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Balance control in children and adolescents with intellectual disability: a systematic review and meta-analysis

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To systematically summarise and analyse published research, which assessed balance control deficiencies of children and adolescents with intellectual disability (ID) in various balance domains by comparing their performance with that of typically developing (TD) peers. This study followed PRISMA principles and conducted a systematic search in six electronic databases in May 2025, including PubMed, Web of Science Core Collection, Scopus, EBSCO, LILACS, Cochrane Library, PEDro and Embase. The methodological quality of included studies was assessed using the Scottish Intercollegiate Guidelines Network checklist, and the certainty of the evidence was assessed via the GRADE approach. The meta-analysis was performed via RevMan 5.4. Descriptive analysis was performed if the data were insufficient. Fifteen studies were included and eight of which were pooled for meta-analysis. Children and adolescents with ID had poorer balance control than their TD peers. Specific to the various balance domains, individuals with ID presented substantially more difficulties in sensory orientation (eyes open: SMD = 0.89, 95% CI: 0.69 to 1.09, $p < 0.001$; eyes closed: SMD = 0.44, 95% CI: 0.26 to 0.62, $p < 0.001$) and limits of stability (SMD = -0.91, 95% CI: -1.09 to -0.73, $p < 0.001$). They also encountered more hardships in gait stability (SMD = 0.52, 95% CI: 0.27 to 0.78, $p < 0.001$). For domain of anticipatory postural adjustments, inconsistent results were obtained. Children and adolescents with ID have deficient balance control ability than their TD peers. More researches are needed to comprehensively assess various domain of balance in this target group, especially those with longitudinal designs.

Keywords Children and youth, Intellectual deficiency, Balance, Systematic review

Intellectual disability (ID) refers to a condition characterised by significant limitations in intellectual function and adaptive behaviour and emerges before the age of 22 years[1]. With an incidence affecting roughly 2% of the general population[2], ID ranks in the top ten causes of disease burden globally[3]. Children and adolescents with ID also manifest the impairment of sensorimotor function and delay of motor milestones[4]. As the main form of physical activity (PA) in children and youth, fundamental movement skills serve as the gateway to advanced movement skills and a prerequisite for participation in daily exercise[5]. However, children and adolescents with ID experience more and varying levels of difficulty in performing fundamental movement skills[6] compared with their typically developing (TD) peers, especially in terms of balance control performance[7–9].

Balance control is the complex ability to maintain, achieve or restore the state of equilibrium in one's body while standing still, preparing to move, being in movement or readying to halt a movement[10–12]. This ability can be examined in static (the body remains motionless) or dynamic (the body can react to perturbations or is in movement) condition and in both[10]. Within the framework of the International Classification of Functioning, Disability and Health, the achievement and maintenance of balance is described as a structure/function or an activity, and a critical and complex lifelong skill[13]. For children and adolescents with ID, balance deficits increase the risks of falls and fall-related injuries, which range from slight contusion to fractures or death[10]. In addition, poor balance serves as an important contributing factor to low self-esteem and a sedentary lifestyle, which includes poor social adaptability and lack of PA[14]. These conditions eventually lead to overweight, obesity, and other psychophysiological diseases[15–17]. The balance control system involves a coordinated operation and integration of multiple mechanisms. Visual, vestibular, and somatosensory systems provide the body with the surrounding information that is subsequently integrated and processed by the central nervous system[18]. The

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musculoskeletal system, respond to the received information, guaranteeing the efficiency of both the static and dynamic postural balance[10,19]. Deficits in balance control may result from impairments in any or all of these systems[20,21], and thus, full evaluation of the various aspects of balance control through adoption of a range of tests is needed.

Based on the systems theory, Horak et al.[22] developed a comprehensive conceptual framework named the Balance Evaluation Systems Test (BESTest), which integrates the various aspects of balance control into six domains: biomechanical constraints, stability limits/verticality, anticipatory postural adjustment, postural responses, sensory orientation and gait stability. This conceptual framework aids in determining the affected aspects or subsystems of balance control and is important in the design of effective balance intervention programs[22]. The reliability and validity of the BESTest in people with ID have been assessed[23]. In addition, the BESTest is applied to individuals with Parkinson's disease[24], stroke survivors[25], those with vestibular disorders[22] and children and adolescents with cerebral palsy[26] or suffering from developmental coordination disorder[27].

Researchers have used balance scales or balance subscales of a generic motor scale to assess the overall balance performance in children and youth with ID[28,29]. Although these tools are helpful in identifying balance-related problems and providing a comprehensive understanding of the functional status among this population, they may not provide any specifics on which balance domains are compromised. In addition to these balance assessment scales, a number of specific balance tests (such as the one leg stance test and the timed up and go test) were also used to assess the prevalence of balance deficits in this group[7]. However, these tests only measure a very limited aspect of activities or tasks that requires balance control[30]. Maintaining balance involves a complex set of sensorimotor control system[31]. Although balance deficits among children and youth with ID have been well documented[7,8], a comprehensive insights into the affected balance domains remain lacking.

In fact, researchers have conducted reviews to describe the balance performance of children and adolescents with Down syndrome (DS)[31–33], which is the most common chromosomal disorder in humans. These reviews mainly summarized the relevant cross-sectional studies and concluded that, in general, children and adolescents with DS exhibit lower levels of postural stability compared to their TD peers. However, these reviews merely summarise the overall balance characteristics of the target population, while relevant evidence pertaining to potential impairments in different balance domains is not available. Furthermore, since the studies included in these reviews employed a variety of assessment tools to measure the outcome of interest, a meta-analysis could not be conducted. Therefore, this systematic review and meta-analysis aimed to summarise and analyse published research that described balance deficits in children and adolescents with ID, especially the various balance domains, compared with their TD peers. The findings of this review will help therapists, professionals in the field of rehabilitation and PE teachers to identify whether all or specific balance domains are compromised and develop individualised interventions to improve the balance control ability of this target populations. Moreover, the research gaps identified in the literature will subsequently offer guidance for future research in this area.

