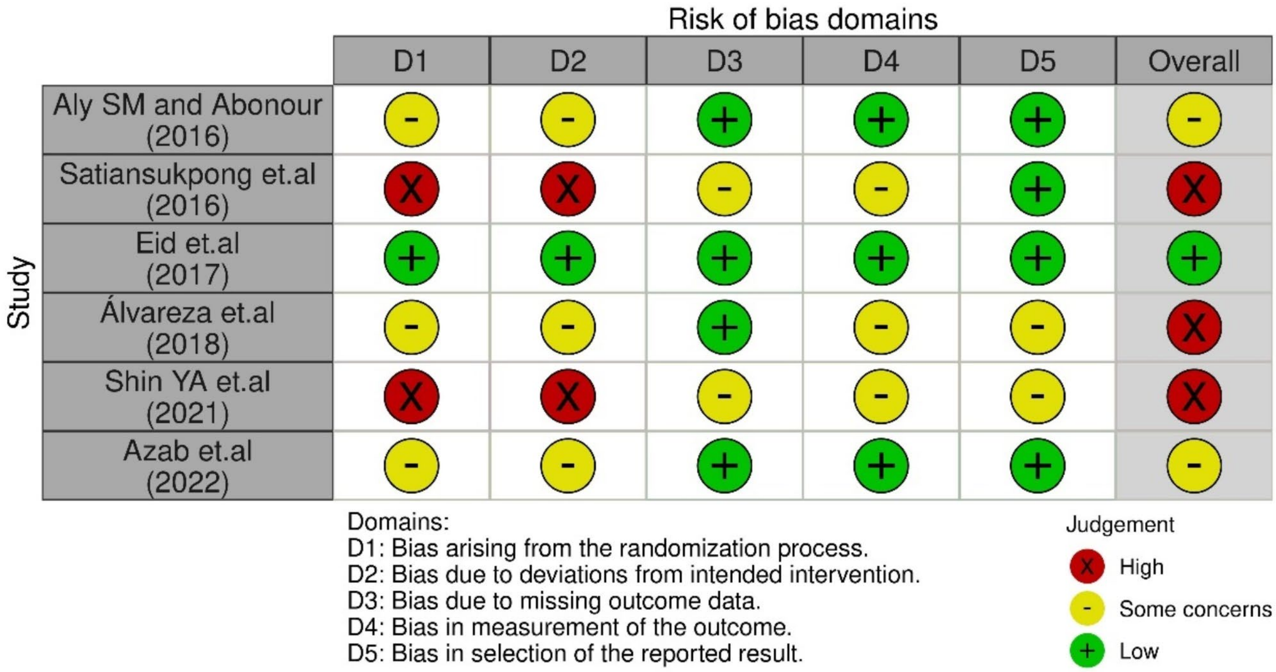

Fig. 2 Risk of bias of the studies included in the systematic review

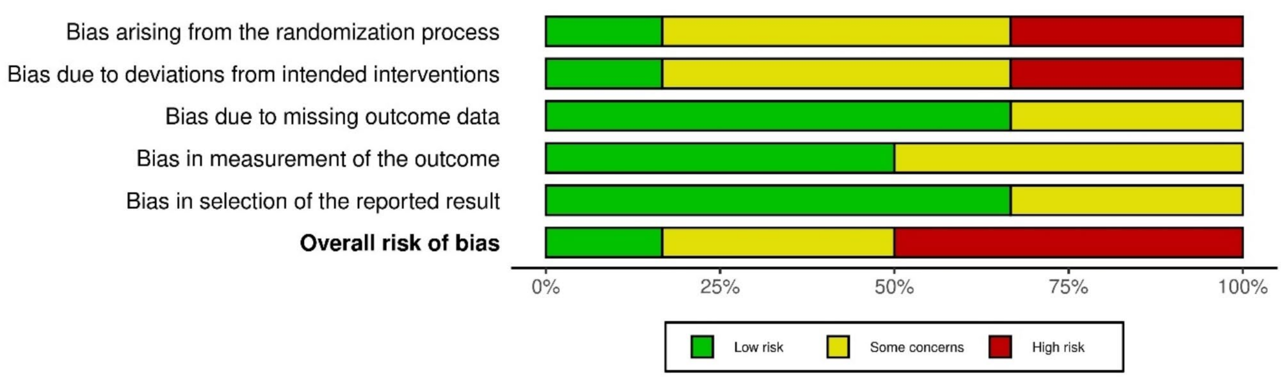

Fig. 3 Overall risk of bias. Each category is presented by percentages

Table 4 Quality of evidence using the grading of recommendations assessment, development and evaluation (GRADE)

