Exercise interventions to improve balance for young people with intellectual disabilities: A systematic review and meta-analysis

Christophe Maïano[1,2], Olivier Hue[3], Alexandre J. S. Morin[4], Geneviève Lepage[2], Danielle Tracey[5], Grégory Moullec[2,6,7]

[1] Cyberpsychology Laboratory, Department of Psychoeducation and Psychology, Université du Québec en Outaouais (UQO), Gatineau, Canada.
[2] Department of Psychoeducation and Psychology, Université du Québec en Outaouais (UQO), Saint-Jérôme, Canada.
[3] Department of Physical Activity Sciences, Université du Québec à Trois-Rivières, Trois-Rivières, Canada
[4] Substantive-Methodological Synergy Research Laboratory, Department of Psychology, Concordia University, Montréal, Canada.
[5] School of Education, Western Sydney University, Sydney, Australia
[6] School of Public Health, Department of Social and Preventive Medicine, Université de Montréal, Montréal, Canada
[7] Research Center, Centre intégré universitaire de santé et de services sociaux (CIUSSS) du Nord-de-l'Île-de-Montréal, Montréal, Canada

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Corresponding author: Christophe Maïano, Université du Québec en Outaouais, Campus de Saint-Jérôme, Département de Psychoéducation et de Psychologie, 5 rue Saint-Joseph, Saint-Jérôme, Québec, J7Z 0B7, email: christophe.maiano@uqo.ca

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Abstract

Aim. To conduct a systematic review and meta-analysis of the effects of exercise interventions designed to improve balance in young people with intellectual disabilities.

Method. A systematic literature search was performed on 10 databases. Studies in press or published in English in a peer-reviewed journal were included if: (1) participants were young people with intellectual disabilities, (2) exercise interventions were designed to improve balance, and (3) they used quasi-experimental or experimental designs. Studies focusing only on a specific subpopulation of young people with intellectual disabilities or having a specific physical characteristic were excluded. Risk of bias was assessed for randomization, allocation sequence concealment, blinding, incomplete outcome data, selective outcome reporting, and other biases.

Results. The search strategy identified 937 articles and 15 studies, published between 1991 and 2017, that met the inclusion criteria. Exercise intervention groups showed a significant and larger improvement in static (pooled effect size, Hedges' g=0.98) and dynamic (g=1.34) balance compared with the control groups. However, although the pooled improvement of static–dynamic balance was large (g=2.80), the result was non-significant. None of the subgroup analyses were significant, except for the improvement in: (1) static balance (higher in quasi-experimental than in experimental studies) and (2) dynamic balance (higher in young people with a mild vs a mild–moderate intellectual disability).

Interpretation. The reviewed exercise interventions seem to represent an effective means for improving the static and dynamic balance of young people with intellectual disabilities. However, the present findings should be considered as preliminary given the small number of studies and their limitations.

Keywords. Intellectual disabilities; exercise interventions; balance function; clinical tests; posturography.

"What this paper adds"

- Exercise intervention results in large and significant improvements in static and dynamic balance.
- Exercise intervention results in a large but non-significant improvement in static–dynamic balance.
- Static balance improvement was significantly higher in quasi-experimental versus experimental studies.
- Dynamic balance improvement was significantly higher in young people with mild versus mild–moderate intellectual disability.
- No significant differences related to age group, balance measures, and components of exercise intervention were found.

Individuals with intellectual disabilities are 'characterized by significant limitations both in intellectual functioning and in adaptive behavior as expressed in conceptual, social, and practical adaptive skills. This disability originates before age 18' (p. 118).[1] They are known to present a greater risk for a variety of health concerns compared with the general population.[2] In addition, emerging findings also suggest that individuals with intellectual disabilities may experience greater levels of difficulties with motor development and fundamental movement skills[3] and be characterized by lower levels of physical fitness[4] than typically developing individuals. More specifically, studies show that young people with intellectual disabilities tend to be characterized by a significantly lower balance or postural control than typically developing peers.[5–7]

Balance is the ability to maintain one's body in a state of equilibrium in static conditions (i.e. the body is static), in dynamic conditions (i.e. the body is moving or in reaction to stimuli or external perturbations), or in both types of condition.[8,9] This ability depends on a complex organization 'which is developed with sensory inputs and is based on body geometry (segmental organization), kinetics (ground force reaction), and body orientation and vertical perception (subjective verticality) cues' (p. 1).[9] Therefore, young people's ability to maintain their body in equilibrium, or strategies to maintain this balance, are often assessed by disturbing the base of support (i.e. one leg or double leg: feet apart, feet together, and semi-tandem or full tandem), the visual inputs (eyes opened, eyes closed), and/or plantar cutaneous sensitiveness (hard floor, foam floor).[8] All of these conditions are used to observe young people's ability to maintain their postural stability and to characterize their postural strategies when the postural control is challenged, to quantify their balance deficits.[9] Indeed, deficits in static balance control are related to deficits in the visual or sensorimotor systems which have been identified as a risk factor for falls.[10] However, deficits in dynamic balance control are more likely owing to a delayed reaction to balance perturbations resulting in an insufficient recovery response increasing the risk of falling.[11]

Two mechanisms have been proposed to explain the balance deficit of young people with intellectual disabilities: (1) the delay in cognitive development that also affects the motor function; and (2) an inactive lifestyle leading to lower physical capacities and functioning.[12] This balance deficit is a serious concern for young people with intellectual disabilities, given that it represents an important risk factor for falling.[12,13] Indeed, falls are highly prevalent in young people with intellectual disabilities (compared with typically developing peers) and they represent their highest cause of injury (i.e. fracture).[14] The more the balance deficit is present, the more young people with intellectual disabilities present a risk of falling and fall-related injuries. Balance deficits may also contribute to this significant health problem by reducing the likelihood that young people with intellectual disabilities will want to, and feel able to, participate in physical activity. Therefore, the improvement of balance among young people with intellectual disabilities represents a critical issue to prevent falls and possibly to enhance participation in physical activity. Exercise interventions are generally recognized as an efficient way to increase balance in older persons[15–17] or in children with cerebral palsy.[18] Indeed, they 'induce structural and functional adaptations of the postural function (each of its sensory, central and motor components) which improve postural performance and refine postural strategy' (p. 147).[8] Because these mechanisms are directly related to postural control mechanisms, interventions involving balance exercises tend to lead to better postural stability in static and dynamic conditions.[8] Additionally, other exercise interventions focused on muscle strength may help given the role of lower-limb strength in the ability to maintain the body in equilibrium.[8] Nevertheless, to our knowledge, no systematic review and meta-analysis has yet synthesized and quantified the effects of exercise interventions designed to improve balance among young people with intellectual disabilities.

We aimed to conduct a systematic review and meta-analysis of quasi-experimental or experimental studies examining the effects of exercise interventions designed to improve balance in young people with intellectual disabilities. More specifically, this meta-analysis foresaw two objectives: (1) to estimate the pooled effect size of exercise interventions on the improvement of balance in young people with intellectual disabilities; and (2) to explore the reasons for potential heterogeneity between studies' effect sizes. A better understanding of the potential effects of balance training through exercise interventions, by providing recent and stronger evidence-based practices in young people with intellectual disabilities, will be very helpful for informing: (1) scholars, as they develop and design interventions to evaluate in future studies, and (2) physical therapists, adapted physical educators, or teachers, as they seek to implement effective interventions.

Method

Search Strategy

The protocol of this systematic review was not registered. The relevant studies were identified through a systematic electronic search conducted separately in PsycARTICLES (including PsycINFO), Scopus, and SPORTDiscus with Full-Text, as well as 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). No year restriction was imposed on the electronic search, which was performed on March 17th, 2018.

The studies of interest were identified in the electronic databases using four groups of search terms: (group 1) 'intellectual* dis*' OR 'mental* retard*' OR 'developmental dis*'; AND (group 2) balance OR 'postural control*' OR 'postural sway' OR 'postural stabili*' OR 'postural instabilit*' OR 'postural adaptation*' OR 'postural performance*' OR 'postural perturbation*' OR 'postural strateg*' OR posture*; AND (group 3) intervention* OR program* OR treatment OR exercis* OR sport* OR fitness OR trainin* OR improv* OR enhanc* OR therap*; AND (group 4) child* OR adolescen* OR student* OR youth*. These combinations (of three or four groups) were researched in the title, abstract, and keywords of the studies published by the journals indexed in the databases. Finally, the reference lists of the studies considered as eligible were also examined to find additional relevant studies. The search strategy used in Scopus is presented in Appendix S1 (online supporting information).

Criteria for Inclusion

Studies were considered eligible if they met the following inclusion criteria. First, participants had to be school-aged (from 5 to 22y) young people with intellectual disabilities. Studies relying on mixed samples of adolescents and adults with intellectual disabilities were also considered if the sample's mean age was lower than 18 years, or if results were provided separately for participants younger than 22 years. Additionally, studies focusing only on a specific subpopulation of young people with intellectual disabilities (e.g. autism spectrum disorder, Down syndrome, Prader–Willi syndrome, Williams syndrome) or having a specific physical characteristic (e.g. cerebral palsy) were excluded.

Second, the exercise intervention had to be specifically designed to improve balance (i.e. static, dynamic, and/or static–dynamic). Precisely, such interventions refer to exercises in which muscles and neuromuscular responses are solicited to counteract an external force during a voluntary movement or in response to an unexpected perturbation to maintain their balance or posture in the base of support.[15] They can focus, for example, on balance or muscle strength exercises, virtual reality and active game exercises (i.e. Wii Fit balance, exergames), whole-body vibration platform exercises, hippotherapy exercises, tai chi chuan or qigong exercises, or combinations of several exercises.[8,17] If the balance data were not available in the article or after sending a request to the author, the study was excluded from the meta-analysis.

Third, the studies were considered of interest if they followed a quasi-experimental or experimental design. For this review, in a quasi-experimental design an intervention group was compared with a control group, but participants had not been randomly assigned to one group; and in an experimental design, an intervention group was compared with a control group, and participants had been randomly assigned to one group. Case studies and non-original studies (i.e. comments, reviews, and theoretical articles) were excluded. Fourth, only one intervention study was included when the same sample was used in different publications. Fifth, only studies in press or published in English in a peer-reviewed journal were included.

Relevance of Identified Studies

The eligibility of identified studies was assessed by the first two authors (CM, OH) following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[19] The titles and abstracts of the articles were first screened by the two authors independently.

Afterwards, they separately assessed the full text of the studies that were retained. Their results were discussed to reach a consensus in cases of discrepancies.

Extraction of the Reviewed Studies' Information

The following categories of information were independently extracted by the first two authors (CM, OH) for each included study: (1) country and geographic region as defined by the World Health Organization (see http://www.who.int/about/regions/en/); (2) design (quasi-experimental or experimental); (3) recruitment setting (e.g. regular school, special school); (4) age samples (children or adolescents); (5) intellectual disability level (e.g. mild, moderate); (6) characteristics of the intervention and control groups (sample size, percentage of males, age range, and mean age); (7) characteristics of the intervention program (i.e. types; setting in which the intervention was provided; who delivered the intervention; whether the intervention was adapted during the trial; whether strategies to maintain intervention fidelity were provided; total duration; follow-up period; session duration in minutes; number of sessions per week); (8) characteristics of the control condition (e.g. physical education program-classes, regular school schedule); (9) description of balance measures (i.e. types, assessment method, parameters); and (10) results (i.e. intragroup and intergroup). These ratings were then reviewed by both authors and discrepancies were resolved by discussion.

Quality Assessment of the Reviewed Studies

The first two authors (CM, OH) independently assessed the methods' quality of relevant studies using the French-Canadian version of the Physiotherapy Evidence Database scale.[20,21] This scale comprises 11 items measuring the following criteria:[22] (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. A score of 1 was awarded each time a criterion was satisfied, and a total score was obtained by summing up the results obtained from items 2 to 11.[22] Studies with a total score no more than 5 and at least 6 were considered as having a 'low' and 'high' quality respectively.[22,23] Ratings were reviewed by both authors and discrepancies were resolved by the last author (GM).