Method

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement[34] and registered at the International Prospective Register of Systematic Reviews (PROSPERO; Registration no. CRD42022331367; Registration date May 23rd, 2022; https://www.crd.york.ac.uk/PROSPERO/). Furthermore, in order to make our work more rigorous and to ensure the comparability of the research results in related fields, we adopted the method proposed by Verbecque et al.[35] for data extraction, classification and analysis. This method was originally designed for individuals with developmental coordination disorder.

Literature search

We conducted an initial search in December 31th 2022 and an updated-round search on May 23rd 2025. Six databases were searched, including PubMed, Web of Science Core Collection, Scopus, EBSCO, LILACS, and Embase, with no filter application. The search strategy was agreed upon by Y.L., J.Z. and J.Q. and involved the following search terms: (1) intellectual disability, (2) balance and (3) children or adolescents. More details about the search strategy are available in Supplementary Table S1.

Study selection

Relevant studies were identified in accordance with predefined selection criteria based on the Population Intervention Comparison Outcome Study design method[36]:

Population: Individuals between 5 and 19 years old[37] with a diagnosis of ID. Studies were excluded if other neurodevelopmental disorder were the primary population of interest (e.g. Autism Spectrum Disorder and Developmental Coordination Disorder).

Comparison: One or more control groups were necessary for comparison. The performance of children and adolescents with ID in balance assessment was compared with that of their TD peers.

Outcome: Participants' balance control ability, which was measured via a standardised tool (e.g. specific balance tests or balance scales), was reported in detail.

Study design and publication type: Studies with case-control designs were considered in this work. In addition, only articles that were published in English, refereed in journals with full-text availability and only contained original research (i.e. reviews were excluded), were included.

Risk of bias assessment

The methodological quality of included studies was assessed using the Scottish Intercollegiate Guidelines Network (SIGN)[38]. The SIGN checklist comprises two sections. Section 1 involves the evaluation of studies' internal validity and includes 11 items: research question (1 item), sampling (6 items), measurement (2 items), control of confounding (1 item) and data analysis (1 item). Section 2 provides an overall assessment for each study via classification of three degrees. When most criteria were met (≥ 9/11) or (6–8/11), a study was rated to be high (++) or acceptable quality (+). Meanwhile, when the criteria were not met (≤ 5/11), or significant flaws existed in key aspects related to the study design, a research was classified to be low quality (0). The first and second authors independently performed methodological assessment. In addition, Cohen's kappa analysis was used to measure the level of consistency among authors: poor (≤ 0), slight (0.0–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) and almost perfect (0.81–1.0)[39]. On the basis of the SIGN checklist, studies rated to have low methodological quality were excluded[38].

Certainty of the evidence

The overall quality of the evidence contributing to the primary meta-analysis was evaluated using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) methodology, which categorised it as very low, low, moderate, or high[40]. In this method, observational studies were initially classified as low-quality evidence and then downgraded or upgraded according to five downgrading (risk of bias, inconsistency, indirectness, imprecision, and other considerations) and three upgrading principles (the magnitude of an effect, dose-response gradient, and effect of plausible residual confounding). The assessment was carried out by two authors (Y.L. and J.Z.), which was then reviewed by the team. Discrepancies were resolved through discussion until a consensus was reached.

Data extraction

The first author performed data extraction, followed by the verification of data accuracy by the second author. The authors engaged in consensus discussion to resolve discrepancies. For longitudinal studies, we only select the data of participants who meet the inclusion criteria. The researchers extracted the following information: (1) study characteristics (e.g. author, year of publication, geographic location and study design); (2) sample characteristics (e.g. sample size, age, gender and ID type); (3) tests/tasks applied to assess balance control and results.

The numeric values (mean and standard deviation) of outcome variables were extracted. The data from a specific balance test (e.g. functional reach test and one-leg stance) were pooled and grouped into the corresponding domains of balance control. Table 1 depicts the specific tests classified under various balance domains. The values of data derived from a balance scale or subscale of a generic motor scale were also grouped and analysed.

Statistical analysis and synthesis

To comprehensively summarise the pieces of evidence in the current literature, we conducted a meta-analysis if at least two identical outcome variables (e.g. reach distance) for the same test (e.g. functional reach test-forward) were available. Review Manager (Version 5.4.1, The Cochrane Collaboration, Copenhagen, Denmark) was used in data processing. For all outcome measures, a standardized mean difference (SMD) was calculated using Hedges' g[41], and the SMD with a 95% confidence interval (CI) was applied to analyse the effect size. Given the expected clinical heterogeneity across studies stemming from differences in ID subtypes (e.g. DS versus non-syndromic ID) and age ranges (children to adolescents), a random-effects model was chosen for all meta-analyses. This approach takes into account the between-study variance (τ) of the true effect and provides more conservative estimates for clinically diverse populations[42]. Heterogeneity was evaluated using the I^2 test (with $I^2 > 50\%$ indicating moderate heterogeneity and $I^2 > 75\%$ indicating high heterogeneity). Hedges' g method was employed to reflect the magnitude of effect size[41]. According to Cohen[43], small, medium and large effect sizes have values between ≥ 0.2 and < 0.5, between ≥ 0.5 and < 0.8 and ≥ 0.8, respectively. Notably, when a study contained two or more control groups, each result was analysed separately. Statistical significance was set at $p < 0.05$ for the comparisons between groups. In addition, 95% prediction intervals (PIs) were calculated using R (version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria) and RStudio (Posit Software, PBC, Boston, America) to quantify the dispersion of true effects across studies. For inappropriate data or those that were impossible to pool quantitatively (e.g. overall stability index), we conducted a descriptive analysis and provided a narrative summary.

