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# The Impact of Physical Exercise Interventions on Body Composition in Overweight and Obese Children and Adolescents with Intellectual Disabilities: A Meta-Analysis

**yan xiao**
Capital University of Physical Education And Sports
**jinghui zhong**
Capital University of Physical Education And Sports
**tongwu yu**
Capital University of Physical Education And Sports
**qinhao zhang**
The affiliated high school of Peking University
**hongjie shi**
24008016003@cupes.edu.cn

Capital University of Physical Education And Sports

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## Abstract

Background: Overweight and obesity are highly prevalent among children and adolescents with intellectual disability (ID), yet the comparative effectiveness of specific exercise modalities is not well established. Therefore, a meta-analysis was conducted to examine the impact of physical exercise on body composition in children and adolescents with intellectual disability who are overweight or obese, providing an evidence-based foundation for future research.

Methods: We conducted a pre-registered systematic review and Bayesian arm-based random-effects network meta-analysis of randomised trials in participants aged 6–22 years with ID, comparing aerobic exercise (AE), resistance exercise (RE), combined AE+RE (ARE), high-intensity interval training (HIIT), swimming (SWIM), whole-body vibration (WBV), Tai Chi, active gaming (ARG), and multi-component programmes combining exercise with diet (PAD) against usual activity or active controls. Primary outcomes were post-intervention changes in body weight, BMI, fat mass, and waist circumference, synthesised as Hedges' g (standardised mean difference, SMD) with 95% CIs. Interventions were ranked using SUCRA; heterogeneity, inconsistency, and certainty were evaluated with conventional diagnostics.

Results: Twenty-five trials were eligible. Between-study heterogeneity was low-to-moderate ($\tau^2$=0.02–0.05), and no global inconsistency was detected. Compared with usual activity, HIIT produced the largest reductions in weight (SMD=−0.64, 95% CI −0.89 to −0.39) and BMI (SMD=−0.58, −0.84 to −0.31). Ranking results supported these findings: for body weight, PAD ranked highest (SUCRA 92.1%), followed by HIIT (70.7%); for BMI, HIIT ranked first (SUCRA 93.4%). For fat mass, SWIM ranked first (SUCRA 90.1%), followed by ARE (65.7%). For waist circumference, SWIM ranked first (SUCRA 79.3%), followed by AE (75.6%) and RE (67.9%). Certainty for key contrasts was low-to-moderate, limited primarily by lack of blinding and reporting quality; effect directions were coherent and prediction intervals generally favoured benefit.

Conclusions: For children and adolescents with ID, physical exercise emphasising higher intensity appear most effective: prioritise HIIT or exercise-plus-diet programmes when the goal is weight/BMI reduction, and consider ARE or swimming to target fat mass and central adiposity. Incorporating caregiver engagement and nutritional support is likely to improve adherence and amplify outcomes in schools and community settings.


## Research Design

This study aimed to assess the effectiveness of various physical exercise interventions on body composition in children and adolescents with intellectual disabilities (ID) who are overweight or obese. The exercise modalities analyzed include aerobic exercise (AE), resistance exercise (RE), combined aerobic and resistance exercise (ARE), high-intensity interval training (HIIT), swimming (SWIM), and multi-component programs combining exercise with diet (PAD). A Bayesian arm-based random-effects network meta-analysis was conducted, comparing these interventions against usual activity or active controls. Primary outcomes included body weight (BW), BMI, fat mass, and waist circumference. The results showed that HIIT and multi-component interventions produced the greatest reductions in BW and BMI, with SWIM ranking first for fat mass reduction. The study highlights the importance of exercise intensity and structured support, recommending HIIT or exercise-plus-diet programs for weight reduction and ARE or swimming for targeting fat mass and central adiposity.

## 1. Introduction

Childhood and adolescent obesity has increased markedly across the globe over the past three decades. According to a pooled analysis of 2,416 population-based studies including 128.9 million participants, the prevalence of overweight and obesity among individuals aged 5–19 years rose from 4% in 1975 to over 18% in 2016, with a particularly steep rise in low- and middle-income countries [1]. Projections suggest that by 2035, more than 243 million children and adolescents worldwide will be obese if current trends persist [2]. This surge represents a substantial public health challenge, as childhood obesity is a strong predictor of adult obesity and is associated with early-onset type 2 diabetes, cardiovascular disease, and certain cancers [3]. The socioeconomic consequences include reduced educational attainment, diminished productivity, and an estimated US$1 trillion annual cost by the 2030s [4].

Children and adolescents with intellectual disability (ID) are disproportionately affected by obesity. A nationally representative study from the United States reported that approximately 29% of youths with ID were obese, nearly twice the prevalence among typically developing peers [5]. Contributing factors include hypotonia, reduced physical activity, psychotropic medication, and environmental barriers [6]. Excess adiposity in this population increases the risk of metabolic syndrome, obstructive sleep apnoea, and reduced functional independence [7]. Moreover, caregivers face heightened burdens, while healthcare systems incur increased costs associated with managing obesity-related complications [8].

Although physical activity is a cornerstone of obesity management, studies focusing on youths with ID remain limited. Recent systematic reviews indicate that most interventions in this population emphasise physical activity but demonstrate only modest effects on weight and BMI [9, 10]. For instance, a meta-analysis of 27 trials found no significant reductions in adiposity measures following exercise programmes [9]. Another review suggested that exercise alone may not be sufficient for managing weight in individuals with ID without complementary lifestyle modifications [10]. Nonetheless, some small trials, such as a 12-week school-based programme, have reported modest improvements in BMI and fat mass [11]. Importantly, these studies often suffer from small sample sizes, short durations, and heterogeneous designs, making it difficult to identify the most effective exercise modality. To date, no network meta-analysis has systematically compared aerobic, resistance, combined, HIIT, and game-based interventions in youths with ID to establish their relative efficacy [10, 12]. This gap highlights the urgent need for rigorous evidence synthesis to inform practice and policy.

This systematic review and network meta-analysis aims to address this critical gap by comparing and ranking the effects of various exercise modalities on body composition parameters, including body weight (BW), Body mass index (BMI), fat mass(FM), and waist circumference (WC), in children and adolescents with ID. Specifically, we will (1) synthesise evidence from randomised trials evaluating exercise-only and multi-component interventions; (2) apply a Bayesian network meta-analysis to compare the relative effectiveness of aerobic, resistance, combined, HIIT, and game-based activities; and (3) examine moderators such as age, sex, ID subtype, and intervention dose to inform precision exercise prescriptions [13]. By doing so, we aim to deliver tailored recommendations to clinicians, educators, and policymakers to support the development of effective, feasible, and safe obesity interventions for this underserved population [14].

## 2. Method

# 2.1 Protocol registration

This systematic review and network meta-analysis protocol was prospectively registered with the International Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY) prior to study initiation (Registration Number: INPLASY202570107; with the registry entry publicly accessible). The protocol was developed in accordance with the PRISMA-P guidelines for protocol development and reporting, and the conduct and reporting of the review adhered to the PRISMA-NMA extension for network meta-analyses [15–16]. Analytical methods were based on the Cochrane Handbook recommendations for network meta-analysis, and the certainty of evidence was evaluated using the CINeMA framework.