Statistical Analysis

Analyses were performed using the Comprehensive Meta-Analysis (version 2.2.064) software (Biostat, Englewood, NJ, USA). The pre-test and post-test means and standard deviations (SDs) were extracted from the intervention and the control groups. The effect size of each study was estimated on the basis of the net change in balance measures (i.e. the differences between the pre–post mean differences for both groups). As recommended,[24] the effect size was then standardized using the change scores' SDs. This method has been preferred to the post scores' SDs, because it is less sensitive to differences in preintervention measures that might occur with small sample sizes, and is most appropriate when the objective is to examine pre–post changes on intervention measures.[24] The change scores' SDs were calculated for each study on the basis of the SD of pre-intervention and post-intervention balance measures for both groups, and the pre–post correlations. Given that the pre–post correlations were not reported in any of the reviewed studies, we used the recommended value of 0.70.[25–27]

Given that multiple studies reported several balance parameters (e.g. center of pressure [maximum, SD, and velocity]; path length of the center of pressure) measured in various conditions (e.g. open/closed eyes, one/double leg stance, foam/hard floor), the estimation of each study's effect size was performed using a composite balance score (combining conditions and parameters) computed by the Comprehensive Meta-Analysis software. Moreover, separate analyses were performed according to the balance parameters used in the studies. When a study had measured a parameter in various conditions, a composite balance parameter score (combining conditions) computed by the Comprehensive Meta-Analysis software was used. Finally, when a study comprised either two control groups or two experimental groups, two distinct effect sizes were estimated.

Given the small sample size (n<20; see Lakens[28]) used in the reviewed studies, the pooled effect size of each balance outcome was estimated using the corrected (J) Hedges' g[29] with 95% confidence intervals (CIs). Because we were expecting heterogeneity (e.g. exercise interventions, participants' characteristics, balance measures, etc.) between the reviewed studies, a random-effects model was used. The forest plots of the pooled Hedges' g for each balance outcome were drawn using a Microsoft Excel spreadsheet retrieved from https://tbslaboratory.com/2014/06/26/forest-plots-in-excel/. A positive value of Hedges' g suggested a balance improvement in the intervention group compared with the control group. On the basis of Cohen's[30] recommendations, Hedges' g values of no more than 0.2, between 0.21 and 0.79, and at least 0.8 were taken to indicate a small, medium, and large effect size respectively.[28,31]

The heterogeneity of the different pooled Hedges' g was examined using a Q test[32] and the I^2 statistic.[33] Additionally, potential publication bias was examined using several statistical tests (Begg and Mazundar's rank correlation test;[34,35] Duval and Tweedie's 'trim and fill' test;[36] Egger's test of the intercept[37]). Finally, a series of prespecified subgroup analyses were examined (using a mixed-effects model) for the five following variables: (1) design (quasi-experimental vs experimental); (2) age group (children vs adolescents); (3) intellectual disability level (mild, mild–moderate, moderate); (4) type of balance measure (clinical measures of balance vs posturography measures of balance parameters [excluding time spend in equilibrium] using a force plate, a stabilometric platform, or a pressure platform); and (5) exercise components (i.e. balance, strength, and multi-components). When only one study was available in a prespecified subgroup, no analysis was performed.

Results

Selection of the Studies

As reported in Figure S1 (online supporting information), the search strategy identified 1954 articles. When duplicates were removed, this number fell to 937. Then, 902 articles that did not meet the inclusion criteria were excluded on the basis of their title or abstract. The full texts of the 35 remaining articles were then examined, leading to the exclusion of a further 20 studies (see Appendix S2 [online supporting information] for the full references of these studies and Fig. S1 for the exclusion motives). A total of 15 studies, published between 1991 and 2017, met the inclusion criteria. Characteristics of these studies and the interventions being assessed are summarized in Table I.

Characteristics of the Reviewed Studies

Sample Characteristics and Design. As shown in Table I, seven of the 15 studies of young people with intellectual disabilities were conducted in Europe, five in the Eastern Mediterranean area, two in Western Pacific, and one in North America. More than half of these studies were experimental (nine out of 15), while the others were quasi-experimental (six out of 15). A total of 403 young people with intellectual disabilities (mean 13 years and 5 months, SD 4 years and 5 months, sample range 8–25y) were involved in these studies. In the reviewed studies, the young people were essentially recruited in schools (73%), half had mild intellectual disabilities (53%), and most of them were males (71%). Finally, seven of the studies were composed of children and eight of adolescents.

Type of Exercise Interventions and Control Condition. As shown in Table II, seven of the studies used balance and/or strength exercises,[40,42,43,48,50,51,52] whereas the remaining used computerized balance exercises (Wii Fit balance game training),[46] creative dance activities,[41] hippotherapy exercises,[38,45] rope-skipping exercises,[47] Swiss ball exercises,[49] tai chi exercises,[39] and trampoline.[44] The main exercise components in these interventions were balance,[38-40,42,43,46,49–51] strength,[40,52] or multiple.[41,44,45,47,48] These interventions lasted from 6 to 16 weeks (mean 9.5wk, SD 2.6), and training sessions were mainly held three times a week (mean 2.9 times, SD 0.7) and lasted from 20 to 60 minutes (mean 39.6min, SD 10.1).

However, none included a follow-up period. Among these studies, nine mentioned who delivered the intervention (e.g. adapted physical activity instructor, physical therapist, physical education teacher), one mentioned the setting of the intervention, and none described whether the intervention was adapted during trial or whether strategies to maintain conformity were provided. Finally, in 12 of the studies, young peoples with intellectual disabilities involved in the control condition followed regular school schedule/training routines, a traditional movement program, or a physical education program. The findings from the different studies are reported in Table SI (online supporting information).

Balance Measures. As shown in Table II, 11 out of 15 studies assessed static balance, seven assessed dynamic balance, and two assessed static–dynamic balance. Participants' static balance was measured with a double leg stance condition in eight studies, and with a one leg stance condition in eight studies. The young peoples' static balance was measured while disturbing visual cues (eyes opened vs eyes closed) in eight studies, and disturbing plantar cutaneous sensitivity (firm floor vs foam floor) in two studies. Participants' balance was measured mostly using force (in nine studies), plate/pressure, or stabilometric platforms (static or dynamic). The remaining studies used clinical balance tests, such as the balance subtest of the balance beam test,[53] Berg Balance Test,[54] Bruininks-Oseretsky Test of Motor Proficiency,[55] one leg stance test,[56] Pediatric Balance Scale,[57] Sit-and-Stand Test,[58] Star or modified Excursion Balance Test,[59,60] Stork Test,[61] and Timed Up and Go Test.[62] In these studies, estimates of balance were standing time (in seconds) in six studies, center of pressure (maximum, SD, radial, sway, and velocity) and path length or sway area in eight, and limits of stability or balance scale's score in five.

Effects of Exercise Interventions Designed to Improve Balance

Static Balance. The pooled Hedges' *g* value was estimated on the basis of the results from 11 studies (12 effect sizes given that one study had two control groups) focusing on static balance (see Fig. 1a for the forest plot). When the effects of all exercise intervention groups were pooled, the results indicated a large and statistically significant improvement in static balance compared with control groups (g=0.98, 95% CI 0.65–1.32, z=5.73, p<0.001). Cochrane's I^2 indicated a very high level of heterogeneity (Q_{11}=44.6, p<0.001; I^2=75.3). No evidence of publication bias was noted by most of the tests (Begg and Mazundar's rank correlation test, p=0.10; Egger's test, p=0.20), except for Duval and Tweedie's 'trim and fill' test (Fig. S2a, online supporting information), which revealed that two studies were missing on the left of the funnel plot. When these studies were imputed to obtain a symmetrical funnel plot, the pooled Hedges' *g* value became 0.82 (95% CI 0.46–1.18). Additional analyses were performed as a function of the individual balance parameters used in the reviewed studies. Results from these analyses are presented in Table SII, online supporting information (references for these studies are provided in Table SIII, online supporting information). The pooled effects of exercise intervention groups were statistically significant for 12 of the 21 static balance parameters and showed a medium to large (g_{range}=0.54–1.79) improvement compared with control groups (Table SII).

Dynamic Balance. The pooled Hedges' *g* value was estimated on the basis of the results from seven (eight effect sizes given that one study had two control groups) studies focusing on dynamic balance (see Fig. 1b for the forest plot). When the effects of all exercise intervention groups were pooled, the results indicated a large and statistically significant improvement in dynamic balance compared with control groups (g=1.34, 95% CI 0.71–1.97, z=4.17, p<0.001). Cochrane's I^2 revealed a very high level of heterogeneity (Q_7=32.1, p<0.001; I^2=78.2). A publication bias was noted by Begg and Mazundar's rank correlation test (p=0.02), Egger's test (p=0.01), and Duval and Tweedie's 'trim and fill' test (Fig. S2b), which showed that three studies were missing on the left of the funnel plot. When these studies were imputed to obtain a symmetrical funnel plot, the pooled Hedges' *g* value became 0.79 (95% CI 0.11–1.46). Additional analyses were performed as a function of the six individual dynamic balance parameters used in the reviewed studies. Results from these analyses are presented in Tables SII and SIII. The pooled effects of exercise intervention groups were statistically significant for half of the dynamic parameters and showed a large (g_{range}=0.99–3.69) improvement compared with control groups (Table SII).

Static-Dynamic Balance. The pooled Hedges' *g* value was estimated on the basis of the results from only two studies (three effect sizes given that one study had two experimental groups) focusing on static–dynamic balance (see Fig. 1c for the forest plot). Although the pooled improvement in static–dynamic balance was large for the exercise intervention groups compared with control groups, this result was statistically non-significant (g=2.80, 95% CI −0.06 to 5.67, z=1.92, p=0.06). Cochrane's I^2 indicated a very high level of heterogeneity ($Q_{2=}$33.1, p<0.001; I^2=94), which may be because of the very small number of studies. A publication bias was noted by Egger's test (p=0.02) and Duval and Tweedie's 'trim and fill' test (but not by Begg and Mazundar's rank correlation test, p=0.15) (Fig. S2c), which showed that two studies were missing on the left of the funnel plot. When these studies were imputed to obtain a symmetrical funnel plot, the pooled Hedges' *g* value became 0.29 (95% CI −2.47 to 3.04). Finally, given the very few reviewed studies, no analysis was performed as a function of the static–dynamic balance parameters.

Subgroup Analyses

Static Balance. Analyses showed significant differences in the pooled Hedges' *g* value according to the design of the study (see Table SIV for results and Table SV for the references to the studies, online supporting information). More specifically, the pooled Hedges' *g* value was significantly higher in the quasi-experimental (g=1.23) than in the experimental (g=0.62) studies. However, no significant differences in pooled Hedges' *g* values were found according to age samples, intellectual disability level, type of balance measure (clinical vs posturography), and components of exercise interventions (Table SIV).

Dynamic Balance. Analyses showed significant differences in the pooled Hedges' *g* value according to the intellectual disability level of the young people included in the reviewed studies (Tables SIV and SV). More specifically, the pooled Hedges' *g* value was significantly higher in studies comprising young people with a mild intellectual disability level (g=1.82) than in those comprising young people with a mild–moderate intellectual disability level (g=0.48). However, even though pooled Hedges' *g* values were higher in adolescents than in children, and in quasi-experimental than in experimental studies, none of these differences were statistically significant (Tables SIV and SV). Additionally, no significant differences in pooled Hedges' *g* values were found according to the components of exercise interventions. Finally, no subgroup analyses were performed as a function of type of balance measure owing to an insufficient number of studies in the prespecified groups.