Results

Search results

The initial search identified 4696 studies. These studies were exported to EndNote X9, and duplicates were eliminated. The remaining 2974 articles were then screened based on the title and abstract, which resulted in the exclusion of 2911 studies. The researchers perused the full text of the 77 articles that were retained and excluded another 57. Among 20 studies that met the selection criteria, 5 were excluded due to their low methodological quality. Thus, 15 studies were ultimately included in this work. The PRISMA flowchart in Fig. 1 displays the selection procedure.

Risk of bias assessment

Table 2 outlines the assessment results on methodological quality. Overall, 1 out of the 20 studies was rated as high quality[8], 15 were of acceptable quality[7,20,28,29,44–53] and 5 had low quality[54–58]. Of these studies, the risk of bias assessment indicated an 'almost perfect' inter-rater agreement (kappa value: 0.880, standard error: 0.032, 95% CI: 0.817–0.945)[39].

Domain	Definitions	Applied tests/tasks in the included studies	Applied outcome variables in the included studies
Stability limits/verticality	The domain biomechanical constraints refer to standing balance include the quality of the base of foot support, geometric postural alignment, functional ankle and hip strength for standing, and ability to rise from the floor to a standing position.	Functional reach test-forward	Push-length[7,28,51]
		Functional reach test-left	Push-length[28,51]
		Functional reach test-right	Push-length[28,51]
Anticipatory postural adjustments	Stability limits/verticality is the ability to move the body's centre of gravity over its base of support before changing the support or losing balance, as well as the extent to which this is possible (stability limits) and the internal perception of posture vertical (verticality).	One leg stance	Total balance time[7]
		Stork stand test	Total balance time[50]
		Goal-directed reaching	The time to accomplish[44]
Sensory orientation	Anticipatory postural adjustments include "tasks that require an active movement of the body's centre of gravity before postural transition from one body position to another".	Force platform-bipedal stance-(F) EO	ROM-AP[52]
			COP-AP[8,46,49,53]
			COP-RMS-AP[20]
			ROM-ML[52]
			COP-ML[8,46,49,53]
			COP-RMS-ML[20]
			COP-TL[52]
			COP-path[8,20]
			COP-V[7,8,46,49,53]
			COP-RMS-V[20]
			Overall stability index[47]
		Force platform-bipedal stance-(F) EC	ROM-AP[52]
			COP-AP[46,53]
			COP-RMS-AP[20]
			ROM-ML[52]
			COP-ML[46,53]
			COP-RMS-ML[20]
			COP-TL[52]
			COP-path[20]
			COP-V[7,46,53]
			COP-RMS-V[20]
		Force platform-one leg stance-(F) EO	COP-V[7]
		Force platform-one leg stance-(F) EC	COP-V[7]
Stability in gait	Postural responses include both in position and compensatory stepping responses to external disturbances induced by the examiner's hand using the unique push and release technique.	Timed up and go test	The time to accomplish[7,45]

Table 1. Definitions of the domains of balance control and the applied methodology for their assessment. *(F) EO* (foam) eyes open, *(F)EC* (foam) eyes closed, *ROM* range of motion, *COP* centre of pressure, *AP* anterior-posterior, *ML* medial-lateral, *TL* trajectory length, *V* velocity, *RMS* root mean square.

Study characteristics

Table 3 presents the study characteristics. The included studies were published between 2007 and 2023, and nearly half of them were conducted in Europe ($n = 7$, 46.67%). All the included research employed a cross-sectional design, with the exception of one longitudinal study. Balance control was assessed in a total of 616 ID and 684 TD participants. Most studies reported the sample's mean age (ID group: 12.23 ± 4.68 years; TD group: 12.24 ± 4.73 years) and gender distribution (ID group: 62% male; TD group: 58% male).

Balance control scale or subscale performance of children and adolescents with ID

Two studies[28,29] used Pediatric Balance Scale (PBS) and the Bruininks Oseretsky Test of Motor Proficiency, 2nd edition (BOT-2) subscale to measure the participants' balance performance. The results consistently show the significantly poorer balance performance of participants with ID than their TD peers (PBS score: SMD = -1.30, 95% CI: -2.12 to -0.47, p = 0.002; BOT-2 subscale score: SMD = -3.43, 95% CI: -3.88 to -2.99, $p < 0.001$). Two other research[45,48] that used Berg Balance Scale (BBS) and Movement Assessment Battery for Children-2 (MABC-2) were unable to calculate SMD values due to the lack of relevant data. However, both still revealed a trend of balance deficits in participants with ID compared with the TD groups (See Supplementary Table S2).

Balance control test performance of children and adolescents with ID

13 studies adopted specific balance tests to assess balance control ability (See Table 1). The included research involved four out of the six balance domains, that is, sensory orientation, stability limits/verticality, anticipatory postural adjustments and stability in gait. Biomechanical constrain and postural response were not covered.

