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Exercise training to improve balance ability for individuals with Down Syndrome: A systematic review and meta-analysis

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Abstract

Down syndrome (DS) is associated with exhibit specific balance problems due to inter alia deficits in the postural control system and hypotonia. One approach to reducing balance impairments in this population is exercise training. This study presents a systematic review and meta-analysis of the effects of exercise training designed to improve balance ability in people with DS.

A search for relevant articles was carried out on seven electronic databases: MEDLINE, PubMed, Cochrane Library, Google Scholar, Scopus, PEDro, and Web of Science. This systematic review was carried out between 2010 and 2022. Utilizing a set of predetermined inclusion and exclusion criteria, the studies were selected and their methodology was assessed using the PEDro scale. Data analyses were performed using the CMA v3 random effects model.

In total, 514 articles were screened, and the data from 15 randomized controlled trials (RCTs) involving DS were subjected to a meta-analysis. The results showed that exercise training was effective in improving balance (ES: 1.20, 95% CIs: 0.95 to 1.53, p = 0.00).

Despite the small number of studies, the findings suggest that exercise training might improve balance in children and young people with DS. In conclusion, exercise training is highly recommended for people with DS, to improve their balance and prevent falling risk.

Keywords: down syndrome, exercise training, meta-analysis, postural balance

Introduction

Down syndrome (DS) is an autosomal disorder brought on by an extra copy of chromosome 21, i.e. a trisomy [1]. The estimated global prevalence is around 0.1% of live births. The condition is characterised by distinctive physical characteristics, varying degrees of intellectual disability (ID), and certain negative impacts on health and development [2].

People with DS often experience delays in the development of motor skills [3] such as walking [4], standing [5], and running [6] caused by muscle hypotonia, ligamentous laxity [7], articular hypermobility [8], impaired balance response [9], poor bilateral coordination

[10], delayed growth and maturation of reflexes, delayed growth of postural reactions [11]. Also, most people with DS lead a sedentary lifestyle; research indicates that less than 10% of individuals with DS achieve the recommended amount of physical activity [12]. One key weak factor in this group is balance, which leads to falls and accompanying injuries [13].

In addition to having a poorer sense of balance compared to their peers [14], people with DS often display proprioception impairment, poor motor coordination, sensory-motor integration issues, and a slower reaction time for anticipatory postural changes, all linked to postural dysfunctions [15,16]. The balance issues manifest as having a large base of support, falling frequently, and encountering trouble performing daily tasks including walking without help, going downstairs, and moving in a dark environment [16].

Previous studies have examined the influence of physical exercise/training on the health status and functional capacity of DS patients. Their findings indicate that forms of exercise training, such as balance training[17], intervention with hippotherapy [18], bicycle intervention [14], core stability exercise [19,20], whole-body vibration [21], vestibular stimulation exercises [22], dance [23] and strength training [17] are suitable for people with DS and yield successful results.

Unfortunately, due to the difficulties in comparing the effectiveness of different studies and the wide range of tools for measuring balance ability, selecting and creating physical teaching content for children with DS presents a challenge [24]. However, combining data from various pertinent studies is a good strategy for gathering a broad range of empirical evidence. To date, no systematic review or meta-analysis has been performed of the literature regarding the effects of exercise training intended to improve the balance of people with DS. Such a synthesis is crucial to inform academics, physical therapists and adaptive physical educators about evidence-based techniques and to enable the development of successful programs intended to improve balance and postural control among persons with DS.

Patients with DS demonstrate favourable correlations between movement health and balance, and exercise training has been found to enhance balance in individuals with DS. However, few studies have specifically looked at how exercise helps persons with DS with their balance.

The aim of this article is to compare the effects of exercise programs created to help persons with DS with their balance and/or postural stability; to this end, a systematic analysis and meta-analysis of previous studies were performed. We hypothesize that patients with DS would experience mild to moderate effects from exercise training on their balance and/or postural stability.

Materials and methods

Literature search

The study observed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [25]. The following databases were searched in 2022: MEDLINE, PubMed, Cochrane Library, Google Scholar, Scopus, PEDro, and Web of Science. The following terms were used: intellectual disability, Down syndrome, mental retardation, mongolism, trisomy, therapeutic exercise, exercise, intervention, training, physical therapy, physical activity, rehabilitation, fitness, balance, postural balance, motor control, postural control, and equilibrium. Only articles from 2010 to 2022 were included. The protocol for this systematic review was published at the Systematic Review and Meta-Analysis Studies Center, Iran (IRD20180203038603N1).

Eligibility criteria

The following requirements had to be met for a study to be included in this systematic review: (a) full-text article published before June 2022; (b) a publication with a prospective RCT design; (c) participants with diagnosed DS (both genders); (d) the participants were children and adults, defined herein as 6 to 64 years old; (e) physical exercise-related intervention; (f) pre-post-tests; (g) exercise-based interventions with a focus on improving balance in participants with DS; (h) a minimum overall PEDro score of three points. Abstracts, posters, unavailable full texts, and unpublished information were excluded from the final analysis.