Static-Dynamic Balance. No subgroup analyses were performed owing to insufficient studies in the prespecified subgroups.

Quality Assessment of the Reviewed Studies

The results of the quality assessment of the reviewed studies are presented in Table III. Most of the studies (12 out of 15) had a low-quality rating. The total mean score obtained by the studies on the Physiotherapy Evidence Database scale was 3.9 out of 10 (SD 1.6; range 1–6). The most frequently satisfied criteria were the point measures and measures of variability (15 out of 15), the random allocation of participants in groups (nine out of 15), the proportion of participants having at least one key outcome measured (nine out of 15), the compliance with assigned intervention (nine out of 15), the intergroup statistical comparisons (nine out of 15), the reporting of inclusion criteria (eight out of 15), and the similarity between groups in relevant variables at baseline (eight out of 15). However, none of the studies met the criteria related to concealed allocation, blinding of participants, blinding of investigators, and blinding of assessors.

Discussion

The purpose of this article was twofold: (1) to estimate the pooled effect size of exercise interventions on the improvement of balance in young people with intellectual disabilities; and (2) to examine whether the pooled effect size of exercise interventions on balance differed as a function of prespecified characteristics of the studies.

Effects of Exercise Interventions and Subgroup Analyses

Static Balance. The postural performance related to static balance reflects the ability of the postural control to minimize body sway in a quiet stance condition. Findings showed that the pooled effect size of 11 studies examining the effects of exercise interventions on the static balance of young people with intellectual disabilities was large (g=0.98) and also remained large when publication bias was considered (g=0.82). More specifically, the present results showed the effects of exercise intervention were large (g>0.80) in 45% of the reviewed studies,[39,43,46–48] and medium in 55%.[38,42,44,45,50,51] Studies demonstrating the largest effect size (g>0.80) relied on tai chi exercises,[39] balance and/or strength exercises,[43,48] Wii Fit balance game training,[46] and rope-skipping exercises.[47] This suggests that types of exercise intervention focusing on balance or multiple components (balance, coordination, and strength components) are highly efficient in improving the balance of young people with intellectual disabilities. This conclusion is in accordance with results observed in the literature in other populations.[15–18] Indeed, types of exercise inducing greater increases of postural stability in older persons[15–17] or in children with cerebral palsy are those specifically targeting balance abilities.[18] Moreover, standing balance measured by stabilometry in children with cerebral palsy was not improved after a strength exercise intervention (resisted ankle and knee exercise).[18] These results could be explained by a better improvement of the integration of the efferent neuromuscular and sensorimotor inputs associated with balance or multi-component exercise training leading to an increased postural control.

Subgroup analysis revealed that the improvement of static balance was significantly higher in quasi-experimental studies (g=1.23) than in experimental studies (g=0.62). This difference might have been due to a selection bias (non-randomly assigned vs randomly assigned) where participants in the exercise intervention group had a profile more likely to benefit from exercise to improve their balance parameters. Nevertheless, additional results showed that the effects of these exercise interventions were of similar magnitude between studies: (1) focusing on males or adolescents, (2) focusing on young people with mild, mild–moderate, or moderate intellectual disability, and (3) measuring static balance with a clinical test or posturography. Consequently, on the basis of the present findings, it can be concluded that the reviewed exercise interventions represent an effective means for improving the static balance of young people with intellectual disabilities.

Dynamic Balance. The postural performance related to dynamic balance refers to the ability to maintain body balance in challenging postural conditions (dynamic stance). Findings showed that the pooled effect size of the six studies examining the effects of exercise interventions on the dynamic balance of young people with intellectual disabilities was large (g=1.34), even when it was corrected for publication bias (g=0.79). More specifically, the present results showed that the effectiveness of exercise intervention was large (g>0.80) in 57% of the reviewed studies,[39,46,47,52] and medium in 43%.[41,42,49] Studies demonstrating the largest effect size (g>0.80) focused on strength exercises,[52] tai chi exercises,[39] Wii Fit balance game training,[46] and rope-skipping exercises.[47] Subgroup analysis revealed that dynamic balance improvement was significantly higher in studies comprising young people with a mild intellectual disability level (g=1.82) than in those comprising young people with a mild–moderate intellectual disability level (g=0.48). This result may be explained by differences in mechanisms of postural control and regulation according to the level of intellectual disability in the young person. However, the effects of exercise interventions were of a similar magnitude on dynamic balance according to age group, design of the studies, and type of balance measures. These findings are encouraging, but they should be considered as preliminary given the very few studies examining dynamic balance in young people with intellectual disabilities. In contrast with the results observed for static balance, dynamic balance appeared to improve with exercise interventions focusing on balance, strength, or multiple components. This result is in accordance with a conclusion reported in older individuals, suggesting that performance in tasks involving dynamic balance (i.e. gait) increases when targeting muscle function.[16]

Static-Dynamic Balance. Findings showed that the pooled effect size of the two studies examining the effects of exercise interventions on the static–dynamic balance of young people with intellectual disabilities was large (g=2.80) but non-significant. However, when publication bias was considered, the effect of these interventions was medium (g=0.29). More specifically, in one study, the effects of balance or strength exercises on static–dynamic balance were large,[40] whereas in the study focusing on the Swiss ball exercises the effects were medium.[49] No subgroup analyses were performed owing to insufficient studies in prespecified subgroups. Given the limited number of studies and their heterogeneity, further research is needed to estimate the effectiveness of exercise interventions on static–dynamic balance more precisely.

Posturography versus clinical tests. The performance of the postural control system is typically evaluated with static (static position and environment during quiet standing) and/or dynamic (postural response to an applied or voluntary postural perturbation) posturography.[63] Mean speed displacement of the center of pressure, which corresponds to the cumulative distance over the sampling period, is used to assess the ability of individuals to control their balance and is considered one of the most sensitive and discriminant parameters of postural stability.[64,65] Conversely, clinical tests or practical tests are commonly used for individuals with weak postural abilities (especially older people) when it seems impossible to perform qualitative analyses of postural control among young patients with pathologies.[9] However, the subgroup analyses of the current meta-analysis did not show any difference in the effects of exercise interventions according to the method used to measure balance of young people with intellectual disabilities. This suggests that both methods can correctly assess the positive effect of an exercise intervention in young people with intellectual disabilities.

Clinical Implications

Young people with intellectual disabilities often experience balance problems reflected in their reduced motor capacity.[44,48] Static and dynamic balance improvements are very important for these young people, because they provide them with greater stability while performing activities inherent in daily living, and thus decrease the occurrence of accidents or falls, resulting in a lower incidence of injuries.[66] From a clinical perspective, on the basis of the present findings, professionals should focus their intervention on postural adaptations related to balance and neuromuscular control with specific balance components or multi-component exercises to improve static balance. When targeting dynamic balance, strength components should be used in the same way as balance components or multi-components to improve postural function with an exercise intervention.

Directions for Future Studies

Although informative, the present conclusions should be interpreted with caution given the limitations of the reviewed studies. First, the number of studies focusing on static–dynamic balance is insufficient to draw firm conclusions about the effect of exercise interventions. Second, except Borji et al.,[40] none of the reviewed studies directly compared the effects of different exercise interventions on balance improvement, which results in minimal direction for clinicians to decide which exercise interventions to implement to maximize outcomes for young people with intellectual disabilities. Similarly, most studies failed to provide sufficient details about their exercise interventions (e.g. setting of the intervention, who delivered the intervention, adaptation of the intervention during the trial, strategies to maintain the fidelity of the intervention). It is therefore impossible to determine which configurations of exercise intervention characteristics and contextual features are critical for successful outcomes. This issue should be more thoroughly examined in future studies so that research findings are able to translate to improved practice in the field. Third, the exercise interventions were only conducted for a short period (mean 10wk). Short-duration programs may not suffice to support the physical and cognitive integration of the new skills and thus the long-term modification of balance ability. Additionally, the duration and frequency of the training sessions were very similar between studies, and none examined the dosage effects of their training program. Fourth, none of the reviewed studies examined the maintenance of benefits after the training program. These various issues (optimal exercise intervention components, dosage, long-term maintenance, etc.) should thus be more thoroughly considered in future studies. Fifth, it is important to keep in mind that most of the reviewed studies obtained a low score for method quality. Most notably, all studies failed to demonstrate concealed allocation, blinding of participants, blinding of investigators, and blinding of assessors, which are all required to substantiate evidence of the strong efficacy of an intervention.[67] Moreover, most of the reviewed studies conducted with adolescents were not experimental. Improvement in method quality of exercise interventions designed to improve balance in young people with intellectual disabilities should thus be a priority in future research. Sixth, given that we used a composite balance score, we were not able to perform meta-regression on continuous moderators such as the total duration of the exercise intervention, session duration in minutes, and number of sessions per week. Therefore, this issue should be examined in future meta-analytical studies. Finally, as mentioned by Greenland[68] and Bailar,[69] meta-analyses are not without critics or limitations. Indeed, even though the reviewed studies share similar features, they remain heterogeneous in their design, characteristics, and methodological quality. This heterogeneity was considered in the analyses, which still revealed consistent findings across this diverse set of studies. Still, the conclusion of this initial meta-analysis on the effects of exercise interventions on the balance of young people with intellectual disabilities must be interpreted with caution given this heterogeneity as effects might have been harder to fully consider given the globally small number of studies reviewed.

Conclusion

In conclusion, findings from this first systematic review and meta-analysis show that exercise interventions seem to be an efficient means to improve static and dynamic balance among young people with intellectual disabilities. The exercise interventions also successfully improved static–dynamic balance, but the findings for this should be considered as preliminary given the small number of studies and their limitations. Although these results may support the implementation of exercise interventions by clinicians, educators, and policy-makers, more rigorous research is required to better inform resource allocation. Intervention formulation requires that future studies rely on a design and methodology with a lower risk of bias and that the intervention program should be better described concerning, for example, the setting in which the intervention was provided, who delivered the intervention, whether the intervention was adapted during the trial, and whether strategies to maintain intervention fidelity were provided. It is only through the conduct of such high-quality research, and detailed reporting, that practice can be efficiently adjusted to strengthen the physical ability, physical activity, and ultimately physical health of young people with intellectual disabilities.

References

1. Schalock RL, Luckasson RA, Shogren KA. The renaming of mental retardation: understanding the change to the term intellectual disability. *Intellect Dev Disabil* 2007; **45**: 116–24.

2. Krahn GL, Hammond L, Turner A. A cascade of disparities: health and health care access for people with intellectual disabilities. *Ment Retard Dev Disabil Res Rev* 2006; **12**: 70–82.

3. Lloyd M. Physical activity of individuals with intellectual disabilities: challenges and future directions. *Curr Dev Disord Rep* 2016; **3**: 91–3.

4. Hartman E, Smith J, Westendorp M, Visscher C. Development of physical fitness in children with intellectual disabilities. *J Intellect Disabil Res* 2015; **59**: 439–49.

5. Adamović M, Stošljević M. The ability to maintain postural balance in adolescents with mild intellectual disability and adolescents with typical development. *Spec Eduk Rehabil* 2013; **12**: 425–39.

6. Blomqvist S, Olsson J, Wallin L, Wester A, Rehn B. Adolescents with intellectual disability have reduced postural balance and muscle performance in trunk and lower limbs compared to peers without intellectual disability. *Res Dev Disabil* 2013; **34**: 198–206.

7. Salaun L, Berthouze-Aranda SE. Physical fitness and fatness in adolescents with intellectual disabilities. *J Appl Res Intellect Disabil* 2012; **25**: 231–9.