Outcome	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication	Certainty of evidence
Postural Control	Serious [a]	Not serious	Not serious	Serious [b]	Not serious	Low ⊕⊕◯◯

GRADE Working Group grades of evidence
High certainty (⊕⊕⊕⊕): We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty (⊕⊕⊕◯): We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty (⊕⊕◯◯): Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
Very low certainty (⊕◯◯◯): We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.a. Downgraded by one level because > 25% of the studies were at high risk of bias (i.e., scored < 6 on the PEDro scale and had a high risk of bias in the RoB tool)

a. Downgraded by one level because >25% of the studies were at high risk of bias (i.e., scored <6 on the PEDro scale and had a high risk of bias in the RoB tool)

b. Downgraded to imprecision (because there is total sample size is less than 400)

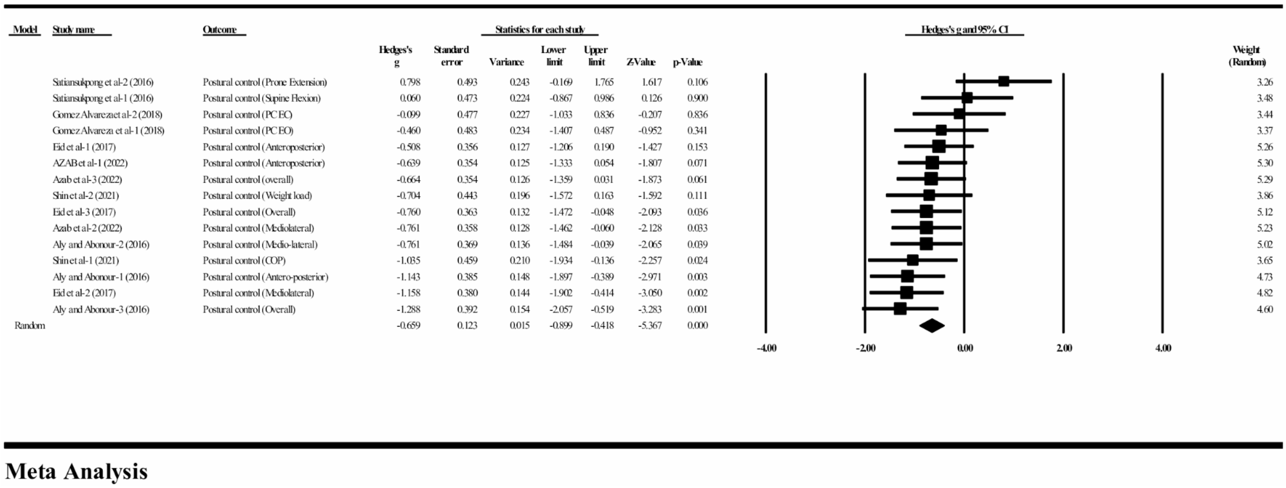

Fig. 4 Q1

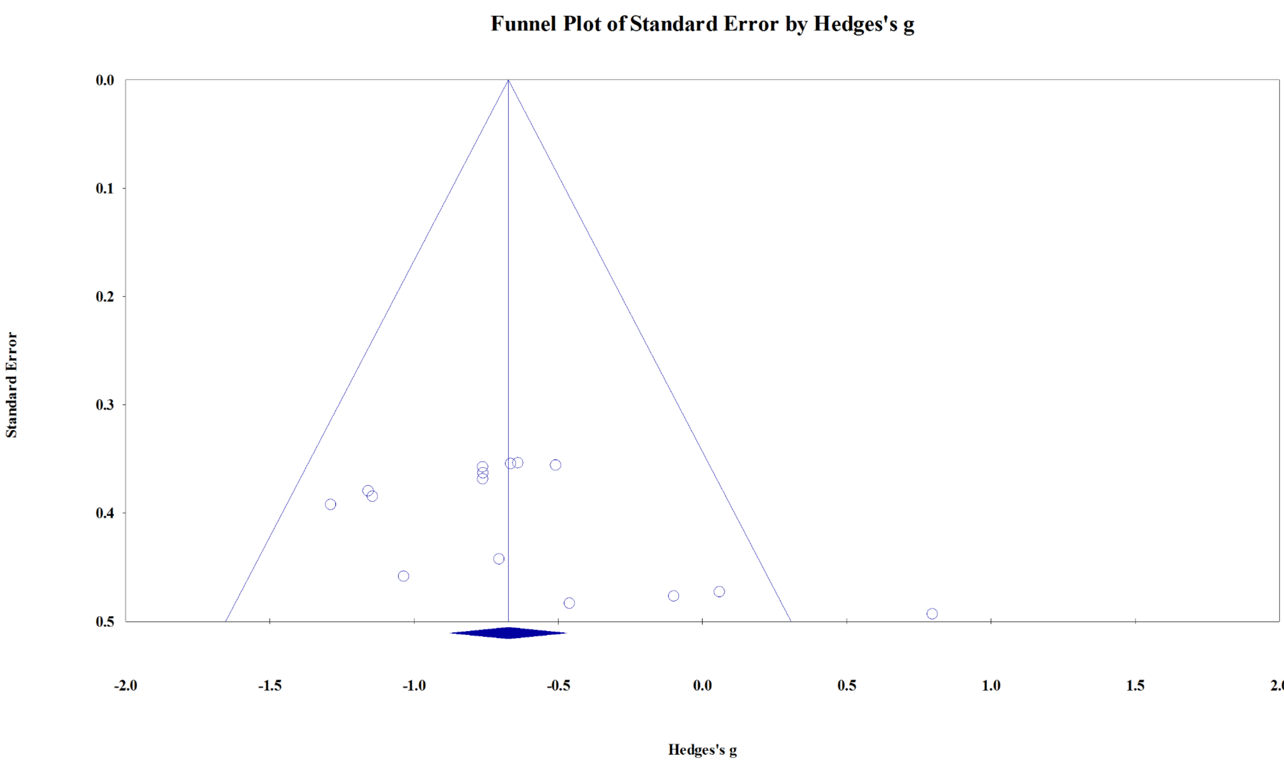

Fig. 5 Funnel plot of the quality of studies

lacking in previous investigations. By presenting effect sizes and confidence intervals, we enhance the evidence base to advise practitioners and researchers regarding the advantages of tailored exercise programs. Also, the quality of the studies and the risk of bias were examined. (4) Emphasis on special needs: This study pays attention to the special needs of people with Down syndrome and shows that exercise interventions should be designed according to their individual characteristics and ability levels. This point was less discussed in the existing literature and can help develop personalized exercise programs. Overall, this systematic review and meta-analysis sheds light on the impact of exercise interventions on postural control in individuals with Down syndrome and contributes to a better understanding and development of more effective exercise programs. We hope these findings will contribute to growth and progress in this field.

Limitations and recommendations for future studies in investigating the effects of exercise interventions