# 2.2 Eligibility Criteria

Participants (P): Children and adolescents (aged 6–18 years) with intellectual disabilities who were overweight or obese at baseline. Weight status was defined according to the criteria used in the primary studies, based on age- and sex-specific BMI cut-offs (e.g., WHO, CDC, IOTF, or equivalent national references). Studies involving mixed-weight populations were eligible only if data for the overweight/obese subgroup were reported separately or could be obtained from the authors; otherwise, they were excluded.

Interventions (I): Any structured exercise or physical activity programme, including aerobic (AE), resistance (RE), combined aerobic+resistance (ARE), High-Intensity Interval Training (HIIT), swimming, Whole Body Vibration (WBV), Tai Chi (TC), adapted rhythmic gymnastics/exergames (ARG), school-based PA, and exercise plus diet (PAD). Multi-component trials were eligible if the exercise component could be analysed separately.

Comparators (C): Usual care, wait-list, or non-exercise attention control, such as health education or stretching, or another eligible exercise modality. TUA (no intervention) was used as the network reference node.

Outcomes (O): Primary outcomes included body weight (BW), BMI, total fat mass, and waist circumference (WC). The secondary outcome was waist-to-hip ratio (WHR). Post-intervention (or the time point closest to 12–24 weeks) change scores were prioritised; where only pre-post means and SDs were available, change values and SDs were derived using standard formulae. DXA or multifrequency BIA were preferred methods for assessing fat mass. Outcome selection and definitions were aligned with contemporary paediatric adiposity measurement guidance. Adherence and adverse events were not prespecified outcomes.

Study design (S): Eligible designs included parallel or cluster RCTs and well-described quasi-RCTs. Cross-over and single-arm pre-post studies were excluded. Multi-arm designs were included, provided appropriate statistical methods were applied. No restrictions were imposed on language or publication status.

## 2.3 Information Sources and Search Strategy

We conducted a comprehensive search in PubMed/MEDLINE, Embase (Ovid), Cochrane CENTRAL, Web of Science Core Collection, SPORTDiscus (via EBSCOhost), VIP, and CNKI from database inception to 30 June 2025. To reduce publication bias, grey literature was also searched, including ProQuest Dissertations & Theses and major conference proceedings. No language restrictions were applied; however, English- and Chinese-language studies were prioritised for inclusion.

The search strategy combined controlled vocabularies, such as MeSH in PubMed, Emtree in Embase, SPORTDiscus Thesaurus, and Chinese subject headings, together with free-text terms. These were organised into four main conceptual domains encompassing population, intervention, outcomes, and study design. Specifically, population terms covered intellectual disabilities and intellectual developmental disorder, including Down syndrome; intervention terms encompassed exercise or physical activity such as aerobic training, resistance training, HIIT, swimming, Tai Chi, whole-body vibration, and adapted physical activity or exergaming; outcome terms referred to obesity parameters, including body weight, BMI, fat mass, waist circumference, and waist-to-hip ratio; and study design terms captured randomised or controlled trials. Database-specific syntax and controlled vocabularies were adapted as necessary while ensuring conceptual consistency.

An example of a cross-database Boolean string was as follows: (“intellectual disab*” OR “intellectual developmental disorder” OR “developmental disab*” OR “mental retardation” OR “Down syndrome”) AND (child* OR adolescen* OR youth OR teen* OR “young adult*”) AND (“exercise” OR “physical activ*” OR aerobic OR “resistance training” OR HIIT OR “strength training” OR swimming OR “tai chi” OR exergam* OR “whole body vibration” OR “adapted physical activity”) AND (“body weight” OR weight OR BMI OR “body mass index” OR adipos* OR “fat mass” OR “body fat” OR “waist circumference” OR “waist-to-hip ratio” OR WHR) AND (random* OR controlled OR trial OR quasi-random* OR cluster OR crossover).

Full database-specific strategies, including exact syntax, field tags, controlled vocabulary mappings, and retrieval counts, are detailed in Supplementary Table 1. In addition, we performed backward and forward citation chasing and contacted subject experts and study authors to identify ongoing or unpublished trials and to obtain missing data where possible.

## 2.4 Study Selection

After de-duplication in Covidence, two reviewers (YX and JHZ) independently screened titles, abstracts, and full texts against the predefined PICOS criteria. Standardised exclusion reasons were recorded and summarised in the PRISMA flow diagram. Prior to formal screening, a calibration exercise of 30–50 records was conducted, and inter-rater agreement (κ) was calculated and is reported. Any discrepancies were resolved through discussion or, where necessary, arbitration by a third reviewer. During full-text screening, we verified baseline weight status and excluded trials without an overweight/obese definition or without extractable overweight/obese data. Both English- and Chinese-language databases were covered, and Chinese full texts were cross-checked by bilingual reviewers to minimise language bias. The PRISMA 2020 flow diagram is presented in Fig. 1.

## 2.5 Data extraction

Two reviewers independently extracted study information, including bibliographic details; participant characteristics such as age, sex, height, ID subtype, and comorbidities; intervention and control FITT components and weekly dose (or MET-min/week, where available); co-interventions such as diet or parental support; and outcomes (weight, BMI, fat mass, WC, WHR) at baseline and at all reported time points. We additionally extracted the operational definition of overweight/obesity (reference standard and cut-offs) and baseline BMI-related metrics.

Change scores (Δ) were prioritised, and where only pre- and post-intervention data were available, ΔSD was derived using standard formulae. If the pre-post correlation (r) was not reported, a default of r = 0.5 was assumed, with sensitivity analyses conducted over a range of 0.3–0.7. Unit conversions were applied where necessary, and BMI was computed from weight/height² when required. Multi-arm trials were analysed using shared-control variance adjustments, and cluster trials were adjusted for design effects using intraclass correlation coefficients (ICCs), either empirical or assumed with sensitivity analyses. Study authors were contacted to obtain missing data; where this was unsuccessful, recommended imputation strategies from the Cochrane Handbook were applied [17].

## 2.6 Risk-of-bias assessment

Risk of bias was evaluated using the Cochrane Risk of Bias (RoB) tool [19] across seven domains: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias. Two reviewers conducted the assessments independently, with disagreements resolved by consensus. Acknowledging the inherent difficulty of achieving blinding in exercise trials, particular emphasis was placed on assessor blinding and the use of objective outcome measurements, such as DXA or BIA, and anthropometry performed by independent assessors. Sensitivity analyses excluding studies judged at high risk of bias were planned to test the robustness of the findings. Risk-of-bias summary bar plots and per-study traffic-light plots are presented and referenced in the Results section. All ratings in this review were generated using the RoB 1 tool (Fig. 2).

## 2.7 Statistical Synthesis

A Bayesian arm-based random-effects network meta-analysis was conducted in R (brms 2.20). Continuous outcomes were analysed as standardised mean differences (Hedges' g). Global heterogeneity ($\tau^2$) and 95% prediction intervals were reported, and SUCRA was interpreted as the mean cumulative ranking probability across all possible ranks [17]. Model convergence was assessed using Gelman–Rubin diagnostics, and inconsistency was evaluated through node-splitting and design-by-treatment interaction tests [18]. For secondary outcomes such as WHR, where a connected network was not available, we performed descriptive summaries only, without pairwise or network pooling and without inclusion in SUCRA rankings. We fitted models using 4 chains with 5,000 iterations per chain (2,500 warm-up) and weakly informative priors for treatment effects and heterogeneity. Convergence was considered adequate if R-hat < 1.01 and effective sample sizes were sufficient; full model code and priors are provided in the Supplementary Appendix.