8. Paillard T. Plasticity of the postural function to sport and/or motor experience. *Neurosci Biobehav Rev* 2017; **72**: 129–52.
9. Paillard T, Noé F. Techniques and methods for testing the postural function in healthy and pathological subjects. *Biomed Res Int* 2015; **2015**: 891390.
10. Horak FB, Shupert CL, Mirka A. Components of postural dyscontrol in the elderly: a review. *Neurobiol Aging* 1989; **10**: 727–38.
11. Sparrow WA, Shinkfield AJ, Summers JJ. Gait characteristics in individuals with mental retardation: unobstructed level-walking, negotiating obstacles, and stair climbing. *Hum Mov Sci* 1998; **17**: 167–87.
12. Enkelaar, L, Smulders E, van Schrojenstein Lantman-de Valk H, Geurts AC, Weerdesteyn V. A review of balance and gait capacities in relation to falls in persons with intellectual disability. *Res Dev Disabil* 2012; **33**: 291–306.
13. Patikas, D. Gait and balance. In: Matson JL, Matson ML, editors. Comorbid conditions in individuals with intellectual disabilities. Cham, Switzerland: Springer, 2015: 317-349.
14. Sherrard J, Tonge BJ, Ozanne-Smith J. Injury in young people with intellectual disability: descriptive epidemiology. *Inj Prev* 2001; **7**: 56–61.
15. Howe TE, Rochester L, Neil F, Skelton DA, Ballinger C. Exercise for improving balance in older people. *Cochrane Database Syst Rev* 2011; **11**: CD004963.
16. Lesinski M, Hortobágyi T, Muehlbauer T, Gollhofer A, Granacher U. Effects of balance training on balance performance in healthy older adults: a systematic review and meta-analysis. *Sports Med* 2015; 4**5**: 1721–38.
17. Low DC, Walsh GS, Arkesteijn M. Effectiveness of exercise interventions to improve postural control in older adults: a systematic review and meta-analyses of centre of pressure measurements. *Sports Med* 2017; **47**: 101–12.
18. Dewar R, Love S, Johnston LM. Exercise interventions improve postural control in children with cerebral palsy: a systematic review. *Dev Med Child Neurol* 2015; **57**: 504–20.
19. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analysis of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med* 2009; **6**: e1000100.
20. Moseley AM, Maher C, Herbert RD, Sherrington C. Reliability of a scale for measuring the methodological quality of clinical trials. Proceedings of the VIIth Cochrane Colloquium*.* Rome, Italy: Cochrane Center, 1999: 39.
21. Brosseau L, Laroche C, Sutton A, et al. Une version franco-canadienne de la Physiotherapy Evidence Database (PEDro) Scale: L'Échelle PEDro. *Physiother Can* 2015; **67**: 232–9.
22. Moseley AM, Herbert RD, Sherrington C, Maher CG. Evidence for physiotherapy practice: a survey of the Physiotherapy Evidence Database (PEDro). *Aust J Physiother* 2002; **48**: 43–9.
23. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther* 2003; **83**: 713–21.
24. Johnsen TJ, Friborg O. The effects of cognitive behavioral therapy as an anti-depressive treatment is falling: a meta-analysis*. Psychol Bull* 2015; **141**: 747–68.
25. Rosenthal R. Meta-analytic Procedures for Social Research. Newbury Park, CA: Sage Publications, 1993.
26. Khoury B, Lecomte T, Fortin G, et al. Mindfulness-based therapy: a comprehensive meta-analysis. *Clin Psychol Rev* 2013; **33**: 763–71.
27. Lever Taylor B, Cavanagh K, Strauss C. The effectiveness of mindfulness-based interventions in the perinatal period: a systematic review and meta-analysis. *PLoS One 2016*; **11**: e0155720.
28. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol* 2013; **4**: 863.
29. Hedges LV. Distribution theory for Glass's estimator of effect size and related estimators. *J Educ Stat* 1981; **6**: 107–28.

30. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Hillsdale, NJ: Lawrence Earlbaum Associates, 1988.
31. Durlak JA. How to select, calculate, and interpret effect sizes. *J Pediatr Psychol* 2009; **34**: 917–28.
32. Cochran WG. The comparison of percentages in matched samples. *Biometrika* 1950; **37**; 256–66.
33. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003; **327**: 557–60.
34. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. *Biometrics* 1994; **50**: 1088–101.
35. Begg CB, Berlin JA. Publication bias: a problem in interpreting medical data. *J R Statist Soc A* 1988; **151**: 419–63.
36. Duval S, Tweedie R. Trim and fill: a simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics* 2000; **56**: 455–63.
37. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997; **315**: 629–34.
38. Ambroży T, Mazur-Rylska A, Chwała W et al. The role of hippotherapeutic exercises with larger support surface in development of balance in boys aged 15 to 17 years with mild intellectual disability. *Acta Bioeng Biomech* 2017; **19**: 143–51.
39. Azadeh M, Yahya S, Reza S. The effect of 8 weeks of tai chi exercises on girls' static and dynamic balance with intellectual disability. *Biol Forum* 2015; **7**: 1256–9.
40. Borji R, Sahli S, Baccouch R, Laatar R, Kachouri H, Rebai H. An open-label randomized control trial of hopping and jumping training versus sensorimotor rehabilitation programme on postural capacities in individuals with intellectual disabilities. *J Appl Res Intellect Disabil* 2018; **31**: 318–23.
41. Boswell B. Comparison of two methods of improving dynamic balance of mentally retarded children. *Percept Mot Skills* 1991; **73**: 759–64.
42. Dehghani M, Gunay M. The effect of balance training on static and dynamic balance in children with intellectual disability. *J Appl Environ Biol Sci* 2015; **5**: 127–31.
43. Fotiadou EG, Neofotistou KH, Giagazoglou PF, Tsimaras VK. The effect of a psychomotor education program on the static balance of children with Intellectual Disability. *J Strength Cond Res* 2017; **31**: 1702–8.
44. Giagazoglou P, Kokaridas D, Sidiropoulou M, Patsiaouras A, Karra C, Neofotistou, K. Effects of a trampoline exercise intervention on motor performance and balance ability of children with intellectual disabilities. *Res Dev Disabil* 2013; **34**: 2701–7.
45. Giagazoglou P, Arabatzi F, Dipla K, Liga M, Kellis E. Effect of a hippotherapy intervention program on static balance and strength in adolescents with intellectual disabilities. *Res Dev Disabil* 2012; **33**: 2265–70.
46. Hsu TY. Effects of Wii Fit® balance game training on the balance ability of students with intellectual disabilities. *J Phys Ther Sci* 2016; **28**: 1422–6.
47. Ilbeigi S, Khirkhah M, Mahjur M, Soltani H, Jafarkhoshbakhti. Investigating the effects of 8 weeks of rope skipping on static and dynamic balance of educable mentally retarded boys. *Int J Med Res Health Sci* 2016; **5**: 349–53.
48. Kachouri H, Borji R, Baccouch R, Laatar R, Rebai H, Sahli S. The effect of a combined strength and proprioceptive training on muscle strength and postural balance in boys with intellectual disability: An exploratory study. *Res Dev Disabil* 2016; **53**: 367–76.
49. Kubilay NS, Yildirim Y, Kara B, Harutoğlu-Akdur HH. Effect of balance training and posture exercises on functional level in mental retardation. *Fizyoter Rehabil* 2011; **22**: 55–64.
50. Lee K, Lee M, Song C. Balance training improves postural balance, gait, and functional strength in adolescents with intellectual disabilities: single-blinded, randomized clinical trial. *Disabil Health J* 2016; **9**: 416–22.
51. Mikolajczyk E, Jankowicz-Szymanska A. The effect of unstable-surface functional exercises on static balance in adolescents with intellectual disability – a preliminary report. *Stud Med* 2014; **30**: 1–5.

52. Rahmat R, Daneshmandi H, Barati AH. The effect of 6 weeks core stabilization training program on the balance in mentally retarded students. *Med Sport* 2012; **8**: 2003–8.
53. Deoreo K, Wade M. Dynamic and static balancing ability of pre-school children. *J Mot Behav* 1971; **3**: 326–35.
54. Berg K, Wood-Dauphinee S, Williams J, Gayton D. Measuring balance in the elderly preliminary development of an instrument. *Physiother Can* 1989; **41**: 304–11.
55. Bruininks RH. Bruininks Oseretsky Test of Motor Proficiency. Circle Pines, MN: American Guidance Service, 1978.
56. Bohannon RW, Larkin PA, Cook AC, Gear J, Singer J. Decrease in timed balance test scores with aging. *Phys Ther* 1984; **64**: 1067–70.
57. Franjoine MR, Gunther JS, Taylor MJ. Pediatric Balance Scale: a modified version of the berg balance scale for the school-age child with mild to moderate motor impairment. *Pediatr Phys Ther* 2003; **15**: 114–28.
58. Bohannon RW. Sit-to-stand test for measuring performance of lower extremity muscles. *Percept Mot Skills* 1995; **80**: 163–6.
59. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther* 2009; **4**: 92–9.
60. Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. *J Orthop Sports Phys Ther* 1998; **27**: 356–60.
61. Peltenburg AL, Erich WB, Bernink MJ, Huisveid IA. Selection of talented female gymnasts, aged 8 to 11, on the basis of motor abilities with special reference to balance: a retrospective study. *Int J Sports Med* 1982; **3**: 37–42.
62. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991; **39**: 142–8.
63. Prieto TE, Myklebust JB, Hoffmann RG, Lovett EG, Myklebust BM. Measures of postural steadiness: differences between healthy young and elderly adults. *IEEE Trans Biomed Eng* 1996; **43**: 956–66.
64. Baratto L, Morasso PG, Re C, Spada G. A new look at posturographic analysis in the clinical context: sway-density versus other parameterization techniques. *Motor Control* 2002; **6**: 246–70.
65. Raymakers JA, Samson MM, Verhaar HJ. The assessment of body sway and the choice of the stability parameter(s). *Gait Posture* 2005; **21**: 48–58.
66. Seagraves F, Horvat M, Franklin C, Jones K. Effects of a school-based program on physical function and work productivity in individuals with mental retardation. *Clin Kinesiol* 2004; **58**: 18–29.
67. National Health and Medical Research Council. NHMRC levels of evidence and grades for recommendations for guideline developers. Canberra, Australia: National Health and Medical Research Council, 2009.
68. Greenland S. Can meta-analysis be salvaged? *Am J Epidemiol* 1994; **140**: 783–7.
69. Bailar JC 3rd. The promise and problems of meta-analysis. *N Engl J Med* 1997; **337**: 559–61