The eligibility of each study was evaluated in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement (PRISMA) by the first two authors. Briefly, the titles and abstracts of the publications were evaluated independently to select papers for further analysis, then the whole texts of these selected studies were independently reviewed. Their findings were then addressed by three authors in order to resolve any disagreements.

Risk of Bias assessment of articles

The 11-item PEDro scale was used to investigate possible sources of bias (http://www.pedro.org.au). Scores of 4 are considered ‘poor’, 4 to 5 are considered ‘fair’, 6 to 8 are considered ‘good’ and 9 to 10 are considered excellent [26].

Data extraction

The first two authors independently retrieved the following categories of data from each included study: (1) The nation and area as identified by the World Health Organization; (2) the recruitment environment (such as ordinary school, or special school); (3) age samples; (4)

intellectual disability level (such as mild, moderate); and (5) design (quasi-experimental or experimental); (6) information on the intervention and control groups, including sample size, gender distribution, age range, and mean age; (7) the characteristics of the intervention program; and (8) a description of balance measures. Both authors then examined these evaluations, and disagreements were settled by discussion.

Statistical analysis

For the meta-analysis, quantitative data were combined using comprehensive meta-analysis (CMA) software, version 3 (Biostat, Englandwood, NJ, USA). For illustration, the ES was represented by Cohen's d, weighted mean differences and 95% confidence intervals, heterogeneity and forest plot. In CMA, Cohen's d was automatically converted to Hedges' g to account for a small sample bias and prevent overestimation. I^2 statistics were calculated to assess the heterogeneity among the included studies, and thresholds of 25%, 50%, and 75% were defined as having a low, moderate, and high level of heterogeneity, respectively. An alpha level of 0.05 was assumed to indicate statistical significance for all tests

Results

Selection of the studies

In total, 514 articles were found during the database search. Of these, 113 were removed before screening due to various reasons, such as duplication, with 401 remaining (Figure 1). Following title and abstract analysis, 343 of the 401 publications were excluded for not matching the inclusion criteria or could not be retrieved. After evaluating the complete texts (n = 58), 43 publications were excluded, 23 for not meeting the inclusion criteria (Fig. 1). Of the remaining 15 papers, nearly 75% (n = 11) concentrated on children and adolescents with DS. The remaining three focussed on adults with DS. This procedure is summarised in Table 1.