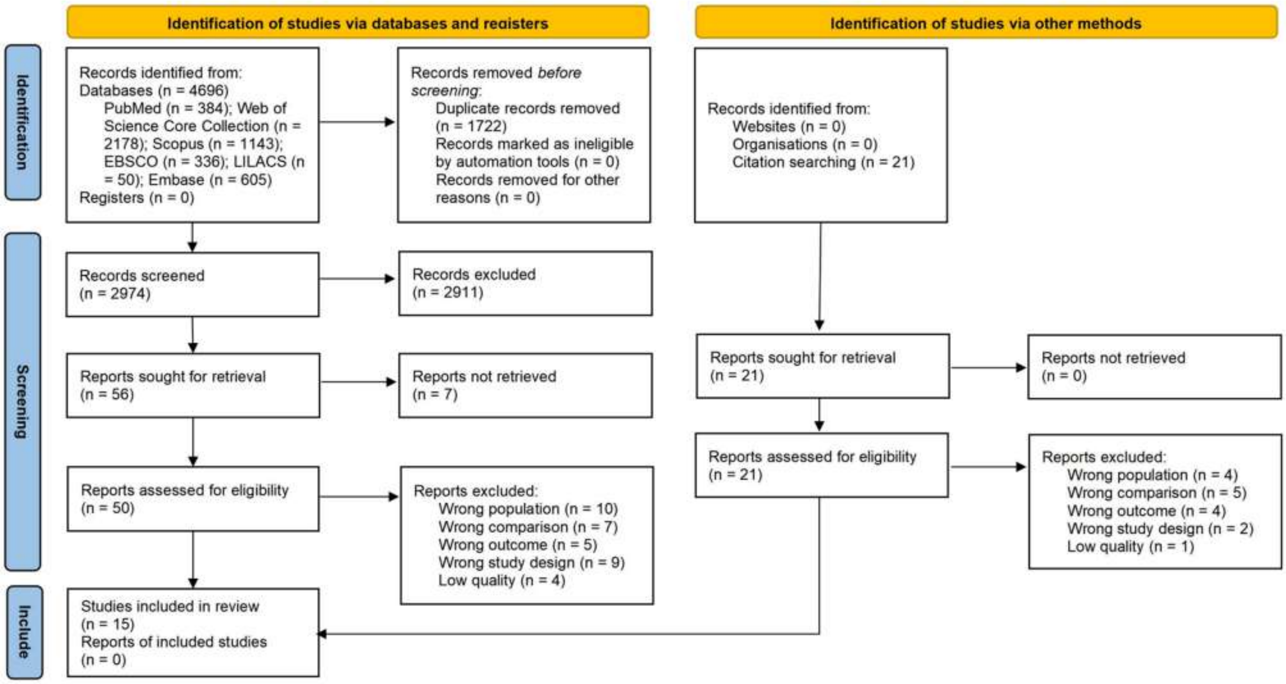

Fig. 1. PRISMA flow diagram for the identification, screening, eligibility and inclusion of studies.

Sensory orientation

Eight studies, of which six were pooled for meta-analysis, used a force platform to measure the sensory orientation[7,8,20,46,49,53]. We analysed the various parameters of the centre of pressure (COP) sway, such as velocity (V), direction of anterior–posterior (AP) and medial–lateral (ML), and pooled the data based on the following test conditions: (1) bipedal stance with eyes open[7,8,20,46,49,53] (See Fig. 2) and (2) bipedal stance with eyes closed[7,46,53] (See Fig. 3).

Figure 2 shows that children and adolescents with ID had a significantly larger COP sway than their TD peers during their bipedal stance with eyes open (COP-AP: SMD = 0.90, 95% CI: 0.31 to 1.50, $I^2 = 67\%$, $p = 0.003$, 95% PI: -0.97 to 2.78; -ML: SMD = 0.81, 95% CI: 0.48 to 1.14, $I^2 = 0\%$, $p < 0.001$, 95% PI: 0.27 to 1.35; -path: SMD = 1.14, 95% CI: 0.73 to 1.56, $I^2 = 0\%$, $p < 0.001$; -V: SMD = 0.86, 95% CI: 0.51 to 1.20, $I^2 = 46\%$, $p < 0.001$, 95% PI: -0.02 to 1.73). Figure 3 reveals the participants' similar results during bipedal stance with eyes closed compared with their controls (COP-AP: SMD = 0.46, 95% CI: 0.03 to 0.90, $I^2 = 0\%$, $p = 0.04$; -V: SMD = 0.44, 95% CI: 0.22 to 0.66, $I^2 = 0\%$, $p < 0.001$, 95% PI: -0.30 to 1.26). However, no significant difference was observed in the COP-ML (SMD = 0.43, 95% CI: -0.01 to 0.87, $I^2 = 0\%$, $p = 0.05$) between the two groups. The SMDs of COP sway with eyes closed and open were considered as small to large effect size.

Although two other studies[47,52] were excluded in the meta-analysis owing to differences in their outcome variables, the extent of postural sway showed similar trends during the participants were standing bipedally with their eyes open or closed (See Supplementary Table S2). In addition, with the increased task difficulty (i.e. standing on one leg with eyes open or closed)[7], participants with ID also exhibited a significantly poorer performance than their TD peers (See Supplementary Table S2).

Stability limits/verticality

Three studies involved stability limits[7,28,51]. Data from the same direction were pooled (See Fig. 4). Overall, participants with ID exhibited significantly poorer stability limits in various directions compared with those with TD peers: forward (SMD = -0.96, 95% CI: -1.21 to -0.75, $I^2 = 11\%$, $p < 0.001$, 95% PI: -1.35 to -0.61), leftward (SMD = -0.73, 95% CI: -1.17 to -0.30, $I^2 = 0\%$, $p < 0.001$, 95% PI: -1.69 to 0.22) and rightward (SMD = -0.84, 95% CI: -1.28 to -0.40, $I^2 = 0\%$, $p < 0.001$, 95% PI: -1.81 to 0.12). All SMDs of different directions in functional reach test were considered as large effect sizes. None of the included studies provided discussions on verticality.