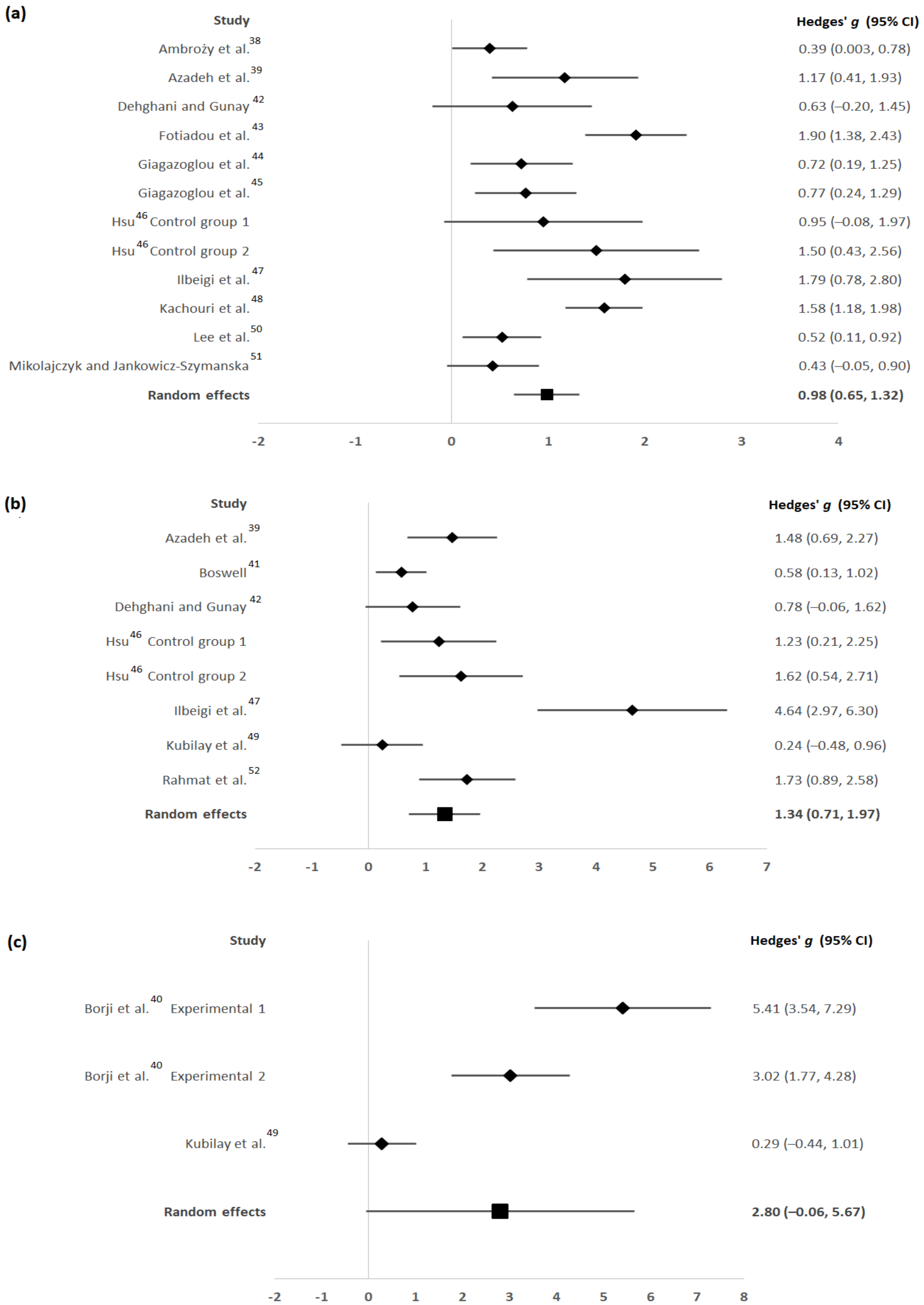


Figure 1. Forest plot of Random-Effects Pooled Hedges' *g* for (a) static, (b) dynamic, and (c) static-dynamic balance

Table I: Characteristics of the studies included in the meta-analysis

Study	Country	Design	Recruitment setting	Age samples	Intellectual disability level	Intervention group				Control group			
						Sample size (*n*)	Males (%)	Age range (y)	Mean age (y:mo)	Sample size (*n*)	Males (%)	Age range (y)	Mean age, y:mo
Ambroży et al.[38]	Poland	QE	SS	Adolescents	Mild	25	100	15–17	16:1	25	100	15–17	16:0
Azadeh et al.[39]	Iran	QE	NM	Adolescents	NM	15	0	12–19	NM	15	0	12–19	NM
Borji et al.[40]	Tunisia	EXP	NUAMI	Children	Mild	10/10 [a]	NM	NM	11:5/12:4 [a]	10	NM	NM	11:6
Boswell[41]	USA	EXP	RS	Children	Mild–mod	13	46	8–13	10:6	13	62	8–13	11:1
Dehghani and Gunay[42]	Turkey	EXP	SS	Children	Mild	11	NM	8–13	10:4	11	NM	8–13	10:1
Fotiadou et al.[43]	Greece	QE	RS, SS	Children	Mild–mod	10	NM	8–12	NM	10	NM	8–12	NM
Giagazoglou et al.[44]	Greece	EXP	SS	Children	Mild–mod	9	78	NM	NM	9	78	NM	NM
Giagazoglou et al.[45]	Greece	QE	SS	Adolescents	Mod	10	NM	NM	15:2	9	NM	NM	15:4
Hsu[46]	Taiwan	EXP	NM	Adolescents	Mild	8	NM	NM	17:6	8/8[b]	NM	NM	17:10/17:5 [b]
Ilbeigi et al.[47]	Iran	QE	SS	Adolescents	Mild	10	100	10–17	12:2	10	100	10–17	13:7
Kachouri et al.[48]	Tunisia	QE	SS	Children	Mild	10	100	9–13	11:5	10	100	9–13	11:6
Kubilay et al.[49]	Turkey	EXP	SS	Adolescents	Mild–mod	14	36	NM	14:4	14	50	NM	16:8
Lee et al.[50]	South Korea	EXP	SS	Adolescents	Mild	15	53	14–19	16:4	16	56	14–19	17:1
Mikolajczyk and Jankowicz-Szymanska[51]	Poland	EXP	SS	Adolescents	Mod	17	88	14–16	NM	17	76	14–16	NM
Rahmat et al.[52]	Iran	EXP	NM	Children	Mild	17	100	NM	11:2	14	100	NM	11:1

EXP, experimental; NM, not mentioned; QE, quasi-experimental; SS, special school; mod, moderate; NUAMI, National Union of Aid to Mental Insufficiency; RS, regular school. [a]This study comprises two intervention groups: strength and balance; [b]This study comprises two control groups: sedentary and physical education.

Table II: Description of exercise interventions, control condition, and balance measures of the studies included in the meta-analysis

Study	Exercise interventions						Types of control condition	Balance measures		
	Types (exercise components)	Setting (delivery)	Adaptation (fidelity)	Total duration (wk)	Follow-up	Session duration, min (frequency/wk)		Types (conditions)	Assessment method	Parameters
Ambroży et al.[38]	Hippotherapy exercises (balance)	Equestrian center (HIP)	NM (NM)	12	—	45 (3)	PE classes	Static (DLS; NBOS, RBOS)	Force plate	COP-max (M-L and A–P [cm]), COP-sway (SD and in mean; M-L and A–P [cm]), COP-radial (cm), COP-velocity (cm/s), PATH-L (cm)
Azadeh et al.[39]	Tai chi exercises (balance)	NM (RES)	NM (NM)	8	—	60 (3)	NM	Static (OLS), dynamic	Stork Test, Sit-and-Stand Test	STAND-T (s)
Borji et al.[40]	Group 1 strength (strength) and group 2 balance (balance)	NM (NM)	NM (NM)	8	—	45 (3)	NM	Static–dynamic balance (EO–EC)	BBS[a]	Static–dynamic balance score
Boswell[41]	Creative dance activities (multi-components)	NM (NM)	NM (NM)	8	—	30 (3)	Traditional movement program	Dynamic (DLS-EO, forward–backward)	Dynamic stabilometric platform, balance beam test	STAND-T (s), total distance of walk (cm)
Dehghani and Gunay[42]	Balance exercises (balance)	NM (NM)	NM (NM)	10	—	40 (2)	Regular school schedule	Static (OLS-EC–EO), dynamic	BOTMP (balance subtest)	Static and dynamic balance scores
Fotiadou et al.[43]	Balance exercises (balance)	NM (NM)	NM (NM)	16	—	45 (3)	Regular school schedule	Static (DLS-EO/EC, DLS-VT/VAT)	Pressure platform	COP-max (M-L and A–P [cm]), COP-SD (M-L and A–P [cm])
Giagazoglou et al.[44]	Trampoline exercises (multi-components)	NN (PET)	NM (NM)	12	—	20 (5)	Regular school schedule	Static (DLS-EO/EC, OLS-EO)	Pressure platform	COP-max (M-L and A–P [mm]), COP-SD (M-L and A–P [mm])
Giagazoglou et al.[45]	Hippotherapy exercises (multi-component)	NM (PHT)	NM (NM)	10	—	30 (2)	Regular school schedule	Static (DLS-EO/EC, OLS-LLS[b]/RLS)	Pressure platform	COP-max (M-L and A–P [mm]), COP-SD (M-L and A–P [mm])

Hsu[46]	Wii Fit balance game training (balance)	NM (NM)	NM (NM)	8	—	40 (2)	PE program (group 1), sedentary (group 2)	Static (OLS-EC), dynamic	Force plate, Timed Up and Go test	COP-velocity (M-L and A–P [cm/s]), sway area (cm^2/s), STAND-T (s)
Ilbeigi et al.[47]	Rope-skipping exercises (multi-components)	NM (RSC)	NM (NM)	8	—	45 (3)	NM	Static (OLS-EO), dynamic	Stork Test, Modified Star Excursion Balance Test	Limits of stability (anterior, P-L, and P-M), STAND-T (s)
Kachouri et al.[48]	Balance and strength exercises (multi-components)	Gymnasium of TUAMI (APAI)	NM (NM)	8	—	45-60 (3)	Regular school schedule	Static (OLS-EO/EC-FF, DLS-EO/EC-FF/FOF)	Static stabilometric platform	COP-velocity (mm/s) and PATH-L (M-L and A–P [mm])
Kubilay et al.[49]	Swiss ball exercises (balance)	NM (NM)	NM (NM)	8	—	30 (3)	PE program	Dynamic, static–dynamic	Timed Up and Go test, PBS	STAND-T (s), static–dynamic balance score
Lee et al.[50]	Balance training activities (balance)	NN (PET)	NM (NM)	8	—	40 (2)	PE program	Static (DLS-EO/EC, OLS-EO)	Force platform, OLS test	COP-velocity (M-L and A–P [mm/s], moment [mm/s^2]), STAND-T (s)
Mikolajczyk and Jankowicz-Szymanska[51]	Unstable surface dual-task functional exercises (balance)	NM (PHT)	NM (NM)	12	—	45 (3)	PE classes	Static (DLS-EO/EC)	Static stabilometric platform	COP-sway (M-L and A–P [cm]), PATH-L (cm), SWAY area (cm^2)
Rahmat et al.[52]	Strength exercises (strength)	NM (SCS)	NM (NM)	6	—	NM (3)	Training routines	Dynamic	Star Excursion Balance Test	Limits of stability (anterior, P-L and P-M)

[a]Data from the Tinetti test were not considered given that only the balance and gait scale score was provided in the study. [b]The data for the OLS-LL were not provided. NM, not mentioned; SCS, strength and conditioning specialist; P-L, posterolateral; P-M, posteromedial; HIP, hippotherapists; DLS, double leg stance; NBOS, normal base of support; RBOS, reduced base of support; COP, center of pressure; COP-max, peak-to-peak amplitude of the COP; M-L, mediolateral; A–P, anterior–posterior; COP-sway, displacement of the COP; COP-radial, mean radial displacement of the COP; COP-velocity, velocity of the COP; PATH-L, path length of the center of pressure; RES, researcher; OLS, one leg stance; STAND-T, standing time; EO, eyes open; EC, eyes closed; BBS, Berg Balance Scale; BOTMP, Bruininks-Oseretsky Test of Motor Proficiency; VT, visual target; VAT, visual-auditory target; COP-SD, standard deviation of the COP; PET, physical education teacher; LL, left leg stance; RL, right leg stance; PE, physical education; RSC, rope-skipping coach; TUAMI, Tunisian Union of Aid to Mental Insufficiency; APAI, adapted physical activity instructor; FF, firm floor; FOF, foam floor; PBS, Pediatric Balance Scale; PHT, physical therapist.