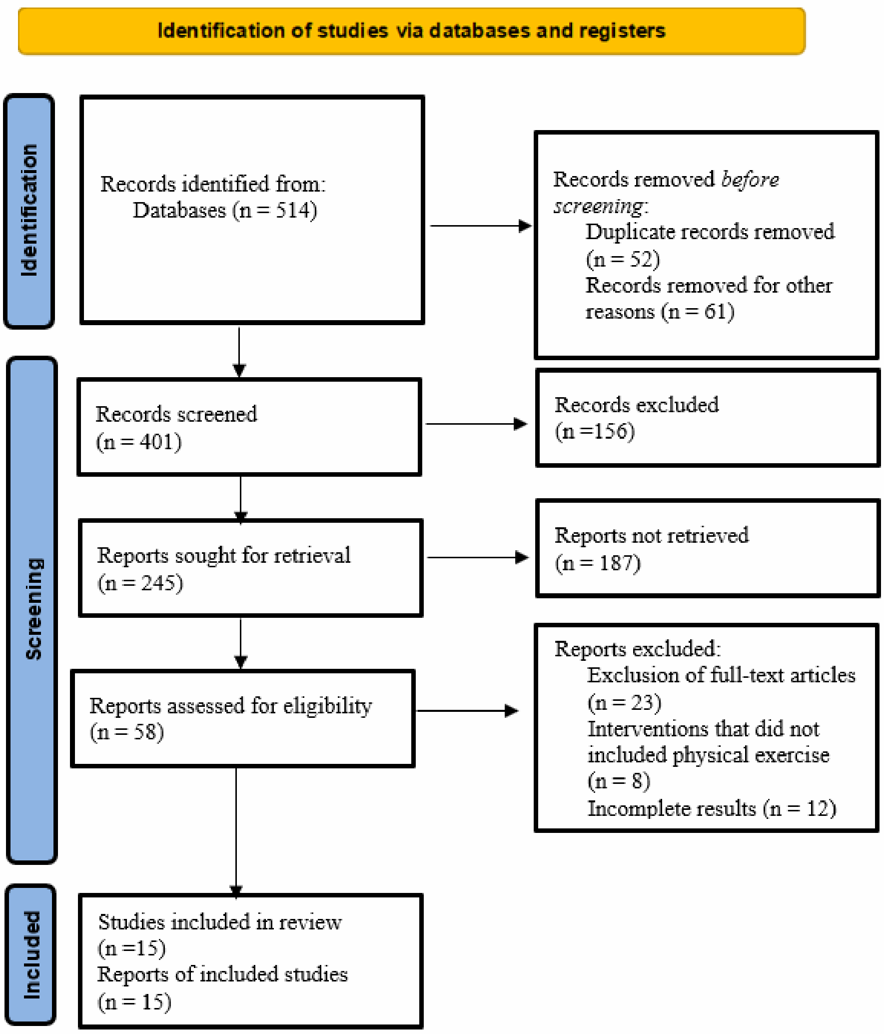

Fig. 1. Diagram of the PRISMA flow of the articles included in the review and meta-analysis

Tab. 1. Descriptions of the interventions, controls, and balancing measurements of the studies included in the meta-analysis

Study (country)	PEDro scale	Design	Effect size	Participants (Female and male %)	Age range (Mean) years old	Intervention	Session Duration, in min (Frequency/wk.)	Total Duration (wk.)	Assessment (Method)
Abdel Rahman et al. [27]	5	RCTs	1.61	**IG**: 15 (40% males) **CG**:15 (47% males)	**IG**:10–12 (10.9) age **CG**:11–13 (11.6) age	Wii Fit balance game training	60(2)	6	Static balance (OLS: EC + EO), dynamic balance (BOTMP)
Ulrich et al.[28]	5	RCTs	0.27	**IG**: 19 (47% males) **CG**:27 (41% males)	**IG**: 8–15 (12.4) age **CG**: 8–15 (12) age	Bicycle intervention	75 (5 consecutive days)	5 days	Standing Balance (right leg and left leg)
Eid [29]	9	RCTs	0.91	**IG**: 15 (53% males) **CG**:15 (60% males)	**IG**: 8–10 (8.9) age **CG**: 8–10 (9.3) age	Physical therapy + whole–body vibration	80–90(3)	24	Dynamic balance (DLE:EO) (Biodex Balance System
Eid et al. [30]	8	RCTs	1.55	**IG**: 15 (53% males) **CG**:16 (56% males)	**IG**: 9–12 (10.3) age **CG**: 9–12 (10.1) age	Physical therapy + isokinetic training	60(3)	12	Dynamic balance (DLE:EO) (Biodex Balance System
Gupta et al. [17]	7	RCTs	1.20	**IG**: 12 (67% males) **CG**:11 (55% males)	**IG**: 11–14 (13.5) age **CG**: 10–14 (13) age	Strength and Balance exercises	NM(3)	6	Static balance (OLS: EC + EO), dynamic balance (BOTMP)
Jankowicz-Szymanska et al. [31]	3	RCTs	0.25	**IG**: 20 (NM) **CG**:20 (NM)	**IG**: 16–18 (NM) age **CG**: 16–18 (NM) age	Training program targeting balance capacities	45(2)	12	Static balance (OLS: EC + EO), (Pressure platform)
Naczk [32]	5	RCTs	0.51	**IG**: 11 (64% males) **CG**:11 (64% males)	**IG**: NA (14.9) age **CG**: NA (14.4) age	water–based exercise and a swimming program	90(2)	33	Flamingo balance test which is a single leg balance test
Perrot et al. [33]	6	RCTs	1.96	**IG**: 6 (NA) **CG**:6 (NA)	**IG**: 35–64 (49.3) age **CG**: 35–64 (51.4) age	Exergaming(Wii–based program)	60(2)	12	Timed Up and Go Test and Timed Up and Down Stairs Test
Raghupathy et al. [23]	8	RCTs	0.25	**IG**: 18 (61% males) **CG**:18 (56% males)	**IG**: 6–10 (7.8) age **CG**: 6–10 (8.4) age	Traditional Indian Dance	60(3)	6	Paediatric balance scale

Tab. 1. Cont.