# 3. RESULTS

### 3.1 Study Selection

A total of 3165 records were identified across databases (Embase=1216; Cochrane Library=175; Web of Science=607; SPORTDiscus/EBSCO=74; PubMed=1011; CNKI=31; VIP=51), with a further seven records identified through citation searching. After the removal of 529 duplicates, 2636 records were screened by title and abstract, of which 2458 were excluded as irrelevant. Full texts were sought for 178 records, and three could not be retrieved, leaving 175 reports assessed for eligibility. Of these, 155 were excluded for the following reasons: review articles (n=84), non-exercise or physical activity interventions (n=34), case reports (n=17), absence of an appropriate control or comparator (n=11), and participant age exceeding 20 years (n=6). From the database searches, 23 studies met the inclusion criteria. Citation searching identified seven additional reports, of which five were excluded (two meta-analyses and three systematic reviews), yielding two further eligible studies. In total, 25 studies were included in the qualitative synthesis, all of which were subsequently entered into the quantitative network meta-analysis. The PRISMA 2020 flow diagram is presented in Figure 1.

### 3.2 Characteristics of Included Studies

We included 25 randomised or quasi-randomised trials published between 2007[30] to 2024[32,43], conducted in China[27,38-40,43-47], Spain[25-26,32-33,44], the United States[23,33,35,42], Poland[29,41], Türkiye[30], Romania[24], Belgium[34] and Brazil[37]. Key sample and study characteristics are summarised in Table 1. Several trials employed multi-arm designs, enabling direct head-to-head comparisons between different exercise modalities. Per-arm sample sizes generally ranged from 10[23] to 63[36]. All participants were children and adolescents with intellectual disabilities within the prespecified age range; mean ages

across studies varied from 7.2 to 20.5 years, with trials including participants up to 22 years retained as planned for sensitivity analyses. Some studies focused specifically on cohorts with Down syndrome, particularly in Spain and China, whereas others recruited mixed or unspecified intellectual disabilities. Comorbidities were rarely excluded, except where required for participant safety.

The spectrum of interventions was broad and clinically relevant, with detailed information on modality, intensity, dose, frequency, and comparators presented in Table 2. Aerobic exercise (AE) was reported in eight study arms [24,27,31-32,35,37,43-44], resistance exercise (RE) in six, and combined aerobic plus resistance training (ARE) in five [34,38-39,45,47], High-Intensity Interval Training (HIIT) appeared in one trial [30], whole-body vibration (WBV) in one [28], swimming in two [41,44], Tai Chi in one[40], and adapted rhythmic gymnastics or exergaming in one[46]. Physical activity or school-based physical education frequently served as active comparators, and two trials incorporated dietary control in combination with exercise. A true usual-activity (TUA) control, defined as no structured intervention beyond daily routines, was used in 11 trials [21,24-25,27,33,35,37-38,42,45,47] and served as the reference node in the network.

FITT dosing was generally reported with sufficient detail to enable modelling. Session duration ranged from 25 minutes[25] to 120 minutes[33] , with frequencies between one and five sessions per week, and programme lengths spanning 8 weeks [35] to 48 weeks [24], with a median of approximately 20 weeks. Prescribed intensities were most commonly moderate to vigorous, although a minority of trials adopted light-to-moderate approaches such as Tai Chi, gentle swimming, or low-intensity physical activity. Several studies incorporated progressive loading through adjustments in sets, repetitions, or aerobic volume, whereas others adhered to fixed schedules aligned with school timetables or rehabilitation blocks.

Primary outcomes included body weight (BW, kg), body mass index (BMI), total fat mass measured by dual-energy X-ray absorptiometry, multi-frequency bioelectrical impedance, or skinfold estimation, and waist circumference (WC). Waist-to-hip ratio (WHR), the secondary outcome, was rarely reported and was predominantly compared only against the usual-activity control, which precluded the formation of a connected treatment network; this is detailed in Section 3.6. Outcome assessments were typically conducted at post-intervention, most commonly between 12 and 24 weeks, with a smaller number of studies extending follow-up to 36–48 weeks. The inclusion of diverse exercise nodes, the availability of common comparators such as usual-activity and school-based physical activity, and several direct head-to-head contrasts (e.g., resistance versus aerobic training, or light versus moderate-to-vigorous swimming) together yielded an analysable and adequately connected network for the four primary adiposity outcomes. Variability in FITT dosing additionally provides scope for exploratory dose–response meta-regression in subsequent analyses. A study-level summary is presented in Table 1.

**3.3 Risk of Bias**

The original Cochrane Risk of Bias tool (RoB1) was used rather than RoB2, as most included trials pre-dated 2019 and did not provide the outcome-specific, time-anchored details required for RoB2. Forcing the application of RoB2 would have resulted in numerous “no information” ratings and reduced cross-study comparability. Moreover, the primary outcomes (BW, BMI, fat mass, and WC) were objective or semi-objective anthropometric measures, meaning that the main sources of bias operated at the study level, which RoB1 is well suited to capture [15,20]. Across domains, random sequence generation and completeness of outcome data were predominantly rated as low risk, indicating acceptable randomisation and limited attrition. In contrast, allocation concealment and blinding of outcome assessors were frequently judged “unclear” owing to under-reporting, while blinding of participants and personnel was often rated as high risk, reflecting the inherent challenges of exercise trials. Selective reporting was also commonly judged “unclear”, largely due to the lack of preregistration and limited availability of study protocols in older trials. These patterns are illustrated in Figure 2: the domain-level bar chart shows green bars clustered around randomisation and attrition, yellow bars prominent for allocation concealment and assessor blinding, and red bars concentrated in performance blinding. The corresponding traffic-light plot provides study-level judgements, highlighting trials at high risk or with insufficient reporting.

Illustratively: Ozmen[30] reported only “random assignment” without describing allocation concealment and was unable to blind either participants or assessors, resulting in several domains judged at high risk. Curtin [23] combined diet and physical activity without preregistration and showed indications of selective outcome reporting. Wu [45] experienced notable attrition with unclear

handling of missing data, while Mikolajczyk [29] reported randomisation but omitted procedural details and lacked a study protocol, leading to multiple domains being rated as “unclear”.

Overall, internal validity was acceptable with respect to randomisation and outcome data completeness, whereas structural limitations in blinding and reporting persisted. To safeguard inference, we conducted sensitivity analyses excluding trials judged at high risk of bias; the primary conclusions remained unchanged (Section 3.8) [21-22]. Small-study effects were examined using comparison-adjusted funnel plots for the four primary outcomes. The adjusted funnel plots displayed overall symmetry, indicating no clear evidence of small-sample effects (Figure 3).

### 3.4 Network Geometry

Across all outcomes, the evidence networks were connected but varied considerably in density. For BW and BMI, the networks were the most robust, with multiple head-to-head loops anchored by common comparators such as TUA or school-based physical activity. The presence of several closed loops provided more stable indirect estimates and strengthened the reliability of treatment rankings. In contrast, the networks for fat mass and WC were sparser and more star-shaped, with many interventions linked primarily through control nodes and relatively few direct comparisons between non-aerobic modalities. As these networks contained fewer closed loops, some indirect estimates relied on single links, meaning that the resulting hierarchies should be interpreted with greater caution. For WHR, the available evidence did not form a connected network due to the small number of trials and absence of a consistent comparator. Consequently, a valid network meta-analysis could not be performed, and WHR findings were summarised descriptively, with pairwise meta-analysis conducted only where at least two trials contributed to the same comparison. The network geometries for BW, BMI, fat mass, and WC are illustrated in Figure 4a–d.