Table III: Quality assessment of the reviewed studies

Studies	PEDro criterion											Total score[a]	Quality
	1	2	3	4	5	6	7	8	9	10	11		
Ambroży et al.[38]	●	○	○	○	○	○	○	○	○	○	●	1	Low
Azadeh et al.[39]	●	○	○	○	○	○	○	●	●	○	●	3	Low
Borji et al.[40]	○	●	○	●	○	○	○	●	●	○	●	5	Low
Boswell[41]	●	●	○	○	○	○	○	○	○	○	●	2	Low
Dehghani and Gunay[42]	●	●	○	●	○	○	○	●	●	○	●	5	Low
Fotiadou et al.[43]	○	○	○	○	○	○	○	●	●	●	●	4	Low
Giagazoglou et al.[44]	○	●	○	●	○	○	○	●	●	●	●	6	High
Giagazoglou et al.[45]	○	○	○	●	○	○	○	●	●	●	●	5	Low
Hsu[46]	○	●	○	●	○	○	○	○	○	○	●	3	Low
Ilbeigi et al.[47]	○	○	○	○	○	○	○	○	○	●	●	2	Low
Kachouri et al.[48]	●	○	○	●	○	○	○	●	●	●	●	5	Low
Kubilay et al.[49]	●	●	○	●	○	○	○	●	●	●	●	6	High
Lee et al.[50]	●	●	○	●	○	○	○	●	●	●	●	6	High
Mikolajczyk and Jankowicz-Szymanska[51]	○	●	○	○	○	○	○	○	○	●	●	3	Low
Rahmat et al.[52]	●	●	○	○	○	○	○	○	○	●	●	3	Low
Total (out of 15)	8	9	0	8	0	0	0	9	9	9	15		

1, eligibility criteria specified; 2, random allocation of participants in groups; 3, concealed allocation; 4, similarity between groups in relevant variables at baseline; 5, blinding of participants; 6, blinding of investigators administering the intervention; 7, blinding of assessors measuring the key outcome; 8, proportion of participants having at least one key outcome measured; 9, compliance with assigned intervention; 10, intergroup statistical comparisons reported for at least one key outcome; 11, point measures and measures of variability provided for at least one key outcome. [a]Sum of items 2–11. ●, 1 point; ○, 0 points. PEDro, Physiotherapy Evidence Database scale.

Online Supplemental Materials for:

Exercise interventions to improve balance for young people with intellectual disabilities: a systematic review and meta-analysis

This online supplement comprises nine sections including:

Appendix S1: Search strategy for the Scopus database

Three groups of search terms
TITLE-ABS-KEY ((“intellectual* dis*” OR “mental* retard*” OR “developmental dis*”) AND (balance OR “postural control*” OR “postural sway” OR “postural stabili*” OR “postural instabilit*” OR “postural adaptation*” OR “postural performance*” OR “postural perturbation*” OR “postural strateg*” OR posture*) AND (intervention* OR program* OR treatment OR exercis* OR sport* OR fitness OR trainin* OR improv* OR enhanc* OR therap*)) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re") OR LIMIT-TO (DOCTYPE,"ip")) AND (LIMIT-TO (LANGUAGE,"English"))

Four groups of search terms
TITLE-ABS-KEY ((“intellectual* dis*” OR “mental* retard*” OR “developmental dis*”) AND (balance OR “postural control*” OR “postural sway” OR “postural stabili*” OR “postural instabilit*” OR “postural adaptation*” OR “postural performance*” OR “postural perturbation*” OR “postural strateg*” OR posture*) AND (intervention* OR program* OR treatment OR exercis* OR sport* OR fitness OR trainin* OR improv* OR enhanc* OR therap*) AND (child* OR adolescen* OR student* OR youth*)) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re") OR LIMIT-TO (DOCTYPE,"ip")) AND (LIMIT-TO (LANGUAGE,"English"))

Appendix S2: References of full-text articles assessed for eligibility but excluded from the systematic review and meta-analysis.

Adamović M, Stošljević M. The ability to maintain postural balance in adolescents with mild intellectual disability and adolescents with typical development. *Specijalna Edukacija i Rehabilitacija* 2013; **12**: 425-439.

Ahmadnezhad L, Atri AE, Yazdi NK, Sokhangoei Y. The effect of eight-weeks corrective games on kyphosis angle and postural control in mentally retarded children having kyphosis. *J Res Health* 2015; **5**: 178-183.

Biery MJ, Kauffman N. The effects of therapeutic horseback riding on balance. *Adapt Phys Activ* 1989; **6**: 221-229.

Blomqvist S, Wester A, Sundelin G, Rehn B. Test–retest reliability, smallest real difference and concurrent validity of six different balance tests on young people with mild to moderate intellectual disability. *Physiother* 2012; **98**: 313-319.

Blomqvist S, Olsson J, Wallin L, Wester A, Rehn B. Adolescents with intellectual disability have reduced postural balance and muscle performance in trunk and lower limbs compared to peers without intellectual disability. *Res Dev Disabil* 2013; **34**: 198-206.

Borujeni BG, Bakhshi M, Rahimi M, Sadeghi, H. Effect of closed kinetic chain trainings on the ankle joint proprioception of mentally retarded students. *Int J Sport Studies* 2015; **5**: 461-464.

Boswell B. Effects of movement sequences and creative dance on balance of children with mental retardation. *Percept Mot Skills* 1993; **77**: 1290-1290.

Hayakawa K, Kobayashi K. Physical and motor skill training for children with intellectual disabilities. *Percept Mot Skills* 2011; **112**: 573-580.

Lee KJ, Lee MM, Shin DC, Shin SH, Song CH. The effects of a balance exercise program for enhancement of gait function on temporal and spatial gait parameters in young people with intellectual disabilities. *J Phys Ther Sci* 2014; **26:** 513-516.

Mazur-Rylska A, Ambroży T, Ambroży D. The effect of horse riding on stabilographic parameters in teenage children with mild mental retardation. *Acta Facultatis Educationis Physicae Universitatis Comenianae* 2011; **52**: 51-61.

Mikolajczyk E, Jankowicz-Szymanska A. Does extending the dual-task functional exercises workout improve postural balance in individuals with ID? *Res Dev Disabil* 2015a; **38**: 84-91.

Mikolajczyk E, Jankowicz-Szymanska A. The effect of dual-task functional exercises on postural balance in adolescents with intellectual disability-a preliminary report. *Disabil Rehabil* 2015a; **37**: 1484-1489.

Mikołajczyk E, Jankowicz-Szymańska A. Dual-task functional exercises as an effective way to improve dynamic balance in persons with intellectual disability–continuation of the project. *Medical Studies/Studia Medyczne* 2017; **33**: 102-109.

Rahmat A, Daneshmandi H. The effect of core stabilization exercises on factors physical fitness to mental retardation. *Medicina Sportiva* 2013; **9**: 2058-2062.

Smail KM, Horvat M. Effects of balance training on individuals with mental retardation. *Clinical Kinesiology: Journal of the American Kinesiotherapy Association* 2005; 43-47.

Suomi R, Koceja DM. Postural sway patterns of normal men and women and men with mental retardation during a two-legged stance test. *Arch Phys Med Rehabil* 1994; **75**: 205-209.

Top E, Akil M. Effects of a 3-month recreative exercise applied to individuals with intellectual disability on their electromyogram (EMG) variations and balance performance. *Int J Dev Disabil* 2017. Advance online publication. doi: 10.1080/20473869.2017.1317459

Tsimaras VK, Giamouridou GA, Kokaridas DG, Sidiropoulou MP, Patsiaouras AI. The effect of a traditional dance training program on dynamic balance of individuals with mental retardation. *J Strength Cond Res* 2012; **26**: 192-198.

Vuijk PJ, Hartman E, Scherder E, Visscher, C. Motor performance of children with mild intellectual disability and borderline intellectual functioning. *J Intellect Disabil Res* 2010; **54**: 955-965.

Wuang YP, Su CY. Reliability and responsiveness of the Bruininks–Oseretsky Test of Motor Proficiency-in children with intellectual disability. *Res Dev Disabil* 2009; **30**: 847-855.

Table SI: Synthesis of results of the studies included in the meta-analysis

Study	IG (pre- vs post-test)	CG (pre- vs post-test)	IG vs CG (pre-test)	IG vs CG (post-test)
Ambroży et al.[38]	Improvement for COP-max in A–P (NBOS, RBOS), COP-sway in A–P (mean and SD; NBOS, RBOS), COP-radial (NBOS, RBOS), COP-velocity (NBOS), PATH-L (NBOS)	NM	IG>CG (COP-max in M-L)	IG>CG for COP-max in A–P (NBOS, RBOS), COP-sway in A–P (mean and SD; NBOS, RBOS), COP-radial (NBOS, RBOS), COP-velocity (NBOS), PATH-L (NBOS)
Azadeh et al.[39]	Improvement[a]	NM	NM	NM
Borji et al.[40]	Improvement	All effects NS (p>0.05)	All effects NS (p>0.05)	NM
Boswell[41]	All effects NS (p>0.05)	All effects NS (p>0.05)	NM	NM
Dehghani and Gunay[42]	Improvement	All effects NS (p>0.05)	All effects NS (p>0.05)	NM
Fotiadou et al.[43]	Improvement	All effects NS (p>0.05)	NM	IG>CG
Giagazoglou et al.[44]	Improvement all (excepted for COP-SD in A–P and DLS-EC, OLS-EO)	All effects NS (p>0.05)	All effects NS (p>0.05)	NM
Giagazoglou et al.[45]	Improvement only for COP-max (RLS-EO in M-L)	All effects NS (p>0.05)	All effects NS (p>0.05)	NM
Hsu[46]	Improvement all (except for COP-velocity M-L, STAND-T for dynamic balance)	All effects NS (p>0.05)	All effects NS (p>0.05)	NM
Ilbeigi et al.[47]	Improvement	All effects NS (p>0.05)	NM	IG>CG
Kachouri et al.[48]	Improvement	Improvement only for PATH-L in M-L (DLS-EO-FF, DLS-EC-FF) and in A–P (DLS-EC-FOF)	All effects NS (p>0.05)	IG>CG
Kubilay et al.[49]	Improvement	Improvement only for PBS	All effects NS (p>0.05)	NS (p >.05)
Lee et al.[50]	Improvement	All effects NS (p>0.05)	All effects NS (p>0.05)	IG>CG
Mikolajczyk and Jankowicz-Szymanska[51]	Improvement only for PATH-L (EO/EC) and sway area (EC)	All effects NS (p>0.05)	IG<CG (COP-sway, EC/A–P)	IG>CG (sway area, EC)
Rahmat et al.[52]	Improvement all (except anterior)	All effects NS (p>0.05)	NM	IG>CG (P-L and P-M)

[a]Owing to an inconsistency between the information presented in the table and in the text, the result of the dynamic balance between the pre-test and post-test was not considered. IG, intervention group; CG, control group; NS, non-significant; NM, not mentioned; P-L, posterolateral; P-M, posteromedial; COP, center of pressure; COP-max, peak-to-peak amplitude of the COP; A–P, anterior–posterior; NBOS, normal base of support; RBOS, reduced base of support; COP-sway, displacement of the COP; COP-radial, mean radial displacement of the COP; COP-velocity, velocity of the COP; PATH-L, path length of the center of pressure; >, better balance; COP-SD, standard deviation of the COP; DLS, double leg stance; EC, eyes closed; OLS, one leg stance; EO, eyes open; RLS, right leg stance; M-L, mediolateral; STAND-T, standing time; FF, firm floor; FOF, foam floor; PBS, Pediatric Balance Scale; <, lower balance.

Table SII: Results of the random-effects models, tests for heterogeneity, and publication bias across types of balance measure and types of parameter.