Study (country)	PEDro scale	Design	Effect size	Participants (Female and male %)	Age range (Mean) years old	Intervention	Session Duration, in min (Frequency/wk.)	Total Duration (wk.)	Assessment (Method)
Alsakhawi et al. [19]	5	RCTs	2.36	**IG(A)**: 15 (NA) **IG(B)**:15 (NA) **IG(C):** 15 (NA)	**IG(A)**: 4–6 (4.6) age **IG(B)**: 4–6 (4.6) age **IG(C):** 4–6 (4.6) age	Core Stability Exercises and Treadmill Training	60(3)	8	Berg balance scale and the Biodex Balance System
el-Meniawy et al. [34]	4	RCTs	2.03	**IG(A)**: 15 (NA) **IG(B)**:15 (NA)	**IG(A)**: 8–10 (9.34) age **IG(B)**: 8–10 (9.34) age	suspension therapy and treadmill training	60(3)	12	Biodex instrument system
Boer [35]	6	RCTs	0.48	**IG**: 13 (50% males) **CG**:13 (50% males)	**IG**: 18–45 (34.2) age **CG**: 18–45 (30.3) age	freestyle swim training	40(4)	8	Standing on one leg and WOBB
Silva et al. [36]	8	RCTs	0.64	**IG**: 12 (NA) **CG**:13 (NA)	**IG**:18–60 (NA) age **CG**: 18–60 (NA) age	Wii–basedexercise program	60(3)	8	Flamingo Balance Test and TUG
Azab et al. [37]	7	RCTs	1.10	**IG**: 16 (56.3% males) **CG**:15 (73.3% males)	**IG**: 7–9 (9.19) age **CG**: 7–9 (8.60) age	trampoline–based stretch–shortening cycle exercises	10–15(2)	12	Balance Biodex System
Aly et al. [20]	5	RCTs	1.41	**IG**: 15 (73% males) **CG**:15 (66% males)	**IG**: 6–10 (8.11) age **CG**: 6–10 (8.34) age	Core stability exercises	45–60(3)	8	Dynamic balance (DLE:EO) (Biodex Balance System

BOTMP – Bruininks-Oseretsky Test of Motor Proficiency, CG – Control Group, DLE – Dynamic Leg Stretches, EC – Eye Close, EO – Eye Open, IG – Intervention Group, OLS – One Leg Stance, TUG – Timed Up and Go Test, WOBB – Wobbel balance board.

Characteristics of the Review and Meta-analysis Studies

As illustrated in Table 1, seven of the final 15 studies (47%) were conducted in the Eastern Mediterranean region, four were conducted in Europe (27%), one was conducted in the USA (6%), and three were conducted in Southeast Asia and Africa (20%). All of these studies (100%) were RCTs. In total, these studies included 447 people with DS, including 384 children and adolescents (mean = 10.6; 57.3% boys) and 63 adults (mean = 41.3; 50% boys).

Overview of results

Figure 2 displays the descriptive statistics and forest plots of the 15 research, while Table 1 displays the effect size of each study. The square in the forest plot indicates the effect size of each study, determined as an analysis unit. The horizontal lines indicate the confidence interval (often the 95% CI), and the area of the square represents the weight of each included study. The confidence interval (CI) correlates with the size of the intervention effect and may indicate whether the effect of each study was statistically significant.

Exercise interventions

As shown in Table 1, all 15 studies included in the analysis examined the effect of an intervention on balance in people with DS. Balance training was conducted by various methods, such as bicycle intervention, whole body vibration, isokinetic training, strength and balance exercises, as well as training programs targeting balance capacities, water-based exercise and a swimming program; in addition, other studies used Exergaming (Wii-based program), traditional Indian dance, core stability exercises, treadmill, training suspension therapy, freestyle swim training, and trampoline-based stretch-shortening cycle exercises. Exercise interventions lasted between 6 and 33 weeks (mean = 11.92). Additionally, only one study out of 15 relied on a follow-up period of seven weeks to one year. Finally, the training sessions, were held two or four times per week (mean = 2.7) and lasted between 10 and 90 minutes per session.

The homogeneity test indicated that the included studies had diverse effect sizes (Tab. 2). Therefore, a random effects model was used to calculate the overall effect size, which was found to be 1.24. The results are in the form of hedges, in which a modified standard difference of 0.2–0.5 was considered as low effect