### 3.5 Primary Outcomes

#### 3.5.1 BW

The BW network included TUA as the reference and multiple active interventions (AE, HIIT, PAD, SWIM, WBV, ARE, RE, PA, ARG, and Tai Chi; Figure 4a). The design-by-treatment interaction test detected no global inconsistency, and between-study heterogeneity was low to moderate ($\tau^2$=0.02). Compared with the reference, HIIT produced the largest standardised reduction in body weight (SMD=−0.64, 95% CI −0.89 to −0.39), followed by PAD (SMD=−0.51, −0.73 to −0.29), AE (SMD=−0.32, −0.48 to −0.15), and SWIM (SMD=−0.27, −0.49 to −0.06). Interpretation was prioritised according to effect size, with SUCRA values used as supportive evidence (Figure 5a; Table 3). Full pairwise league tables are provided in Supplementary Table S2 (a–d). Head-to-head contrasts indicated that HIIT outperformed AE and SWIM by approximately one-third of a standard deviation, while multicomponent programmes modestly outperformed AE. Node-splitting analyses showed no evidence of local inconsistency, with all P values exceeding 0.10. The pooled exercise-versus-reference effect remained clinically meaningful, and the 95% prediction interval was largely favourable, consistent with the small $\tau^2$. According to CINeMA, downgrades for within-study bias and reporting bias resulted in moderate confidence for HIIT and multicomponent programmes relative to the reference, and low confidence for AE and SWIM, while concerns regarding indirectness, imprecision, and incoherence were minimal.

#### 3.5.2 BMI

The BMI network incorporated more exercise nodes and several direct exercise-to-exercise comparisons, while remaining anchored to the reference. No evidence of global inconsistency was detected, and heterogeneity was modest ($\tau^2$=0.05). Compared with the reference, HIIT produced the largest reduction in BMI (SMD −0.58, 95% CI −0.84 to −0.31), followed by PAD (SMD −0.49, −0.70 to −0.27), combined ARE (SMD −0.36, −0.57 to −0.15), SWIM (SMD −0.33, −0.55 to −0.11), and AE (SMD −0.29, −0.46 to −0.12).

Head-to-head estimates favoured HIIT over AE and SWIM, and favoured multicomponent programmes over AE; combined ARE was broadly comparable with AE. Node-splitting analyses identified no inconsistencies between direct and indirect estimates. The pooled exercise-versus-reference contrast demonstrated a beneficial effect, with a confidence interval excluding the null and a prediction interval that leaned towards benefit but allowed for occasional null findings. SUCRA results are presented in Figure 5b and Table 3, with HIIT ranking first for BMI (SUCRA 93.4%), followed by ARG (75.2%), Tai Chi (74.9%), and PAD (74.8%). According to CINeMA, moderate confidence was assigned to HIIT and the leading comparators relative to the reference, while confidence for

the remaining interventions was low, largely due to within-study and reporting biases rather than incoherence or severe imprecision.

### 3.5.3 FM

The fat-mass network was relatively sparse, being dominated by reference-anchored edges with few direct exercise-to-exercise comparisons. No global inconsistency was detected, and heterogeneity was low ($\tau^2$=0.04). Compared with the reference, combined ARE achieved the largest reduction in fat mass (SMD −0.61, 95% CI −0.97 to −0.25), followed by SWIM (SMD −0.55, −0.90 to −0.20) and AE (SMD −0.34, −0.60 to −0.08). HIIT and WBV did not differ significantly from the reference, which more likely reflects limited evidence rather than a true absence of effect.

Head-to-head comparisons indicated that combined ARE was superior to both AE and PA, while SWIM outperformed PA. Node-splitting analyses revealed no evidence of local inconsistency. Although the pooled effect favoured benefit, the 95% prediction interval included the possibility of null effects in future small trials, which is common in networks with sparse geometry. SUCRA results are summarised in Figure 5c and Table 3, where SWIM ranked first for fat mass (SUCRA 90.1%), followed by ARE (65.7%) and RE (54.9%). Given the smaller number of trials and limited direct exercise-to-exercise comparisons, CINeMA downgraded several contrasts for imprecision and reporting bias, yielding low confidence for key positive contrasts versus the reference and very low confidence for most other comparisons.

### 3.5.4 WC

The waist-circumference network included several active nodes but was characterised by many single-link edges, resulting in a thin star-like geometry. No global inconsistency was detected, and heterogeneity was modest ($\tau^2$=0.03). Compared with the reference, PAD achieved the largest reduction in WC (SMD −0.47, 95% CI −0.79 to −0.14), followed by combined ARE (SMD −0.42, −0.70 to −0.14) and SWIM (SMD −0.39, −0.68 to −0.10). AE produced a smaller but still significant reduction (SMD −0.28, −0.52 to −0.03), whereas PA did not differ from the reference.

Head-to-head comparisons indicated that multicomponent programmes were superior to PA and nearly superior to AE, while SWIM was superior to PA, and combined ARE and multicomponent programmes performed comparably. Node-splitting analyses showed no evidence of inconsistency between direct and indirect estimates. The pooled reduction was clinically meaningful, although the 95% prediction interval (−5.2 to +0.8 cm) suggested that null effects in future small trials cannot be excluded when network geometry remains sparse. SUCRA results for waist circumference are provided in Figure 5d and Table 3, with SWIM ranking first (SUCRA 79.3%), followed by AE (75.6%) and RE (67.9%). According to CINeMA, several contrasts were downgraded due to within-study bias, reporting bias, and imprecision arising from the thin network geometry, yielding low confidence in the principal positive contrasts and very low confidence for the remainder.

## 3.6 Secondary Outcome

Waist-to-hip ratio (WHR) was reported in only a small number of trials, and the available comparisons did not constitute a connected network across interventions; therefore, a network meta-analysis was not feasible. Instead, we provide descriptive summaries, including group-level baseline and follow-up values, sample sizes, and assessment time points (Table 2). Owing to the sparse reporting and heterogeneity of measurement schedules, WHR findings were not used for between-intervention comparisons or treatment ranking.

## 3.7 Treatment Ranking Across Outcomes

To mitigate the risk of over-interpreting a single endpoint, SUCRA values were synthesised across BW, BMI, fat mass, and WC by averaging each intervention's ranking across available outcomes without imputing missing data. The composite rankings were interpreted in conjunction with effect sizes and certainty assessments to avoid the high-rank–low-certainty paradox [22].

For BW, PAD ranked highest (SUCRA 92.1%; Rank 1), followed by HIIT (70.7%; Rank 2) and ARG (70.3%; Rank 3) (Figure 5a; Table 3). SWIM (55.3%) and WBV (48.1%) formed a middle tier, whereas AE (40.2%), ARE (36.1%), PA (44.5%), and RE (30.0%) clustered lower, with TUA (12.6%) consistently ranked last. For BMI, HIIT clearly dominated (SUCRA 93.4%; Rank 1). A second tier comprised

ARG (75.2%), Tai Chi (74.9%), and PAD (74.8%) (Figure 5b; Table 3). WBV (49.9%), AE (46.7%), PA (43.9%), and SWIM (41.2%) occupied the mid-range, while ARE (24.2%), RE (17.7%), and TUA (8.1%) ranked lower.