Type of balance	Type of balance parameters	*k*	Random effects models				Tests for heterogeneity				Publication bias				
			Hedges's *g*	95%CI	*Z*-value	*p*	*Q*	df	*p*	I^2 (%)	B-M test	Egger-T	DT-TF	Hedges's *g*	95%CI
Static	Balance score	1	0.63	(-0.20 to 1.45)	1.49	0.14	0	0	1	0	NA	NA	NA		
	STAND-T	5	1.18	(0.79 to 1.57)	5.93	<.001	2.5	4	0.64	0.0	0.11	0.08	0 missing		
	COP-max-AP	4	1.14	(0.36 to 1.92)	2.88	0.004	29.1	3	<.001	89.7	0.04	0.10	0 missing		
	COP-max-ML	4	0.85	(0.21 to 1.50)	2.59	0.01	21.8	3	<.001	86.2	0.50	0.17	0 missing		
	COP-radial	1	0.54	(0.14 to 0.93)	2.67	0.01	0	0	1	0	NA	NA	NA		
	COP-SD-AP	3	0.94	(0.32 to 1.55)	2.99	0.003	8.7	2	0.01	77.0	0.50	0.11	0 missing		
	COP-SD-ML	3	1.04	(0.09 to 1.99)	2.15	0.03	19.5	2	<.001	89.7	0.15	0.11	0 missing		
	COP-sway-AP	1	0.91	(0.42 to 1.40)	3.64	<.001	0	0	1	0	NA	NA	NA		
	COP-sway-mean-AP	1	0.74	(0.34 to 1.14)	3.63	<.001	0	0	1	0	NA	NA	NA		
	COP-sway-mean-ML	1	0.24	(-0.14 to 0.63)	1.23	0.22	0	0	1	0	NA	NA	NA		
	COP-sway-ML	1	0.15	(-0.32 to 0.61)	0.62	0.54	0	0	1	0	NA	NA	NA		
	COP-sway-SD-AP	1	0.66	(0.26 to 1.05)	3.25	0.001	0	0	1	0	NA	NA	NA		
	COP-sway-SD-ML	1	0.21	(-0.17 to 0.60)	1.08	0.28	0	0	1	0	NA	NA	NA		
	COP-velocity	2	0.81	(-0.22 to 1.84)	1.55	0.12	14.2	1	<.001	93.0	NA	NA	NA		
	COP-velocity-AP	3	1.29	(0.23 to 2.35)	2.39	0.02	8.3	2	0.02	75.9	0.15	0.06	2 missing	0.50	(-0.50 to 1.50)
	COP-velocity-ML	3	0.57	(-0.04 to 1.17)	1.83	0.07	3.5	2	0.17	43.5	0.15	0.30	0 missing		
	COP-velocity-moment	1	0.29	(-0.20 to 0.78)	1.14	0.25	0	0	1	0	NA	NA	NA		
	PATH-L	2	0.28	(-0.02 to 0.58)	1.85	0.06	0.0	1	0.99	0.0	NA	NA	NA		
	PATH-L-AP	1	1.53	(1.14 to 1.93)	7.58	<.001	0	0	1	0	NA	NA	NA		
	PATH-L-ML	1	1.79	(1.38 to 2.21)	8.54	<.001	0	0	1	0	NA	NA	NA		
	SWAY-area	3	0.67	(-0.13 to 1.47)	1.63	0.10	5.8	2	0.05	65.6	0.15	0.29	0 missing		
Dynamic	Balance score	1	0.78	(-0.06 to 1.62)	1.83	0.07	0	0	1	0	NA	NA	NA		
	STAND-T	5	0.99	(0.46 to 1.52)	3.66	<.001	7.6	4	0.11	47.6	0.11	0.10	0 missing		
	Distance of walk	1	0.51	(-0.03 to 1.05)	1.86	0.06	0	0	1	0	NA	NA	NA		
	STAB-PL	2	3.69	(1.37 to 6.01)	3.11	0.002	5.4	1	0.02	81.6	NA	NA	NA		
	STAB-ANT	2	2.25	(-1.44 to 5.94)	1.20	0.23	18.9	1	<.001	94.7	NA	NA	NA		
	STAB-PM	2	3.32	(0.83 to 5.81)	2.61	0.01	7.0	1	0.008	85.7	NA	NA	NA		

Note. AP = anterior-posterior; B-M test = Begg and Mazumdar rank correlation test; COP = center of pressure; COP-max = peak-to-peak amplitude of the COP; COP-radial = radial displacement of the COP; COP-SD = standard deviation of the COP; COP-sway = displacement of the COP; COP-velocity = velocity of the COP; ML = medio-lateral; DT-FT = Duval and Tweedie's trim and fill; Egger-T = Egger's test of the intercept; PATH-L = path length of the COP; *k* = number of effect sizes; PL = posterolateral; PM = posteromedial; STAND-T = standing time.

Table SIII: Studies included in the results of the random-effects models, tests for heterogeneity, and publication bias across types of balance measures and types of parameter.

Type of balance	Type of balance parameters	*k*	Studies
Static	Balance score	1	Dehghani & Gunay[42]
	STAND-T	5	Azadeh et al.[39]; Hsu[46] Control groups 1 and 2; Ilbeigi et al.[47]; Lee et al.[50]
	COP-max-AP	4	Ambroży et al.[38]; Fotiadou et al.[43]; Giagazoglou et al.[44,45]
	COP-max-ML	4	Ambroży et al.[38]; Fotiadou et al.[43]; Giagazoglou et al.[44,45]
	COP-radial	1	Ambroży et al.[38]
	COP-SD-AP	3	Fotiadou et al.[43]; Giagazoglou et al.[44,45]
	COP-SD-ML	3	Fotiadou et al.[43]; Giagazoglou et al.[44,45]
	COP-sway-AP	1	Mikolajczyk & Jankowicz-Szymanska[51]
	COP-sway-mean-AP	1	Ambroży et al.[38]
	COP-sway-mean-ML	1	Ambroży et al.[38]
	COP-sway-ML	1	Mikolajczyk & Jankowicz-Szymanska[51]
	COP-sway-SD-AP	1	Ambroży et al.[38]
	COP-sway-SD-ML	1	Ambroży et al.[38]
	COP-velocity	2	Ambroży et al.[38]; Kachouri et al.[48]
	COP-velocity-AP	3	Hsu[46] Control groups 1 and 2; Lee et al.[50]
	COP-velocity-ML	3	Hsu[46] Control groups 1 and 2; Lee et al.[50]
	COP-velocity-moment	1	Lee et al.[50]
	PATH-L	2	Ambroży et al.[38]; Mikolajczyk & Jankowicz-Szymanska[51]
	PATH-L-AP	1	Kachouri et al.[48]
	PATH-L-ML	1	Kachouri et al.[48]
	SWAY-area	3	Hsu[46] Control groups 1 and 2; Mikolajczyk & Jankowicz-Szymanska[51]
Dynamic	Balance score	1	Dehghani & Gunay[42]
	STAND-T	5	Azadeh et al.[39]; Boswell[41]; Hsu[46] Control groups 1 and 2; Kubilay et al.[49]
	Distance of walk	1	Boswell[41]
	STAB-PL	2	Ilbeigi et al.[47]; Rahmat et al.[52]
	STAB-ANT	2	Ilbeigi et al.[47]; Rahmat et al.[52]
	STAB-PM	2	Ilbeigi et al.[47]; Rahmat et al.[52]

Note. AP = anterior-posterior; COP = center of pressure; COP-max = peak-to-peak amplitude of the COP; COP-radial = radial displacement of the COP; COP-SD = standard deviation of the COP; COP-sway = displacement of the COP; COP-velocity = velocity of the COP; *k* = number of effect sizes; ML = medio-lateral; PATH-L = path length of the COP; PL = posterolateral; PM = posteromedial; STAND-T = standing time.

Table SIV: Subgroup analyses of Hedges' *g* values of static, dynamic, and static–dynamic balance.

Subgroups	Type of Balance	Subgroups	*k*	Random effects models				Tests for heterogeneity				Subgroup analyses - mixed effects		
				Hedges' *g*	95% CI	*Z*-value	*p*	*Q*	df	*p*	I^2 (%)	*Q*	df	*p*
Age group	Static	Adolescents	8	0.75	(0.46 to 1.04)	5.07	<.001	12.6	7	0.08	44.5	2.3	1	0.13
		Children	4	1.25	(0.67 to 1.84)	4.20	<.001	13.9	3	0.003	78.4			
	Dynamic	Adolescents	5	1.67	(0.59 to 2.75)	3.03	.002	24.2	4	<.001	83.5	1.2	1	0.28
		Children	3	0.97	(0.29 to 1.64)	2.80	.005	5.7	2	0.06	64.7			
	Static-dynamic	Adolescents	-	-	-			-	-	-	-	-	-	-
		Children	-	-	-			-	-	-	-			
Design	Static	QE	6	1.23	(0.69 to 1.78)	4.44	<.001	30.3	5	<.001	83.5	4.1	1	0.04
		EXP	6	0.62	(0.38 to 0.86)	5.07	<.001	4.0	5	0.55	0			
	Dynamic	QE	2	2.97	(-0.12 to 6.06)	1.88	.06	11.3	1	0.001	91.1	1.6	1	0.20
		EXP	6	0.94	(0.47 to 1.41)	3.91	<.001	10.9	5	0.05	54.2			
	Static-dynamic	QE	-	-								-	-	-
		EXP	-	-										
ID level	Static	Mild	7	0.99	(0.51 to 1.47)	4.05	<.001	25.5	6	<.001	76.5	2.8	2	0.25
		Mild-moderate	2	1.31	(0.16 to 2.47)	2.22	.026	9.7	1	0.002	89.7			
		Moderate	2	0.58	(0.23 to 0.93)	3.23	.001	0.9	1	0.34	0.0			
	Dynamic	Mild	5	1.82	(0.87 to 2.78)	3.75	<.001	17.0	4	0.002	76.4	6.6	1	0.01
		Mild-moderate	2	0.48	(0.11 to 0.86)	2.51	.012	0.6	1	0.43	0			
		Moderate	-	-	-			-	-	-	-			
	Static-dynamic	Mild	-	-	-			-	-	-	-	-	-	-
		Mild-moderate	-	-	-			-	-	-	-			
		Moderate	-	-	-			-	-	-	-			

Note. CI = confidence interval; EXP = experimental; ID = intellectual disability; QE = quasi-experimental; *k* = number of effect sizes.

Table SIV (continued)

Subgroups	**Type of Balance**	**Subgroups**	***k***	**Random effects models**				**Tests for heterogeneity**				**Subgroup analyses - mixed effects**		
				Hedges' *g*	**95% CI**	***Z*-value**	***p***	***Q***	**df**	***p***	**I^2 (%)**	***Q***	**df**	***p***
Type of balance measure	Static	Clinical	3	1.15	(0.53 to 1.76)	3.67	<.001	3.1	2	0.21	35.3	0.21	1	0.65
		Posturography	6	0.96	(0.45 to 1.47)	3.70	<.001	35.9	5	<.001	86.1			
	Dynamic	Clinical	-	-	-			-	-	-	-	-	-	-
		Posturography	-	-	-			-	-	-	-			
	Static-dynamic	Clinical	-	-	-			-	-	-	-	-	-	-
		Posturography	-	-	-			-	-	-	-			
Exercise component	Static	Balance	8	0.89	(0.46 to 1.32)	4.10	<.001	28.1	7	<.001	75.1	0.62	1	0.43
		Multi-component	4	1.16	(0.64 to 1.69)	4.32	<.001	10.4	3	0.02	71.3			
		Strength	-	-	-			-	-	-	-			
	Dynamic	Balance	5	1.01	(0.48 to 1.54)	3.73	<.001	7.4	4	0.12	45.8	0.55	1	0.46
		Multi-component	2	2.52	(-1.45 to 6.50)	1.24	.214	21.3	1	<.001	95.3			
		Strength	-	-	-			-	-	-	-			
	Static-dynamic	Balance	-	-	-			-	-	-	-			
		Multi-component	-	-	-			-	-	-	-			
		Strength	-	-	-			-	-	-	-			

Table SV: Studies included in the subgroup analyses of Hedges' *g* values of static, dynamic, and static–dynamic balance.