Study name	Outcome	Hedges's g	Standard error	Lower limit	Upper limit	p-Value
Abdel Rahman, et al. [29]	BOTMP	1.61	0.41	0.80	2.42	0.00
Ulrich et al. [30]	left leg	0.25	0.30	-0.33	0.83	0.40
Ulrich et al. [30]	Right leg	0.29	0.30	-0.29	0.87	0.33
Eid. [31]	Anteroposterior	0.22	0.36	-0.48	0.92	0.53
Eid. [31]	Mediolateral	1.18	0.39	0.42	1.94	0.00
Eid. [31]	Overall	1.34	0.40	0.57	2.12	0.00
Gupta et al. [20]	BOTMP	1.20	0.44	0.34	2.06	0.01
Eid et al. [32]	Overall	1.55	0.40	0.76	2.33	0.00
JankowiczSzymanska et al. [33]	Eyes closed	0.29	0.31	-0.32	0.90	0.35
JankowiczSzymanska et al. [33]	Eyes open	0.21	0.31	-0.40	0.82	0.50
Alicja Naczk. [34]	Flamingo	0.51	0.42	-0.30	1.33	0.22
Perrot, A, et al . [35]	TUDS	1.87	0.65	0.58	3.15	0.00
Perrot, A, et al . [35]	TUG	2.06	0.68	0.73	3.39	0.00
Raghupathy MK, et al. [26]	BOTMP	0.25	0.33	-0.39	0.89	0.44
Alsakhawi RS et al. [22]	Functional balance	2.05	0.44	1.18	2.92	0.00
Alsakhawi RS et al. [22]	Functionan balance/core	2.88	0.51	1.88	3.89	0.00
Alsakhawi RS et al. [22]	Overall	2.67	0.49	1.70	3.64	0.00
Alsakhawi RS et al. [22]	Overall	3.11	0.54	2.06	4.16	0.00
el-Meniawy GH, et al. [36]	Anteroposterior	1.64	0.41	0.83	2.45	0.00
el-Meniawy GH, et al. [36]	Mediolateral	1.90	0.43	1.05	2.75	0.00
el-Meniawy GH, et al. [36]	Overall	2.53	0.48	1.59	3.48	0.00
Boer PH. [37]	Standing one leg	0.10	0.38	-0.64	0.85	0.78
Boer PH. [37]	WOBB	0.86	0.40	0.08	1.64	0.03
Silva V, et al. [38]	Flamingo	0.82	0.40	0.03	1.61	0.04
Silva V, et al. [38]	TUG	0.47	0.39	-0.30	1.24	0.23
Azab, A. R., et al. [39]	Anteroposterior	1.33	0.39	0.56	2.09	0.00
Azab, A. R., et al. [39]	Mediolateral	0.79	0.36	0.08	1.50	0.03
Azab, A. R., et al. [39]	Overall	1.17	0.38	0.43	1.92	0.00
Aly, Sobhy M., et al. [23]	Anteroposterior	1.60	0.41	0.80	2.41	0.00
Aly, Sobhy M., et al. [23]	Mediolateral	1.20	0.39	0.44	1.96	0.00
Aly, Sobhy M., et al. [23]	Overall	1.43	0.40	0.64	2.21	0.00
		1.20	0.14	0.92	1.48	0.00

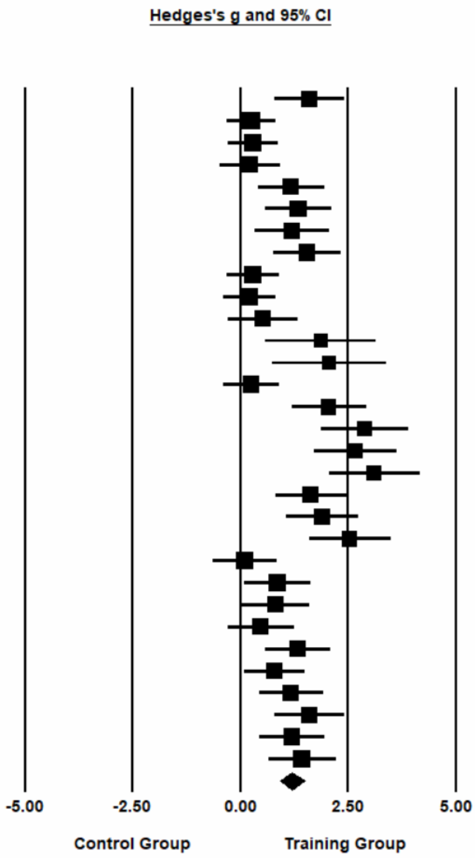

Fig. 2. Forest plot of the effects of exercise programs on balance of individuals with Down syndrome

Tab. 2. Results from the meta-analysis utilizing a random effects model

Number of studies	I^2	P-value	−95%CI	Effect size	+95%CI	Tau^2
15	75.14	<0.00001	0.95	1.24	1.53	0.50

I^2– homogeneity statistic.