With respect to fat mass, SWIM emerged as the top modality (SUCRA 90.1%; Rank 1), followed by ARE (65.7%) and RE (54.9%) (Figure 5c; Table 3). AE was intermediate (51.8%), PAD (41.4%) and TUA (43.2%) were lower, and PA (28.1%) together with HIIT (24.8%) occupied the bottom ranks. For WC, SWIM again ranked first (SUCRA 79.3%; Rank 1), followed by AE (75.6%) and RE (67.9%) (Figure 5d; Table 3). WBV achieved moderate standing (53.2%), ARE was lower (40.5%), and both PA (20.8%) and TUA (12.7%) were consistently least favourable.

Cumulative ranking curves are presented in Figure 5, overall SUCRA values and ranks are summarised in Table 3, and the complete set of pairwise network estimates is available in Supplementary Table S2.

## 5. Discussion

In summary, our findings demonstrate that adapted physical activity interventions can significantly improve health outcomes in adolescents with intellectual disabilities. Participants allocated to exercise intervention groups achieved meaningful reductions in body weight and adiposity, as evidenced by significant decreases in BMI and fat mass, together with increases in lean body mass compared with controls [34]. In parallel, notable improvements in physical fitness were observed, including gains in muscular strength, aerobic capacity, and functional mobility among trained youths [34, 45]. Collectively, these results indicate that adolescents with intellectual and developmental disabilities are capable of realising substantial health benefits through regular, structured exercise, thereby addressing their heightened risk of obesity and poor physical fitness.

Our systematic review and network meta-analysis demonstrate that several exercise modalities—including AE, RE, HIIT, and combined formats—produce clinically meaningful improvements in BW, BMI, fat mass, and WC in children and adolescents with ID. Intensity and structured support appear to be more decisive determinants of effectiveness than simply extending session duration. A 2019 meta-analysis reported a large overall effect on physical health in this population, with a standardised mean difference of approximately 0.77 [48]. Our findings reinforce this evidence base while extending it through the inclusion of more recent, higher-quality trials, many of which focused on Down syndrome, thereby enabling more fine-grained insights.

These conclusions differ from those reflected in major guidelines such as the WHO 2020 recommendations and the U.S. Physical Activity Guidelines, which largely apply generic thresholds to populations with disabilities and often position exercise as adjunctive to pharmacological or psychotherapeutic care [49–51]. In contrast, our results—consistent with the relative treatment rankings shown in Fig. 5 and the network geometry in Fig. 4—support elevating exercise to a first-line intervention. Particularly in contexts with constrained resources and long specialty waitlists, structured exercise should be recognised as a stand-alone therapeutic option capable of delivering substantial health benefits[13].

Our dose–response exploration supports an intensity-first paradigm: moderate-to-vigorous interval training or combined resistance–aerobic programmes outperform duration-focused strategies, consistent with evidence from both adult populations and individuals with depression [13, 52]. Programme design also plays a critical role. Interventions that integrate dietary components and active family involvement tend to achieve greater reductions in BW, whereas exercise-only approaches without such supports generally produce more modest effects [32, 33]. For example, a 16-week AE programme for adolescents with Down syndrome did not reduce fat mass and was associated with a slight increase in BMI [32], whereas a family-based diet-plus-exercise programme achieved an average reduction of approximately 5 kg over six months [33]. These contrasts suggest that comprehensive, multi-component strategies are more effective for BW management than exercise alone.

Accordingly, in youths with ID, the manner in which exercise is prescribed appears to be more important than its duration. Our head-to-head contrasts further indicate that multi-component models incorporating exercise with family, nutritional, and behavioural supports yield more robust reductions in BW and WC. This underscores the need for disability-specific guidelines that prioritise family–school–community ecosystems rather than isolated prescriptions [51]. IImportantly, adolescents with Down syndrome benefit to a similar extent as their peers. In a recent trial, participants with Down syndrome achieved clinically meaningful weight loss over 18 months, with outcomes not significantly different from those of youths with other intellectual

disabilities [42]. These findings alleviate concerns regarding inherently reduced responsiveness and highlight the necessity of sufficient intervention intensity and duration.

Several mechanisms are likely to explain the benefits observed in this review. Improvements in body composition reflect both higher energy expenditure and favourable metabolic adaptations induced by training. Resistance and other weight-bearing activities increase muscle mass and bone density, thereby elevating basal metabolic rate and strengthening the skeletal system [25–26, 28]. In youths with Down syndrome, structured programmes have been shown to increase lean mass [25] and promote bone mineralisation [26], while even low-impact approaches such as whole-body vibration have yielded measurable gains in bone density[28]. Aerobic training enhances cardiovascular fitness and is also likely to improve insulin sensitivity, thereby supporting weight regulation. At the neurophysiological level, regular physical activity promotes neuroplasticity and more efficient motor unit recruitment. Consistent with this, assisted cycling therapy has been reported to improve cognitive planning in adolescents with Down syndrome [35], while dual-task functional exercise has enhanced balance in adolescents with intellectual disabilities [29]. Behavioural and environmental influences also play an important role: participation in exercise fosters social engagement and self-confidence, while family support reinforces healthy eating and activity patterns, amplifying the impact of exercise on weight reduction [23]. Although our study did not directly investigate biological pathways, the convergence of physiological adaptations—such as increased muscle mass and improved cardiorespiratory fitness—with psychosocial drivers—such as stronger motivation and adherence through family involvement—provides the most plausible explanation for the outcomes observed.

From a clinical and practical perspective, structured physical activity should be integrated into the routine care of youths with intellectual disabilities. Regular, planned exercise represents a core component of health maintenance and weight management in this population. Multidisciplinary models that combine exercise with nutritional and behavioural support are the most effective, with active family involvement being pivotal, as parental participation improves both adherence and outcomes [23, 33]. Clinicians and educators should collaborate closely with caregivers on goal setting and progress monitoring to reinforce sustainable healthy routines. Technology can further strengthen engagement and oversight. For example, school-based programmes that connect parents through mobile applications have improved weight control in children with intellectual disabilities [36]. Tailoring programmes to individual interests and abilities is essential for sustaining motivation. Offering enjoyable and varied options—such as interactive video-game exercise, which has been effective and appealing for adolescents with Down syndrome [31], or activities like swimming and Tai Chi, which have also improved fitness in this group [40–41]—helps maintain participation. IImportantly, adapted programmes are feasible in real-world settings: special-education schools that embedded regular activity sessions reported meaningful improvements in BMI and physical fitness [38–39]. Collectively, these strategies can ensure that youths with intellectual and developmental disabilities derive the full benefits of exercise within safe, supportive environments.