Anticipatory postural adjustments

Three studies assessed anticipatory postural adjustments. Given the different types of tests applied in these research (i.e. one leg stance[7], stork stand test[50] and goal-directed reaching[44], the data could not be pooled. A study that applied goal-directed reaching revealed the deficits in the ID group in terms of their anticipatory postural control[44]. Compared with their TD peers, individuals with ID tended to use inefficient and conservative strategies for postural stability and reaching. The results of one-leg stand test indicated that the total time to maintain balance by the ID group was similar to that of their controls[7]. However, the results of stork-stand test revealed that the participants with ID used considerably less total time to maintain balance than their controls[50].

Study	1	2	3	4	5	6	7	8	9	10	11	Overall assessment
Rider et al., 1983	+	+	?	NR	-	-	-	?	+	+	-	L
Vuillerme et al., 2001	+	?	?	NR	+	+	?	?	+	+	-	L
Lahtinen et al., 2007	+	+	+	ID: 82% TD: NR	-	+	+	?	+	+	-	A
Rigoldi et al., 2011	+	+	+	NR	-	+	+	?	+	+	-	A
Villarroya et al., 2012	+	+	+	NR	-	+	+	?	+	+	-	A
Wang et al., 2012	+	+	?	NR	-	+	+	?	+	+	+	A
Blomqvist et al., 2013	+	+	+	ID: 13% TD: 19%	-	+	+	?	+	+	-	A
Chen et al., 2015	+	+	+	NR	-	+	+	+	+	+	-	A
Cheshmi, 2015	+	+	?	NR	-	+	+	+	+	+	-	A
Jung et al., 2017	+	?	-	NR	-	+	+	°×	+	+	-	L
Capio et al., 2018	+	+	+	DS: 47% TD: 47%	-	+	+	+	+	+	-	H
Sretenovic et al., 2019	+	+	?	NR	-	-	-	?	+	-	-	L
Kaya et al., 2021	+	+	?	NR	-	-	-	°×	+	+	-	L
Khallaf et al., 2021	+	+	+	NR	-	+	+	?	+	+	-	A
Promsorn & Taweetanalarp 2021	+	+	°×	DS: 46% TD: 46%	-	+	+	?	+	+	-	A
Jain et al., 2022	+	+	?	DS: 42% TD: 42%	-	+	+	?	+	+	-	A
Klotzbier et al., 2022	+	+	+	NR	-	+	+	?	+	+	-	A
Emir et al., 2023	+	+	?	ID: 33% TD: 31%	-	+	+	?	+	+	-	A
Kavanagh et al., 2023	+	+	°×	NR	-	+	+	°×	+	+	-	A
Laatar et al., 2023	+	+	°×	ID: 27% TD: 27%	-	+	+	?	+	+	-	A

Table 2. Risk of bias assessment of individual studies. Note. 1: the study addresses an appropriate and clearly focused question; 2: the cases and controls are taken from comparable populations; 3: the same exclusion criteria are used for both cases and controls; 4: what percentage (%) of each group (cases and controls) participated in the study; 5: comparison is made between participants and non-participants to establish their similarities or differences; 6: cases are clearly defined and differentiated from controls; 7: it is clearly established that controls are non-cases; 8: measures will have been taken to prevent knowledge of primary exposure influencing case ascertainment; 9: exposure status is measured in a standard, valid and reliable way; 10: the main potential confounders are identified and taken into account in the design and analysis; 11: confidence intervals are provided. "+" indicates yes, the study does this; "-" indicates no, the study does not do this; "?" indicates can't say whether the study does this. *ID* intellectual disability, *TD* typically developing, *DS* Down syndrome, *H* high quality, *A* acceptable quality, *L* low quality; NR: not reported.

Stability in gait

Timed up-and-go test was used to assess gait stability in two studies[7,45]. Given the lack of sufficient data in one study to calculate SMD[45], the results were not pooled. On the whole, participants with ID showed poorer gait stability than their controls (See Supplementary Table S2).

Certainty of the evidence

Since all the included studies were observational studies, the initial level of evidence was classified as low-quality. Due to the risk of bias and inconsistency, the level of evidence was downgraded. Finally, the results revealed that the quality of the evidence was very low (See Supplementary Table S3).

Discussion

This systematic review and meta-analysis aimed to explore balance deficits in children and adolescents with ID through comparison of their balance performance with that of their TD peers. Individuals with ID presented more poorly on balance control abilities than their TD peers. Specific to the various domains of balance control, participants with ID presented substantially more difficulties in their sensory orientation (See Figs. 2 and 3) and limits of stability (See Fig. 4). In addition, they encountered more hardships in gait stability (See Supplementary Table S2). Inconsistent results were obtained for anticipatory postural adjustments (See Supplementary Table S2).

Although previous reviews have provided a descriptive summary of the balance performance of children and youth with ID, the current study provides quantitative evidence as to which specific balance domains are deficient. In terms of overall balance performance, our findings confirmed the previous reviews, in which lower balance ability among individuals with ID than their TD peers was identified[31–33]. Notably, in our review, the SMD values on PBS and BOT-2 (as shown in Supplementary Table S2) both indicated a large effect size,