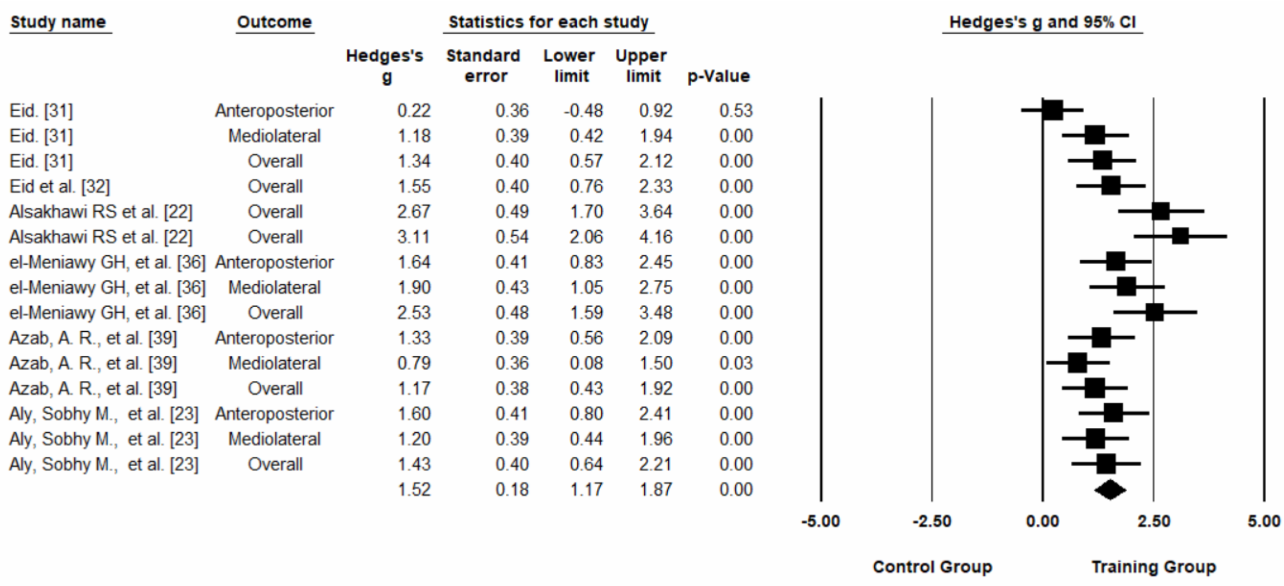

Fig. 3. Forest plot of the effects of exercise programs on Biodex Balance Index(overall, anteroposterior, mediolateral) of individuals with DS

size, 0.5–0.8 as medium effect size, and 0.8 and more as high effect size. Data comparison was performed using the random effect model. The summary values for each study were given in the form of forest plots for each separate section. All 15 effect sizes were greater than 0, which suggested that the interventions were all effective.

The meta-analysis showed that exercise training increased the Bidex Balance Index (ES = 1.52; CI (95%) 1.17 to 1.87; p = 0.00). However, this value demonstrated a high degree of heterogeneity across studies (I^2 = 64.07%, p = 0.00). Six studies used an overall index to assess balance indexes (Table 2). All studies found that the intervention had an influence on the overall balance, as indicated by the ES score (ES: 1.91, 95%CIs: 1.37 to 2.44, p = 0.01, I^2: 64.01 Fig. 3). Four studies used the Biodex Balance System to measure anterior-posterior balance (ES: 1.18, 95% CIs: 0.49 to 1.86, p = 0.00, I^2: 68.70, Fig. 3). In three of the reviewed studies, the SE indicated that the intervention had a large effect on anterior-posterior balance and one study indicated a small, statistically non-significant effect (ES: 0.22, 95%CIs: 0.48 to 0.92, p = 0.53, Fig. 3) on anterior-posterior balance.

Four studies recorded medio-lateral balance values using the Biodex Balance System (ES: 1.23, 95%CIs: 0.79 to1.67, p = 0.00, I^2: 23, Fig. 3). In three reviewed studies, the intervention had a large effect on medial-lateral balance and one study indicated a medium effect (ES: 0.79, 95%CIs: 0.08 to 1.50, p = 0.03, Fig. 3). Three studies used the Bruininks-Oseretsky Test of Motor Proficiency, a validated test in the DS population with a separate part for balance (ES: 0.99, 95%CIs: 0.14 to 1.84, p = 0.02, I^2: 72.88, Fig. 4). In two reviewed studies, the summary effect of the effect sizes indicated that the intervention had a large effect on BOTMP; however, one study indicated a small, non-significant effect (ES: 0.25, 95%CIs: −0.39 to 0.89, p = 0.44, Fig. 4) on BOTMP. Another test for balance frequently used in the studies was based on one-legged standing, such as the Flamingo balance and the TUG, TUDS and WOBB tests.

Additional analyses

When variations are identified between individuals, interventions, or analytical techniques in the included studies, subgroup analysis is typically employed to investigate the origins of heterogeneity. In the present

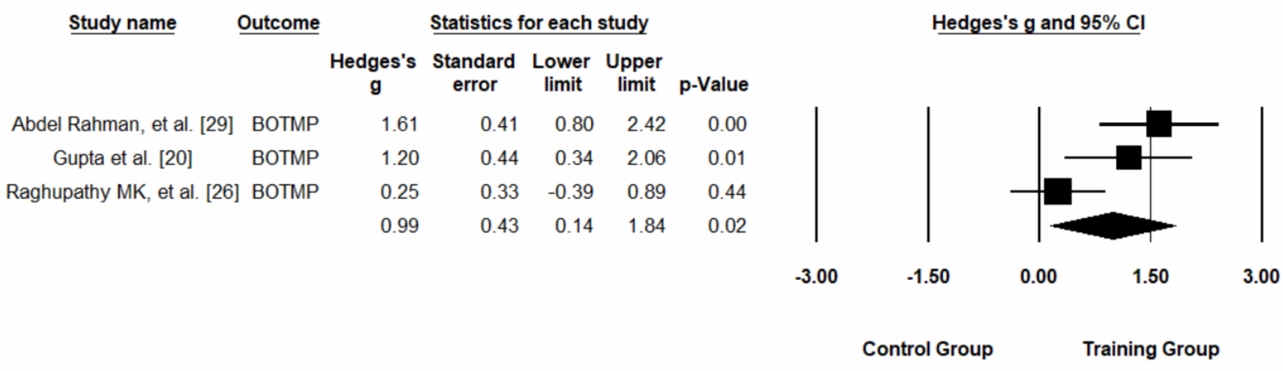

Fig. 4. Forest plot of the effects of exercise programs on BOTMP of individuals with DS