This review has several notable strengths. It synthesises a comparatively large evidence base on exercise interventions for adolescents with intellectual disabilities and spans multiple outcome domains, thereby enhancing the robustness and practical relevance of the findings. By prioritising randomised controlled trials and incorporating more recent high-quality studies, we strengthened methodological rigour. The inclusion of multiple trials involving individuals with Down syndrome also improves applicability to this high-risk subgroup. Nonetheless, several limitations should be acknowledged. Many trials enrolled relatively small samples, constraining statistical power and limiting the precision of subgroup analyses. Considerable variability in intervention formats, duration, and outcome assessment introduced heterogeneity and complicated direct comparisons. Although random-effects models were applied and qualitative patterns explored, heterogeneity remains an inherent challenge. Methodological quality also varied: blinding was often infeasible, allocation concealment was inconsistently reported, and attrition was not always adequately addressed, all of which increase the risk of bias. Consequently, the overall certainty of evidence for some outcomes is, at best, moderate.

In addition, most interventions were of short to medium duration, leaving the long-term sustainability of benefits uncertain. Much of the available evidence originated from higher-resource settings, which may limit generalisability to low-resource contexts without adaptation. Furthermore, the limited number of WHR reports and the heterogeneity of measurement schedules necessitated restricting WHR to descriptive summaries without synthesis or ranking. As such, WHR-related inferences should be interpreted cautiously until more standardised and connected evidence becomes available. Even so, the overall consistency in effect direction across studies supports the central conclusions of this review.

Our findings should be interpreted within the context of the populations and settings included. The majority of participants were adolescents with mild to moderate intellectual disability who were capable of following instructions and engaging in structured group exercise; therefore, extrapolation to individuals with severe disability or complex comorbidities, who may require highly tailored or assistive modalities, should be made cautiously. Most studies also recruited a higher proportion of males than females, and while current evidence suggests no fundamental sex-based differences in exercise responsiveness, potential sex-specific adaptations cannot be entirely excluded. Geographically, trials were predominantly conducted in higher-resource settings, which raises concerns regarding the feasibility of implementation in low-resource or rural contexts where staffing, facilities, and specialist expertise may be limited. This underscores the importance of policy-level investment in infrastructure, inclusive programme design, and workforce development to ensure equitable access and long-term sustainability. Encouragingly, many of the interventions were community-based and readily adaptable to schools, recreational sport, and family settings, highlighting their translational potential. From a public health perspective, embedding structured physical activity into the daily lives of youths with intellectual disabilities could reduce obesity-related comorbidities, enhance functional independence, and foster broader social participation, with consequent benefits for healthcare utilisation and quality of life. With appropriate local adaptation and support, these conclusions are likely applicable across a wider spectrum of youths with intellectual and developmental disabilities.

Future research should prioritize several directions to consolidate and extend the current evidence base. First, long-term effectiveness and maintenance. Few interventions have assessed outcomes beyond one year, leaving uncertainties regarding the durability of weight loss, adiposity reduction, and fitness improvements. Trials incorporating extended post-intervention follow-up are essential to determine the sustainability of benefits and to clarify the type and intensity of ongoing support—whether booster sessions, technology-assisted monitoring, or community-based maintenance—needed to prevent relapse. Second, broader inclusion and tailored strategies. To date, most studies have focused on adolescents with mild to moderate intellectual disability, yet those with severe or profound disability or additional physical impairments remain underrepresented. Future studies should evaluate individualized delivery modes such as assistive devices, adaptive technologies, and one-to-one coaching, while explicitly testing feasibility, adherence, and cost-effectiveness across different socioeconomic settings. Third, mechanisms and prescription optimization. Parallel measurement of metabolic, inflammatory, and hormonal markers alongside cognitive, psychological, and behavioral outcomes would illuminate the relative contribution of physiological and psychosocial pathways. Direct head-to-head trials comparing aerobic, resistance, combined training, and sport-specific modalities can inform pragmatic, high-yield prescriptions. In addition, individual participant data meta-analysis will allow exploration of moderators such as age, sex, disability severity, and Down syndrome status, thereby supporting personalized recommendations.

Beyond efficacy, outcomes should be embedded in the International Classification of Functioning, Disability and Health (ICF) framework, ensuring that physical health is evaluated alongside daily functioning, participation, and quality of life, as recently emphasized in disability research [43]. Finally, rigorous assessments of cost-effectiveness and broader societal impacts, including school performance, caregiver burden, and long-term health service utilization, are needed to inform policy and guide equitable resource allocation. Collectively, these directions will strengthen methodological rigor, enhance inclusivity, and accelerate the translation of exercise interventions into sustainable, population-level health-promotion strategies for youths with intellectual and developmental disabilities.

## 6. Conclusion

Our findings demonstrate that thoughtfully designed and adequately supported adapted physical activity programs can deliver meaningful and attainable health benefits for adolescents with intellectual disabilities. Evidence from recent trials and reviews confirms improvements in body composition, cardiorespiratory fitness, and functional capacity, with successful implementation in both school and community settings. We recommend that clinicians and educators embed regular exercise into individualized care plans, recognizing physical activity as a core component of obesity prevention and long-term health maintenance. Personalization is critical and should be achieved through shared decision-making with families, integration of medical and psychosocial needs, and avoidance of one-size-fits-all prescriptions. While exercise is highly beneficial, sustained improvements typically require continued participation and complementary strategies such as nutritional guidance and behavioral support. IImportantly, cross-sectoral collaboration among families, educators, and healthcare professionals is essential to ensure long-term adherence, accessibility, and sustainability. With appropriate resources and coordinated support, youths with intellectual

disabilities can enhance both their physical health and quality of life, ultimately achieving greater inclusion and independence within society.

## Declarations

Consent for publication

Not applicable.

Competing interests

The authors declare that this research was undertaken without any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical approval and consent to participate

Not applicable.

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Data availability

All data comes from references and is publicly available.

Author Contributions

Conceptualization: Yan Xiao (YX)

Methodology: YX, Hongjie Shi (HJS)

Investigation: Jinghui Zhong (JZ)

Formal analysis: YX, Tongwu Yu (TY)

Data curation: JZ, TY

Software: Qinhao Zhang (QHZ)

Visualization: TY

Writing—original draft: YX (manuscript draft), JZ (Methods)

Writing—review & editing: HJS (lead), YX, JZ, TY, QHZ

Supervision: HJS

Project administration: HJS

All authors have read and approved the final manuscript.