Study	Country	Design	Sample size (ID)	% Males (ID)	Age (ID)	ID type	ID level	Sample size (TD)	% Males (TD)	Age (TD)
Lahtinen et al., 2007	Finland	LG	77	57%	11–16	ID + DS	Moderate	159	NR	11–16
Rigoldi et al., 2011	Italy	CS	95	NR	6–19	DS	NR	25	NR	5–20
Villarroya et al., 2012	Spain	CS	32	53%	10–19	DS	NR	33	58%	10–19
Wang et al., 2012	China	CS	23	69.9%	14.4 ± 2.8	DS	NR	18	61.1%	13.8 ± 3.6
Blomqvist et al., 2013	Sweden	CS	100	60%	17.9 ± 1.2	ID	Mild to moderate	155	43%	17.2 ± 1.0
Chen et al., 2015	China	CS	14	50%	8.26 ± 0.82	DS	NR	14	50%	8.04 ± 0.74
Cheshmi 2015	Iran	CS	39	100%	6–12	ID	NR	33	100%	6–12
Capio et al., 2018	China	CS	20	60%	7.10 ± 2.90	DS	NR	20	80%	7.25 ± 2.47
Khallaf et al., 2021	Saudi Arabia	CS	28	NR	11.07 ± 1.65	DS	NR	28	NR	11.54 ± 1.17
Promsorn & Taweetanalarp, 2021	Thailand	CS	30	37%	7–12	DS	NR	30	37%	7–12
Jain et al., 2022	India	CS	14	43%	10.71 ± 3.00	DS	NR	14	43%	10.71 ± 3.00
Klotzbier et al., 2022	Germany	CS	12	50%	10.5 ± 10.08	DS	NR	24	50%	4–11
Emir et al., 2023	Turkey	CS	21	71%	10.95 ± 2.88	ID	Mild	20	85%	10.68 ± 2.86
Kavanagh et al., 2023	Ireland	CS	96	60.5%	7.7 ± 2	ID + DS	NR	96	60.5%	7.7 ± 2
Laatar et al., 2023	Tunisia	CS	15	NR	8.6 ± 1.42	ID	Mild	15	NR	8.87 ± 1.72
Total			616					684		

Table 3. Main characteristics of the included studies. *ID* intellectual disability, *TD* typically developing, *DS* Down syndrome, *CS* cross-sectional, *LG* longitudinal, *NR* not report.

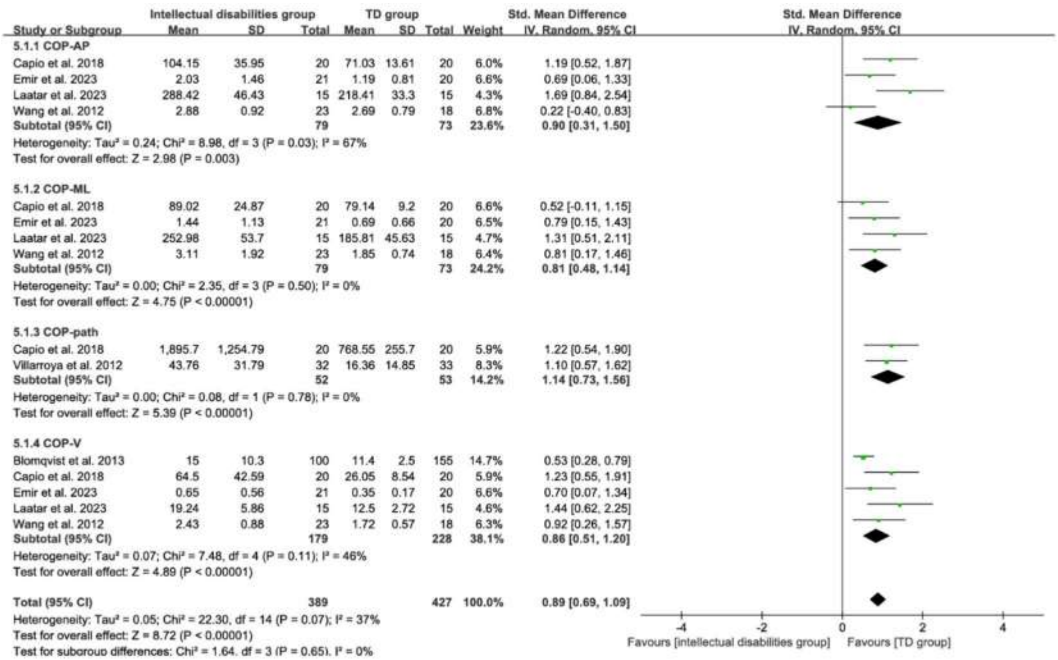

Fig. 2. The forest plots of force platform-standing bipedally with eyes open (sensory orientation domain) meta-analysis for the ID and TD groups.

suggesting that the ID group did present with balance-related issues and the overall balance performance of this group was significantly lower than that of the TD group.

This finding is understandable through four perspectives. Firstly, cases of ID are usually divided into hereditary and non-hereditary, with Down syndrome (DS) being the most common genomic ID disorder[59]. Studies have showed that children with DS have deficits in hippocampal and prefrontal cortex-dependent functions[60,61]. These results are consistent with the magnetic resonance imaging finding of reduced hippocampal and frontal lobes volumes in children with DS[62]. However, there was little or no appreciable anatomical difference at birth between individuals with and without DS[63]. Balance control and cognition are governed and regulated by the prefrontal cortex and hippocampus[64]. When compared to TD peers, the lower volume of hippocampal and frontal lobes in this population may adversely affect their balance control abilities. Secondly, this population is characterised by the delay of motor developmental milestones[65]. This delay is caused by differences in the structure of the brain,