Tab. 3. Effect sizes by subgroup: frequency, length of sessions, age

Subgroup	Categories	Effect size	−95% CI	+95% CI
Duration	≤10	1.19	0.61	1.77
	≥12	1.15	0.76	1.53
Frequency	2 per week	0.84	0.32	1.36
	3 per week	1.44	0.89	1.98
	>3 per week	0.48	–0.28	1.25
Session length	<45	0.80	0.20	1.40
	45–60	1.42	0.90	1.94
	>60	0.51	0.11	0.91
Age	5–13	1.39	0.86	1.92
	14–18	0.59	0.05	1.14
	>18	0.86	0.13	1.59

study, the homogeneity tests suggest that the random effects model should be incorporated in the subgroup analysis to investigate the causes of high variability and moderation. The present meta-analysis included four subgroup analyses based on the following criteria: frequency, length of sessions, duration, and participant age.

The results showed that the duration of exercises should be set at less than or equal to 10 weeks to obtain the best effect. Exercise performed three times per week had the largest effect. The effect of exercise sustained for 45–60 min was greater than that of exercise sustained for less than 45 min, and the balance ability of 5–13-year-old children with DS could be improved more dramatically through physical exercises than that of 14–18-year-old children with DS.

Exercise training for 45 to 60 minutes had a greater effect than exercise training for less than 45 minutes or more than 60 minutes, and it was more effective in improving balance in DS patients aged 5 to 13 than in those aged 14 to 18, or 18 and older (Tab. 3).

Discussion

Down Syndrome (DS), one of the most frequent genetic causes of developmental delays in both children and adults, is often characterised by balance issues. Many people with DS have poor static and dynamic balance compared to the general population [13,35], which has been linked to poorer basic motor abilities and a greater risk of falling in individuals with DS [16,38]. Studies have demonstrated that these parameters influence the capacity to participate in leisure and social activities, as well as physical independence [15,20]. Our present findings demonstrate that exercise training had beneficial effects on balance in people with DS, with all 15 studies demonstrating effect sizes larger than 0. A key value of the present analysis was that all of the included studies were RCTs, as reported by their authors.

This article reviews the use of exercise therapies specifically intended to improve balance in people with DS. The body of works included in the analysis included a total of 447 people with DS, including 384 children and adolescents (mean = 10.6; 57.3% boys) and 63 adults (mean = 41.3; 50% boys) (Table 1). It also includes many therapies that have been previously described to improve balance in people with DS.

The highest effect size (ES: 2.36) was observed by Alsakhawi et al. [19] who indicated that treadmill training and core stability exercises improved balance in children with DS. Their findings indicate that the physical therapist may use using core stability training or treadmill exercise to improve balance in children with DS: these are two of the physical therapy modalities presented herein.

Similarly to our findings, el-Meniawy et al. [34] also report a large effect size for treadmill training (2.03), with a considerable improvement observed for two groups over the course of therapy. In this case, dynamic balance was improved by both treadmill exercises and suspension therapy; however, a significant difference was also seen between the post-treatment outcomes, favouring the suspension therapy (research group II). The authors propose that suspension treatment is a fantastic addition to regularly-planned physical therapy to increase stability in individuals with DS; this strategy may have contributed to the observed improvement by supporting the development of an equilibrium reaction to maintain and restore balance during standing patterns. Proprioception, vision, and vestibular input can all help with this, with vestibular input playing a secondary role. This therapy provides postural stability while encouraging independence and security, which vastly enhances balance, body coordination, and vestibular system functionality [19,34].

Aly and et al. [20] report that core stability exercises appear to enhance muscle balance, i.e. between agonist and antagonist, proximal stability and lumbar-pelvic-hip chain mobility, and result in improvements in acceleration and deceleration, and dynamic balance in general, with a large effect size (ES: 1.41). Their findings indicate that core stability exercises had a significant effect on postural stability, with the study group demonstrating significantly lower anteroposterior, mediolateral, and total stability indices than the control group following treatment. This is consistent with Gupta et al. [17], who examined the effects of resistance and balance training on strength and balance in children with DS.