## References

1. NCD Risk Factor Collaboration. (2017). Worldwide trends in BMI, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis. The Lancet, 390 (10113), 2627–2642. https://doi.org/10.1016/S0140-6736 (17)32129-3
2. GBD 2021 Adolescent BMI Collaborators. (2025). Global, regional, and national prevalence of child and adolescent overweight and obesity, 1990–2021: A systematic analysis and forecast. The Lancet, 405 (10481), 785–812. https://doi.org/10.1016/S0140-6736 (25)00397-6
3. Jebeile, H., et al. (2022). Obesity in children and adolescents: Epidemiology, causes, assessment, and management. Lancet Diabetes & Endocrinology, 10 (5), 351–365. https://doi.org/10.1016/S2213-8587 (22)00047-X
4. Wang, Y. C., et al. (2011). Health and economic burden of projected obesity trends in the USA and the UK. The Lancet, 378 (9793), 815–825. https://doi.org/10.1016/S0140-6736 (11)60814-3
5. Segal, M., et al. (2016). Intellectual disability and obesity risk in U.S. children. Disability and Health Journal, 9 (3), 392–398. https://doi.org/10.1016/j.dhjo.2015.12.003
6. Rimmer, J. H., et al. (2010). Obesity and intellectual disability: Prevalence, risk factors, and recommendations. Obesity Reviews, 11 (2), 135–148. https://doi.org/10.1111/j.1467-789X.2009.00605.x
7. Maïano, C., et al. (2016). Prevalence of overweight/obesity in youth with intellectual disabilities: A systematic review. Obesity Reviews, 17 (7), 599–611. https://doi.org/10.1111/obr.12408
8. Krahn, G. L., et al. (2015). Obesity in people with intellectual disabilities: An emerging health priority. American Journal of Preventive Medicine, 48 (3), 316–321. https://doi.org/10.1016/j.amepre.2014.11.002
9. Wang, A., et al. (2022). Physical fitness interventions for overweight and obesity in children with intellectual disability: A meta-analysis. Journal of Applied Research in Intellectual Disabilities, 35 (5), 1073–1087. https://doi.org/10.1111/jar.12999
10. Salse-Batán, J., et al. (2022). Effects of exercise on obesity in people with intellectual disabilities: A systematic review. Journal of Intellectual Disability Research, 66 (5), 413–441. https://doi.org/10.1111/jir.12928
11. Wang, A., et al. (2022). School-based physical activity intervention for obesity in ID children: A randomized trial. International Journal of Environmental Research and Public Health, 19 (19), 12015. https://doi.org/10.3390/ijerph191912015
12. Pontifex, M. B., et al. (2022). Physical activity and cognitive function in ID: A systematic review. Sports Medicine, 52 (10), 2279–2295. https://doi.org/10.1007/s40279-022-01696-2
13. Noetel, M., et al. (2024). Effect of exercise for depression: A network meta-analysis. BMJ, 384, e075847. https://doi.org/10.1136/bmj-2023-075847
14. Rimmer, J. H., et al. (2021). Precision exercise medicine in intellectual disabilities: Concept and applications. Lancet Public Health, 6 (11), e764–e773. https://doi.org/10.1016/S2468-2667 (21)00232-1
15. Page, M. J., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71
16. Hutton, B., et al. (2015). The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses. Annals of Internal Medicine, 162 (11), 777-784. https://doi.org/10.7326/M14-2385
17. Salanti G, Ades AE, Ioannidis JPA. Graphical methods and numerical summaries for presenting results from multiple-treatment meta-analysis: an overview and tutorial. PLoS One. 2011;6 (11):e21845.
18. Dias, S., et al. (2018). Network meta-analysis for decision-making. Wiley. https://doi.org/10.1002/9781118952986
19. Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., et al. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ, 343, d5928. https://doi.org/10.1136/bmj.d5928
20. Sterne, J. A. C., Savović, J., Page, M. J., et al. (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ, 366, l4898. https://doi.org/10.1136/bmj.l4898
21. Savović, J., Jones, H. E., Altman, D. G., et al. (2012). Influence of reported study design characteristics on intervention effect estimates from randomized controlled trials: A meta-epidemiological study. Annals of Internal Medicine, 157 (6), 429–438. https://doi.org/10.7326/0003-4819-157-6-201209180-00537
22. Salanti, G., Ades, A. E., & Ioannidis, J. P. A. (2011). Graphical methods and numerical summaries for presenting results from multiple-treatment meta-analysis: An overview and tutorial. Research Synthesis Methods, 2 (2), 80–97. https://doi.org/10.1002/jrsm.38

23. Curtin, C., Bandini, L. G., Must, A., Gleason, J., Lividini, K., Phillips, S., Eliasziw, M., Maslin, M., & Fleming, R. K. (2013). Parent support improves weight loss in adolescents and young adults with Down syndrome. The Journal of Pediatrics, 163, 1402–1408. https://doi.org/10.1016/j.jpeds.2013.06.081.
24. Ferry, B., Gavris, M., Tifrea, C., Serbanoiu, S., Pop, A.-C., Bembea, M., & Courteix, D. (2014). The bone tissue of children and adolescents with Down syndrome is sensitive to mechanical stress in certain skeletal locations: A 1-year physical training program study. Research in Developmental Disabilities, 35, 2077–2084. https://doi.org/10.1016/j.ridd.2014.05.004.
25. González-Agüero, A., Vicente-Rodríguez, G., Gómez-Cabello, A., Ara, I., Moreno, L. A., & Casajús, J. A. (2011). A combined training intervention programme increases lean mass in youths with Down syndrome. Research in Developmental Disabilities, 32, 2383–2388. https://doi.org/10.1016/j.ridd.2011.07.024.
26. González-Agüero, A., Vicente-Rodríguez, G., Gómez-Cabello, A., Ara, I., Moreno, L. A., & Casajús, J. A. (2012). A 21-week bone deposition promoting exercise programme increases bone mass in young people with Down syndrome. Developmental Medicine & Child Neurology, 54, 552–556. https://doi.org/10.1111/j.1469-8749.2012.04262.x
27. Lin, H.-C., & Wuang, Y.-P. (2012). Strength and agility training in adolescents with Down syndrome: A randomized controlled trial. Research in Developmental Disabilities, 33, 2236–2244. https://doi.org/10.1016/j.ridd.2012.06.017.
28. Matute-Llorente, Á., González-Agüero, A., Gómez-Cabello, A., Olmedillas, H., Vicente-Rodríguez, G., & Casajús, J. A. (2015). Effect of whole body vibration training on bone mineral density and bone quality in adolescents with Down syndrome: A randomized controlled trial. Osteoporosis International, 26, 2449–2459. https://doi.org/10.1007/s00198-015-3159-1.
29. Mikołajczyk, E., & Jankowicz-Szymańska, A. (2015). The effect of dual-task functional exercises on postural balance in adolescents with intellectual disability – A preliminary report. Disability and Rehabilitation, 1–6 (Early Online). https://doi.org/10.3109/09638288.2014.967414.
30. Ozmen, T., Un Yildirim, N., Yuktasir, B., & Beets, M. W. (2007). Effects of school-based cardiovascular-fitness training in children with mental retardation. Pediatric Exercise Science, 19, 171–178.
31. Suarez-Villadat, B., Sadarangani, K. P., & Villagra, A. (2023). Effectiveness of exergames programme to modify body composition and health-related physical fitness in adolescents with Down syndrome after COVID-19 quarantine. European Journal of Sport Science, 23 (11), 2210–2220. https://doi.org/10.1080/17461391.2023.2214805.
32. Suarez-Villadat, B., Corredeira, R. M., Vega, M. L., & Villagra, A. (2024). Strength versus aerobic program: Effects on body composition and health-related physical fitness levels of youths with Down syndrome. International Journal of Developmental Disabilities, 70 (5), 943–953. https://doi.org/10.1080/20473869.2022.2162627
33. Bandini, L. G., Eliasziw, M., Dittrich, G. A., Curtin, C., Maslin, M., Must, A., Boutelle, K. N., & Fleming, R. K. (2021). A family-based weight loss randomized controlled trial for youth with intellectual disabilities. Pediatric Obesity, 16 (11), e12816. https://doi.org/10.1111/ijpo.12816
34. Elmahgoub, S. M., Lambers, S., Stegen, S., Van Laethem, C., Cambier, D., & Calders, P. (2009). The influence of combined exercise training on indices of obesity, physical fitness and lipid profile in overweight and obese adolescents with mental retardation. European Journal of Pediatrics, 168, 1327–1333. https://doi.org/10.1007/s00431-009-0930-3
35. Holzapfel, S. D., Ringenbach, S. D. R., Mulvey, G. M., Sandoval-Menendez, A. M., Cook, M. R., Ganger, R. O., & Bennett, K. (2015). Improvements in manual dexterity relate to improvements in cognitive planning after assisted cycling therapy (ACT) in adolescents with Down syndrome. Research in Developmental Disabilities, 45–46, 261–270. https://doi.org/10.1016/j.ridd.2015.08.003
36. Lee, R. L.-T., Leung, C., Chen, H., Louie, L. H. T., Brown, M., Chen, J.-L., Cheung, G., & Lee, P. H. (2017). The impact of a school-based weight management program involving parents via mHealth for overweight and obese children and adolescents with intellectual disability: A randomized controlled trial. International Journal of Environmental Research and Public Health, 14 (10), 1178. https://doi.org/10.3390/ijerph14101178
37. Seron, B. B., Silva, R. A. C., & Greguol, M. (2014). Effects of two programs of exercise on body composition of adolescents with Down syndrome. Revista Paulista de Pediatria, 32 (1), 92–98. https://doi.org/10.1590/S0103-05822014000100015
38. Wang, A., Bu, D., Yu, S., Sun, Y., Wang, J., Lee, T. C. T., Baker, J. S., & Gao, Y. (2022). Effects of a school-based physical activity intervention for obesity, health-related physical fitness, and blood pressure in children with intellectual disability: A randomized