Methodological limitations of this study included the unavailability of full text for several studies due to author requests and non-response. In addition, the restriction to sources published only in English further limited the scope of the search. As did the time frame of the search. Although the results obtained from the present review and meta-analysis had some positive outcomes, they should still be interpreted with caution due to the following limitations. First, considering the time frame was investigated in the current study, few studies have focused on the effects of exercise interventions on postural control in individuals with Down syndrome. Therefore, the limited number of studies reduces the strength of conclusions drawn in the present review and meta-analysis. Thus, conducting more studies and utilizing different exercise interventions in the future is recommended. Second, the duration and number of sessions of the exercise interventions were short, with most studies lasting from five to eight weeks. This may not have been sufficient to create significant changes in postural control strategies in individuals with Down syndrome. Additionally, the proportion of participants by gender was lower compared to other studies in this area. One of the main weaknesses of this research is the lack of sufficient data to evaluate mid-term and long-term results. This point is very important because information about long-term outcomes can help understand interventions' effects better. The lack of these data may lead to the inability to evaluate interventions' effectiveness fully. Therefore, conducting more studies in the future to examine the effects of exercise interventions over a longer period and with more participants, as well as investigating the gender-specific effects is necessary. Third, out of the six studies included in the present review, none had used two different training programs and compared them. All six studies had only used one training program, and no comparisons between training programs were made. Therefore, a high-quality training program was not found which made the implementation of training programs by coaches challenging. Fourth, all of the studies in this review used laboratory tests (Biodex and force plates) to assess postural control. Clinical tests such as CTSIB and BESS were not used. While laboratory tests have high accuracy, they also have cost and availability limitations. Therefore, focusing on the use of field and clinical tests that sometimes have similar validity and reliability to laboratory tools can strengthen the process of further studies in this area and also facilitate their use and evaluation in sports facilities and clinics. Fifth, most studies did not provide detailed information on how participants and assessors were blinded in order to prevent bias. Due to this reason, most studies (4 out of 6) were classified as having low-quality qualitative evidence. Therefore, it is recommended that future studies develop a research methodology with higher quality standards. Sixth, no study was found that investigated the long-term effects of exercise interventions after a period of detraining. Therefore, there is a research gap in this area, and it is recommended that future studies focus on examining the persistence of the effects of different training programs. Seventh, most studies did not provide detailed information on the content of the exercise interventions. This factor hinders coaches and therapists from effectively using exercise interventions to improve postural control in individuals with Down syndrome in sports facilities and clinics. Eight, forty-one reports were missing in this study, and seven were not in English. This lack of information can affect the final results. The absence of these reports may lead to the loss of important data and consequently affect the overall results of the research. Therefore, it is necessary to consider strategies to ensure a more complete retrieval of sources and reports in future research.

Strengths

In the current systematic review and meta-analysis, 6 studies with different types of exercises (balance exercises, swimming, Pilates, etc.,), were compared. Results showed that exercise interventions improve postural control in individuals with Down syndrome.

Conclusion

The results of the present review and meta-analysis study showed that exercise interventions improve postural control in individuals with Down syndrome. According to the results of the studies, only one study was conducted to investigate the impact of sports interventions on the postural control of adults with Down syndrome, and the other studies were in the category of children and adolescents. Due to the limited number of studies, participants, and the high risk of bias, the results of the present study should be interpreted with caution. Therefore, the impact of exercise interventions on postural control in individuals with Down syndrome requires more thorough and systematic investigation in the future. Nevertheless, based on the results of the present review and meta-analysis study, it is recommended that sports specialists and therapists use exercise interventions to improve postural control in individuals with Down syndrome. Ultimately, it appears that combined and multi-component exercise interventions may have a greater impact, and it is recommended that they be investigated in future studies.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-025-01096-4.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

Author contributions
HZ and MY were major contributors to writing the manuscript. PS was the supervisor and edited the manuscript. SA contributed to the drafting of the article and the methodology. All the authors gave final approval of the version to be submitted.