In addition, a study on physical training on static balance in young people with DS by Jankowicz-Szymanska et al. [31] found that balance indices improved in both groups treated with Swiss ball training, which produced an unstable environment. Their results support the hypothesis that exercises with unstable surfaces enhance deep sensitivity in individuals with DS. The coordinated interaction of the central nervous system, inner ear, deep sensitivity, and the organ of sight makes it possible to maintain balance in unpredictable external settings, with this dynamic process being guided unconsciously.

Abdel Rahman et al. [27] and Silva et al. [36] investigated the effects of Wii-based exercise programs on balance. Although both sets of findings suggest that Wii-based exercise can be an effective tool to improve the balance of children and adults with DS, Abdel Raman et al reported a larger effect (ES: 1.61) than Silva et al (ES: 0.64). This could be because in Abdel Rahman's research, in another study, in addition to the standard physical therapy program, the research group received a program of three Wii-Fit games, but in another research, the Wii-Fit exercise was done alone [27,36]. In addition, while Abdel Rahman et al [27] used children aged 10 to 13 years old, Silva et al [38] was based on adults. It is likely that the changes in training have more significant effects on children.

In a study investigating the benefits of physical exercise for individuals with DS, Ulrich et al. [28] report that 56% of participants in their experimental group successfully learned to ride a bicycle during a five-day intervention, while the others behaved more like a control group. It is possible that those who did not learn to ride just needed additional days of training and practice, or there may have been significant variation in cognitive development among those with DS. Perhaps these factors account for the small effect size (SE: 0.27).

Eid et al. [30] investigated how the isokinetic training program affected children with DS in terms of postural balance and the peak torque of their knee flexors and extensors. Their data indicates that isokinetic training is a suitable exercise for children and adolescents with DS. Generally, the research group demonstrated improved dynamic postural balance as a result of their involvement in the 12-week training program.

Azab et al. [37] investigated the effects of a 12-week, trampoline-based stretch-shortening cycle (SSC) exercise program on muscle strength and postural control in children with DS. Their main findings were that the combination of SSC exercise (15 minutes/session; twice weekly) with standard Physical Therapy (sPT) increased lower limb muscle strength and enhanced postural control more effectively in children with DS than sPT alone (SE:1/10). There are several possible explanations for these results. Primarily, SSC exercises involve quick and repeated transformations between muscle stretching and contraction; this countermovement action may have enhanced motor unit recruitment via activation of the stretch reflex, and contributed to greater muscle force and power through the recovery of stored elastic energy during jumping and hopping movements. Alternatively, performing SSC exercises on a trampoline may have induced changes in complex sensory-motor stimulation driven by the need for the children to adapt to the unstable surface of the trampoline and maintain their balance. Also, as children with DS often need interventions that are enjoyable and interesting to stay physically active, trampoline-based SSC appears a suitable activity for integration into rehabilitation programs.

Boer [35] investigated how an eight-week freestyle swim training intervention affected the functional fitness and static and dynamic balance of people with DS. The results demonstrate a considerable improvement in dynamic balancing with a high effect size (ES: 1.01). A significant improvement in core strength was noted, which may have contributed to the improvement in dynamic balance; indeed, Aly and Abonour [20] also note a link between core strength and dynamic balance in children with DS.

Taken together, the reviewed studies indicate improvements and positive effects in people with DS following exercise, and that exercise programs from 6 to 24 weeks in length significantly improved the balance in this group. One item in our study was shorter (five days) [28], and hence demonstrated a smaller effect size (0.27). Overall, our results suggest that the best exercise program duration to less than or equal to 10 weeks. Also, the balance ability of 5–13-year-old children with DS could be improved more dramatically through physical exercises than that of 14–18-year-old children with DS. Finally, children between the ages of 7 and 10 years may finally settle any sensory conflicts and use the vestibular system as a reference, and postural control is practically adult-like in this group [34].

The majority of reviewed studies used an equal, or close, male-to-female ratio. Our results suggest that multicomponent exercises could be beneficial for improving balance, especially if a multicomponent training program includes specific balance exercises

However, some limitations should be highlighted. Firstly, participant age varied considerably in the reviewed studies, ranging from under six years to 64 years. Furthermore, the search was restricted to certain databases and studies in the English language; this may be taken into account in future research. Furthermore, the findings of our meta-analyses may not be sufficiently robust, given the limited number of papers pooled into each meta-analysis and the fluctuation in Hedges's g after sensitivity testing.

Conclusions

Our findings support the use of exercise training to improve balance in people with Down syndrome. The reviewed studies show that treadmills, core stability, and Wii-based programs have a positive effect on balance, with a large effect size. We believe our findings may be of value to educators, parents, physiotherapists, healthcare providers, and centres for people with DS In order to improve balance and personal independence, and enhance the quality of life in this group.

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Conflicts of Interest
The authors have no conflict of interest to declare.

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