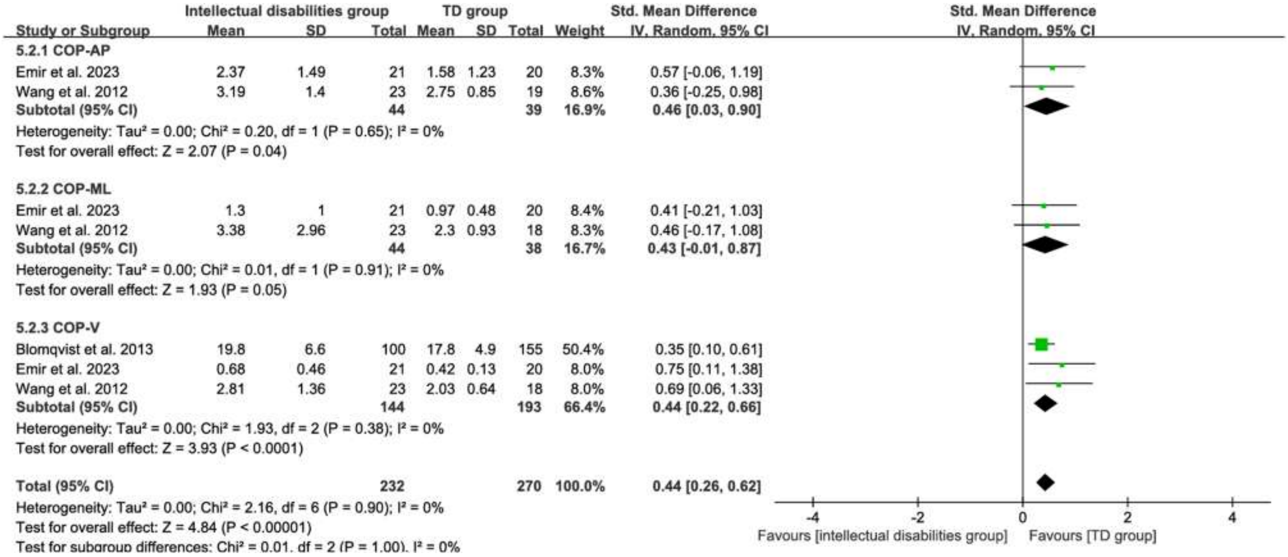

Fig. 3. The forest plots of force platform-standing bipedally with eyes closed (sensory orientation domain) meta-analysis for the ID and TD groups.

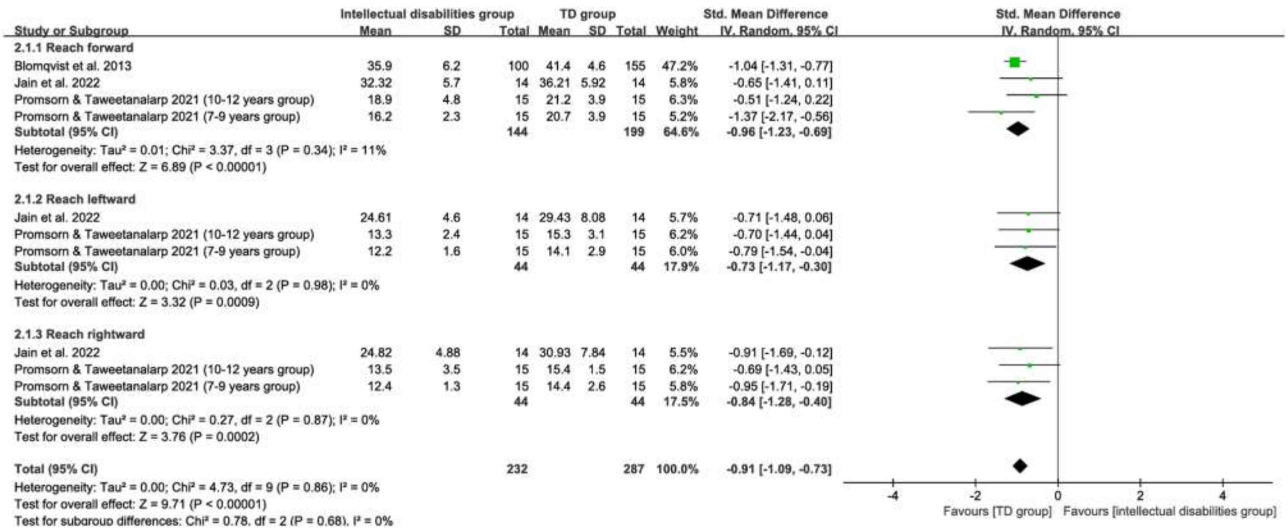

Fig. 4. The forest plots of functional reach test (functional stability limits/verticality domain) meta-analysis for the ID and TD groups.

such as reduced gray and white matter volumes in the cerebellum, temporal lobe, frontal lobe, parietal lobe, corpus callosum, and hippocampus, as well as delays in the myelination processes of the central and peripheral nerves[66,67]. Specific to balance development, individuals with ID have delayed development of approximately two to four years than their TD peers[68]. Thirdly, balance control requires a complex interaction of musculoskeletal and neural systems, such as visual, vestibular and proprioceptive systems. Individuals with ID lack the ability to integrate multiple sensory systems, which negatively affect their overall balance control[69]. Finally, PA levels are positively associated with balance control in children and adolescents[70]. Thus, individuals with higher PA levels showed better balance control ability[71], whereas those with low levels of PA participation usually experienced additional difficulties in exercising balance control[72]. Children and adolescents with ID show less activity than their TD peers, and most of them fail to meet the World Health Organization's guidelines of PA (i.e. at least 60 min/day of moderate-to-vigorous-intensity PA)[73,74], which may also contribute to their poorer balance control performance.