Subgroups	Type of Balance	Subgroups	*k*	Studies
Age group	Static	Adolescents	8	Ambroży et al.[38]; Azadeh et al.[39]; Giagazoglou et al.[45]; Hsu[46] Control groups 1 and 2; Ilbeigi et al.[47]; Lee et al.[50]; Mikolajczyk & Jankowicz-Szymanska[51]
		Children	4	Dehghani & Gunay[42]; Fotiadou et al.[43]; Giagazoglou et al.[44]; Kachouri et al.[48]
	Dynamic	Adolescents	5	Azadeh et al.[39]; Hsu[46] Control groups 1 and 2; Ilbeigi et al.[47]; Kubilay et al.[49]
		Children	3	Boswell[41]; Dehghani & Gunay[42]; Rahmat et al.[52]
Design	Static	QE	6	Ambroży et al.[38]; Azadeh et al.[39]; Fotiadou et al.[43]; Giagazoglou et al.[45]; Ilbeigi et al.[47]; Kachouri et al.[48]
		EXP	6	Dehghani & Gunay[42]; Giagazoglou et al.[44]; Hsu[46] Control groups 1 and 2; Lee et al.[50]; Mikolajczyk & Jankowicz-Szymanska[51]
	Dynamic	QE	2	Azadeh et al.[39]; Ilbeigi et al.[47]
		EXP	6	Boswell[41]; Dehghani & Gunay[42]; Hsu[46] Control groups 1 and 2; Kubilay et al.[49]; Rahmat et al.[52]
ID level	Static	Mild	7	Ambroży et al.[38]; Dehghani & Gunay[42]; Hsu[46] Control groups 1 and 2; Ilbeigi et al.[47]; Kachouri et al.[48]; Lee et al.[50]
		Mild-moderate	2	Fotiadou et al.[43]; Giagazoglou et al.[44]
		Moderate	2	Giagazoglou et al.[45]; Mikolajczyk & Jankowicz-Szymanska[51]
	Dynamic	Mild	5	Dehghani & Gunay[42]; Hsu[46] Control groups 1 and 2; Ilbeigi et al.[47]; Rahmat et al.[52]
		Mild-moderate	2	Boswell[41]; Kubilay et al.[49]
Type of balance measure☆	Static	Clinical	3	Azadeh et al.[39]; Dehghani & Gunay[42]; Ilbeigi et al.[47]
		Posturography	6	Ambroży et al.[38]; Fotiadou et al.[43]; Giagazoglou et al.[44,45]; Kachouri et al.[48]; Mikolajczyk & Jankowicz-Szymanska[51]
Exercise component	Static	Balance	8	Ambroży et al.[38]; Azadeh et al.[39]; Dehghani & Gunay[42]; Fotiadou et al.[43]; Hsu[46] Control groups 1 and 2; Lee et al.[50]; Mikolajczyk & Jankowicz-Szymanska[51]
		Multi-component	4	Giagazoglou et al.[44,45]; Ilbeigi et al.[47]; Kachouri et al.[48]
	Dynamic	Balance	5	Azadeh et al.[39]; Dehghani & Gunay[42]; Hsu[46] Control groups 1 and 2; Kubilay et al.[49]
		Multi-component	2	Boswell[41]; Ilbeigi et al.[47]

Note. EXP = experimental; *k* = number of effect sizes; QE = quasi-experimental. ☆ Given that we used a balance composite score, we were unable to include in this analysis the studies of Hsu[46] and Lee et al.[50] that used both a clinical and a posturography measure.

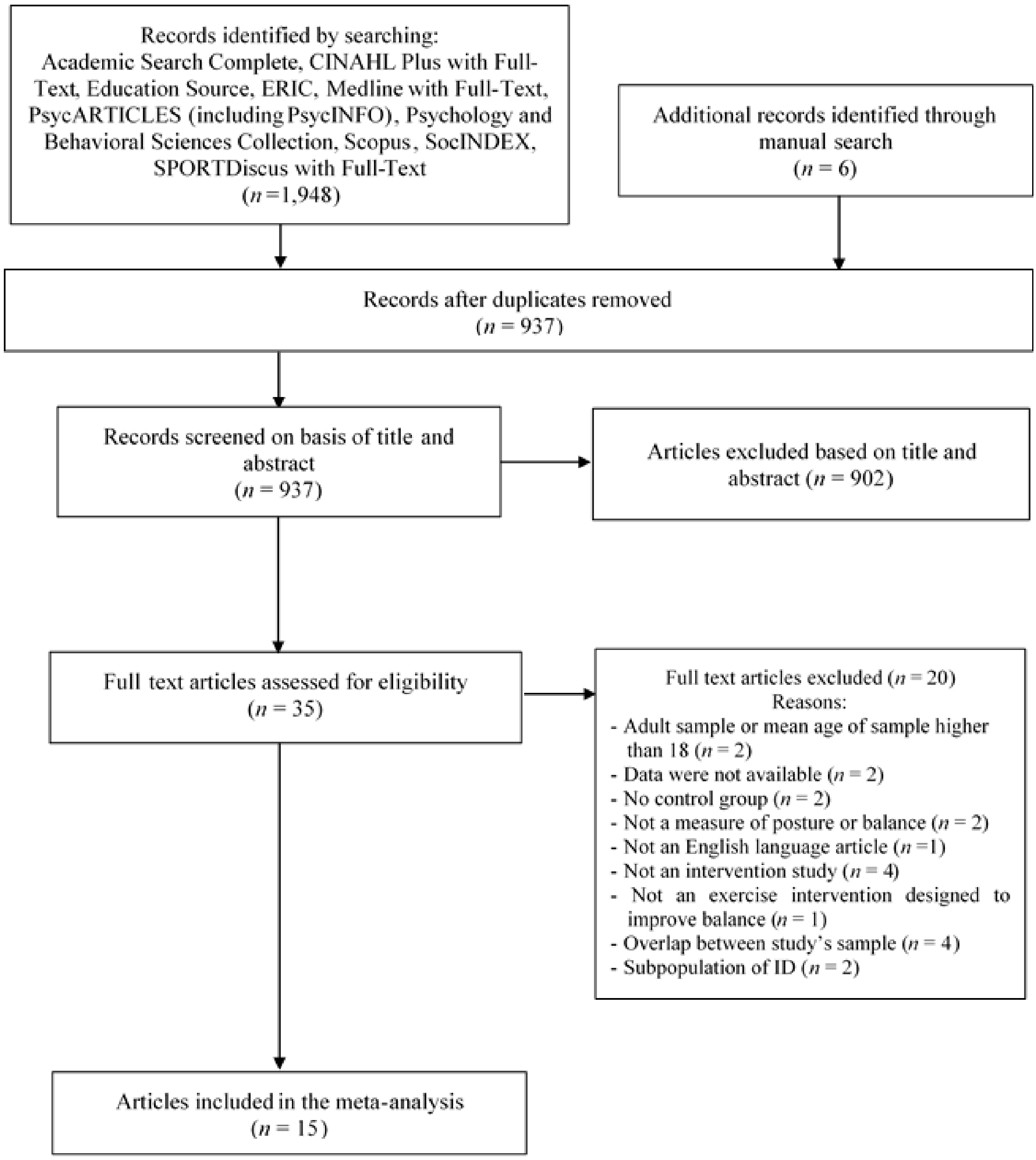
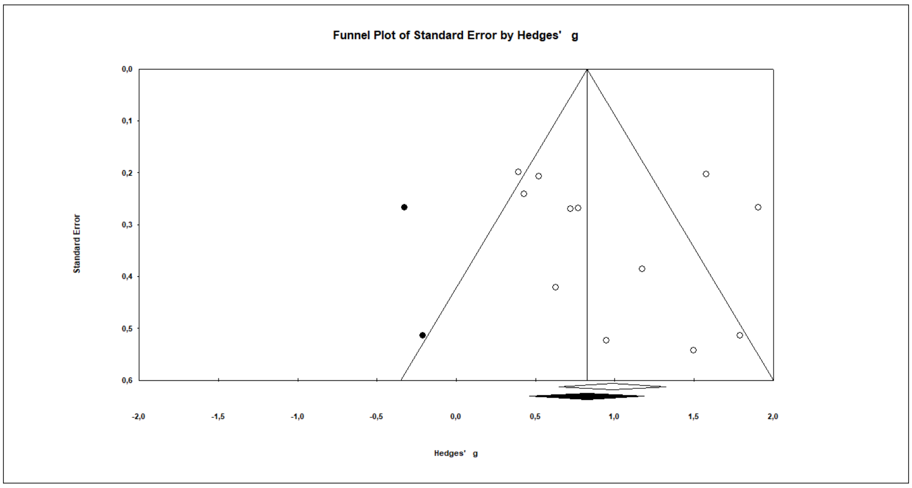
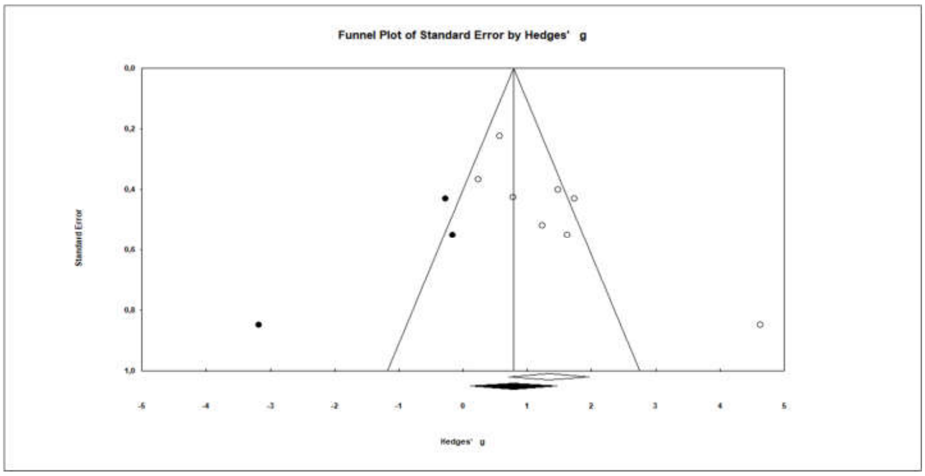


Figure S1: Results of Search Based on the on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement[19]
Note. ID = intellectual disability.

(a)



(b)



(c)

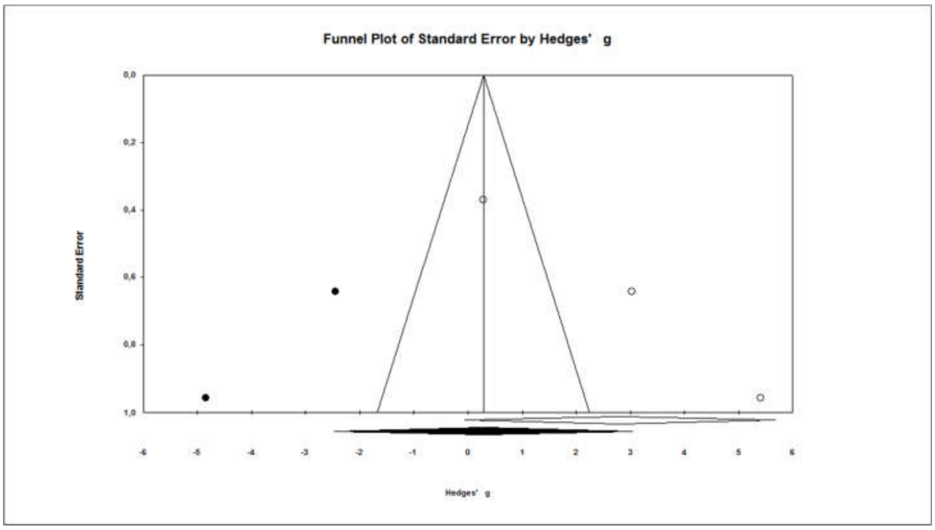


Figure S2: Funnel plot of standard error by Hedges' *g* of (a) static, (b) dynamic, and (c) static–dynamic balance.