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Data availability
The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate
This research was approved by the research vice-chancellor of Guilan University in Iran (Approved Code: IR.GU.136849.1401.10.04).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Down JLH. Observations on an ethnic classification of idiots. Lond Hosp Rep, 1866. 3(1866):259–62.
2. Control CfD, Prevention. Data and Statistics on Down Syndrome. Centers for Disease Control and Prevention. 2023.
3. Fodstad JC et al. Treating obsessive compulsive disorder in adolescents and adults with down syndrome: results from a scoping rapid review. J Autism Dev Disord. 2024:1–9. https://doi.org/10.1007/s10803-024-06336-z
4. Loane M, et al. Twenty-year trends in the prevalence of down syndrome and other trisomies in Europe: impact of maternal age and prenatal screening. Eur J Hum Genet. 2013;21(1):27–33.
5. González-Agüero A, et al. Health-related physical fitness in children and adolescents with down syndrome and response to training. Scand J Med Sci Sports. 2010;20(5):716–24.
6. Webber A, et al. Stiffness and postural stability in adults with down syndrome. Exp Brain Res. 2004;155:450–8.
7. Carr J. Mental and motor development in young Mongol children. J Ment Defic Res. 1970. https://doi.org/10.1111/j.1365-2788.1970.tb01116.x
8. Ulrich DA, et al. Treadmill training of infants with down syndrome: evidence-based developmental outcomes. Pediatrics. 2001;108(5):e84–84.
9. Cimolin V, et al. Postural strategies in Prader–Willi and down syndrome patients. Res Dev Disabil. 2011;32(2):669–73.
10. Galli M, et al. Postural control in patients with down syndrome. Disabil Rehabil. 2008;30(17):1274–8.
11. Giagazoglou P, et al. Effects of a trampoline exercise intervention on motor performance and balance ability of children with intellectual disabilities. Res Dev Disabil. 2013;34(9):2701–7.
12. Anbarian M, et al. A comparison of postural control characteristics between subjects with kyphosis and controls. Avicenna J Clin Med. 2010;16(4):53–60.
13. Chaput J-P, et al. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. Int J Behav Nutr Phys Activity. 2020;17:1–9.
14. Phillips AC, Holland AJ. Assessment of objectively measured physical activity levels in individuals with intellectual disabilities with and without Down's syndrome. PLoS ONE. 2011;6(12):e28618.
15. Ginis KAM, et al. Participation of people living with disabilities in physical activity: a global perspective. Lancet. 2021;398(10298):443–55.
16. Page MJ et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, 2021. 372. https://doi.org/10.1136/bmj.n71
17. Cumpston M, et al. Updated guidance for trusted systematic reviews: a new edition of the Cochrane handbook for systematic reviews of interventions. The Cochrane database of systematic reviews. 2019:(10).
18. Moseley AM, et al. Evidence for physiotherapy practice: a survey of the physiotherapy evidence database (PEDro). Australian J Physiotherapy. 2002;48(1):43–9.
19. Maher CG, et al. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther. 2003;83(8):713–21.
20. Higgins J et al. Cochrane handbook for systematic reviews of interventions version 6.2 (updated February 2021). Cochrane 2021: 2021.
21. Balshem H, et al. GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol. 2011;64(4):401–6.
22. Karanasios S, et al. Exercise interventions in lateral elbow tendinopathy have better outcomes than passive interventions, but the effects are small: a systematic review and meta-analysis of 2123 subjects in 30 trials. Br J Sports Med. 2021;55(9):477–85.
23. Becker LA. Effect size (ES).2000.
24. Montgomery PG, Pyne DB, Minahan CL. The physical and physiological demands of basketball training and competition. Int J Sports Physiol Perform. 2010;5(1):75–86.
25. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. Biometrics. 1994;50(4):1088–101. https://doi.org/10.2307/2533446
26. Eid MA, et al. Effect of isokinetic training on muscle strength and postural balance in children with Down's syndrome. Int J Rehabil Res. 2017;40(2):127–33.
27. Azab A, et al. Distinct effects of trampoline-based stretch-shortening cycle exercises on muscle strength and postural control in children with down syndrome: a randomized controlled study. Volume 26. European Review for Medical & Pharmacological Sciences. 2022:6.
28. Aly SM, Abonour AA. Effect of core stability exercise on postural stability in children with down syndrome. Int J Med Res Health Sci. 2016;5:213–22.
29. Satiansukpong N, Pongsaksri M, Sasat D. Thai Elephant-Assisted therapy programme in children with down syndrome. Occup Therapy Int. 2016;23(2):121–31.
30. Shin Y-A, et al. The effect of resistance and balance training on postural control and physical fitness in adults with down syndrome. Exerc Sci. 2021;30(2):175–82.
31. Álvareza NG, et al. Effect of an intervention based on virtual reality on motor development and postural control in children with down syndrome. Revista chilena de pediatria. 2018;89(6):747–52.
32. Barozzi S, et al. Reliability of postural control measures in children and young adolescents. Eur Arch Otorhinolaryngol. 2014;271:2069–77.
33. Vaugoyeau M, et al. Proprioceptive contribution of postural control as assessed from very slow oscillations of the support in healthy humans. Gait Posture. 2008;27(2):294–302.
34. Viel S, Vaugoyeau M, Assaiante C. Adolescence: a transient period of proprioceptive neglect in sensory integration of postural control. Motor Control. 2009;13(1):25–42.
35. Villarroya MA, et al. Static standing balance in adolescents with down syndrome. Res Dev Disabil. 2012;33(4):1294–300.
36. Vuillerme N, Marin L, Debû B. Assessment of static postural control in teenagers with down syndrome. Adapted Phys Activity Q. 2001;18(4):417–33.
37. Peterka RJ. Sensorimotor integration in human postural control. J Neurophysiol. 2002;88(3):1097–118.
38. Teasdale N, Simoneau M. Attentional demands for postural control: the effects of aging and sensory reintegration. Gait Posture. 2001;14(3):203–10.

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