Gaining a thorough understanding of the balance domains affected is beneficial to designing targeted interventions for the improvement of balance deficiencies of children and adolescents with ID. The results of our study show that individuals with ID performed significantly poorer than their TD peers in the sensory orientation tests. In bipedal stance tests, whether with eyes open or closed, children and adolescents with ID all present with significantly more postural sway (See Figs. 2 and 3). Meanwhile, in more difficult conditions, such as standing on one leg, ID participants exhibited a consistently poorer performance than their TD controls with eyes open and closed (See Supplementary Table S2). One-leg stance decreased the base of support and therefore made the condition proprioceptively more difficult. Sensory organisational processes are essential to balancing control, in which multimodal sensory systems (e.g. somatosensory, visual and vestibular) are involved and integrated within the central nervous system[75]. Sensory orientation deficits in the participants with ID possibly resulted from major disorders in their sensory organisation's cooperation, such as the coordination of their visual organs, inner ear and proprioceptive and central nervous system[23,76,77]. However, at present, there is very limited information regarding how the central nervous system, which is responsible for regulating the postural balance, can adapt to changes in sensory input (such as visual and proprioceptive disturbances) and make corresponding adjustments[31]. In addition, compared with their TD peers, individuals with ID often show less motivation to actively explore the environment and consequently experience few sensory inputs, which are likely to exacerbate difficulties in their motor abilities, especially those relating to balance[78]. Therefore, the implementation of sensorimotor rehabilitation program training may be an effective intervention on balance control in children and adolescents with ID[76,79].

Our review also revealed the compromised stability limits and gait stability in children and adolescents with ID compared with their TD peers (See Fig. 4 and Supplementary Table S2). Individuals with ID experience more motor difficulties, such as decreased muscle strength and joint hypermobility[50,80,81]. One study confirmed that joint hypermobility affects the balance performance of children and adolescents in functional and lateral reaches[82]. As for gait stability, altered gait strategies were observed in this population, manifested as decrease in step length and an increase in step frequency[83]. Impairment in body structures and function, such as the muscle hypotonia and decreased strength in ID group were possibly the main causes of their poor gait performance. From the perspective of neuroanatomy, hypoplasia of the cerebellum and corpus callosum is one of the main factors responsible for muscle hypotonia, incoordination, and decreased fluency of movement in this group[33,84]. Some researchers have conducted interventions for core stability exercises to improve the overall postural stability of children with ID, and their results revealed that core stability exercises effectively improved the participants' postural stability[85,86].

In terms of the anticipatory postural adjustments, three studies compared the performances between ID and TD groups; however, inconsistent findings were achieved. Two studies reported the poorer performance of children and adolescents with ID than their TD peers in this domain[44,50], whereas one study found no significant difference in the performance between these groups[7]. The inconsistent findings may be related to the various criteria for testing and scoring system used in the included studies. In Blomqvist and colleagues' study[7], the participants' hands and non-supporting leg were free, whereas participants in other research[50] were required to place their hands on both sides of their hip and place the heel of their non-supporting leg on the knee of the supporting one. Thus, the difficulty of the test in a former study[7] was possibly reduced, and the participants in this trial probably completed the test more easily. In addition, in Blomqvist's study[7], a full score can be achieved by standing on one leg for 30s compared with standing for 60s to achieve full score in other work[44,50]. This condition possibly enabled the ID and TD groups in the former study[7] to achieve full marks easily, and therefore, no significant difference was observed in the test results. Genetic abnormalities on chromosome 21 are the main genetic factor contributing to the delayed myelin development in children and youth with ID. When implementing task-oriented postural control, these children were found to have an increased reaction time to maintain balance due to their delayed myelin development[44]. Additionally, deficiencies in the temporal and frontal lobes of these children may also cause errors in the process of anticipated postural adjustments[87].

To the best of our knowledge, this study is the first systematic review to comprehensively reveal balance deficits of children and adolescents with ID in various balance domains. The findings can shed light on future research directions and practical implications. Firstly, mapping the balance control ability in accordance with the BESTest framework, detailed insights into the domain and the extent of balance deficits present in children and adolescents with ID can be obtained. Our results can help health professionals, PE teachers and policy makers to develop targeted interventions to improve the balance performance of this study population. Secondly, the included research investigated some balance domains in participants with ID through application of diverse tests or tasks. More studies are warranted to assess the entire construct of balance control (e.g. six domains of balance control) within the target group in the future. The research results will further the understanding of the nature of heterogeneity of children and adolescents with ID. Thirdly, the majority of the included studies applied a cross-sectional research design. Although cross-sectional research may generalise the findings to the whole group of ID, more longitudinal investigations are needed to explore the developmental course of balance control in this population. Finally, most included studies were from English-speaking countries, and language barriers possibly caused the lack of related research from other countries.

The present review encountered several limitations. The first potential limitation is the completeness of literature search. Although an extensive literature search was conducted to identify all published studies, a few published ones were possibly missed in this review due to the use of keywords other than those used in the current work and the vague titles or abstracts of these missed studies. The other limitation is the exclusion of non-English published studies. Certain research that could have added relevant information to this field might have been discarded because they were published in other languages. Finally, implementation of subgroup analysis was difficult due to the lack of detailed information on the participants' ID severity in most of the included studies. The wide range of 95% PIs reported in some of our results also indicated the high dispersion among the included studies. Future confirmation is therefore needed in robust studies stratified by ID severity, age, and comorbidity.

Conclusion

This systematic review and meta-analysis provides information on the overall understanding of balance control deficiencies in children and adolescents with ID. In general, children and adolescents with ID exhibited poorer performance on balance control than their TD peers. Specific to different balance domains, the ID group experienced considerably more difficulties in sensory orientation and limits of stability. In addition, they showed deficient gait stability compared with their TD peers. The findings on the domain of anticipatory postural adjustments were inconsistent. For further understanding, future studies should comprehensively assess balance control in this population and provide longitudinal evidence to gain insights into the developmental course of balance control in individuals with ID.

Data availability

All data generated or analysed during this study are included in this published article [and its supplementary information files].

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Author contributions

Conceptualization (Y.L. and J.Q.), methodology (Y.L. and J.Z.), validation (J.Q. and W.H.), formal analysis (Y.L. and J.Z.), data curation (Y.L. and J.Z.), writing—original draft preparation (Y.L.), writing—review and editing (J.Q. and W.H.) and funding acquisition (W.H.). All authors read and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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