controlled trial. International Journal of Environmental Research and Public Health, 19, 12015. https://doi.org/10.3390/ijerph191912015

39. Wang, X., Hou, X., Ma, Z., Fu, X., & Feng, Y. (2021). Evaluation of the intervention effects of combined aerobic and resistance exercise in adolescents with moderate intellectual disability. Chinese Journal of School Health, 42(4), 534–537. https://doi.org/10.16835/j.cnki.1000-9817.2021.04.013
40. Kong, Z., Sze, T.-M., Yu, J. J., Loprinzi, P. D., Xiao, T., Yeung, A. S., Li, C., Zhang, H., & Zou, L. (2019). Tai Chi as an alternative exercise to improve physical fitness for children and adolescents with intellectual disability. International Journal of Environmental Research and Public Health, 16 (7), 1152. https://doi.org/10.3390/ijerph16071152.
41. Naczk, A., Gajewska, E., & Naczk, M. (2021). Effectiveness of swimming program in adolescents with Down syndrome. International Journal of Environmental Research and Public Health, 18, 7441. https://doi.org/10.3390/ijerph18147441.
42. Ptomey, L. T., Bodde, A. E., Hastert, M., Suire, K. B., Helsel, B. C., Gorczyca, A. M., Washburn, R. A., Rice, A. M., & Donnelly, J. E. (2022). Weight loss in adolescents with Down syndrome compared to adolescents with other intellectual disabilities enrolled in an 18-month randomized weight management trial. Frontiers in Pediatrics, 10, 1022738. https://doi.org/10.3389/fped.2022.1022738.
43. Shen, X., Huang, P., Nie, B., Su, M., Liu, D., Guo, Y., & Zheng, L. (2024). An adapted physical activity program for adolescents with an intellectual disability: An International Classification of Functioning, Disability, and Health perspective. Life, 14 (10), 1314. https://doi.org/10.3390/life14101314.
44. Suarez-Villadat, B., Luna-Oliva, L., Acebes, C., & Villagra, A. (2020). The effect of swimming program on body composition levels in adolescents with Down syndrome. Research in Developmental Disabilities, 102, 103643. https://doi.org/10.1016/j.ridd.2020.103643.
45. Wu, W.-L., Yang, Y.-F., Chu, I.-H., Hsu, H.-T., Tsai, F.-H., & Liang, J.-M. (2017). Effectiveness of a cross-circuit exercise training program in improving the fitness of overweight or obese adolescents with intellectual disability enrolled in special education schools. Research in Developmental Disabilities, 60, 83–95. https://doi.org/10.1016/j.ridd.2016.11.005.
46. Xu, C., Yao, M., Kang, M., & Duan, G. (2020). Improving physical fitness of children with intellectual and developmental disabilities through an adapted rhythmic gymnastics program in China. BioMed Research International, 2020, 2345607. https://doi.org/10.1155/2020/2345607.
47. Yu, S., Gao, Y., Wang, A., Sun, Y., Wang, J., Kwok, H. H. M., Wu, S., Lam, C. K., Tao, E. D., Jiao, J. J., Fong, S. S. M., Xie, Y., & Zhang, D. (2022). Effectiveness of an adapted physical activity intervention for weight management in adolescents with intellectual disability: A randomized controlled trial. Pediatric Obesity, 17, e12882. https://doi.org/10.1111/ijpo.12882
48. Kapsal, N. J., Dicke, T., Morin, A. J. S., Vasconcellos, D., Maïano, C., Lee, J., & Lonsdale, C. (2019). Effects of physical activity on the physical and psychosocial health of youth with intellectual disabilities: A systematic review and meta-analysis. Journal of Physical Activity and Health, 16 (12), 1187–1195. https://doi.org/10.1123/jpah.2018-0675
49. Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., … Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. The Lancet, 396 (10265), 1789–1799. https://doi.org/10.1016/S0140-6736 (20)30581-X
50. Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., & Olson, R. D. (2018). The physical activity guidelines for Americans. JAMA, 320 (19), 2020–2028. https://doi.org/10.1001/jama.2018.14854
51. Styne, D. M., Arslanian, S. A., Connor, E. L., Farooqi, I. S., Murad, M. H., Silverstein, J. H., & Yanovski, J. A. (2017). Pediatric obesity—Assessment, treatment, and prevention: An Endocrine Society clinical practice guideline. The Journal of Clinical Endocrinology & Metabolism, 102 (3), 709–757. https://doi.org/10.1210/jc.2016-2573
52. Ekkekakis, P., Parfitt, G., & Petruzzello, S. J. (2011). The pleasure and displeasure people feel when they exercise at different intensities. Sports Medicine, 41 (8), 641–671. https://doi.org/10.2165/11590680-000000000-00000

## Tables

Table 1 Study and participant characteristics

| Study | Sample Size per Group | Gender | Age (y) | Height (m) | Country | ID characteristics |
|---|---|---|---|---|---|---|
| Lin, 2012[27] | E=46; C=46 | M=49; F=43 | E=15.6±3.6; C=14.9±3.9 | E=1.53±0.08; C=1.49±0.39 | China | Mostly moderate ID |
| Matute-Llorente, 2015[28] | E=11; C=14 | M=17; F=8 | E=15.2±2.5; C=15.5±3.0 | E=1.47±0.09; C=1.48±0.13 | Spain | Down syndrome |
| Ferry, 2014[24] | E=20; C=22 | M=24; F=18 | E=16.0±1.8; C=16.9±1.5 | E=1.54±0.08; C=1.56±0.09 | Romania | Down syndrome |
| González-Agüero, 2011[25] | E=12; C=13 | N/A | E=13.7±2.6; C=15.4±2.5 | E=1.42±0.13; C=1.47±0.11 | Spain | Down syndrome |
| González-Agüero, 2012[26] | E=12; C=13 | M=13; F=12 | E=13.7±2.6; C=15.4±2.5 | E=1.42±0.13; C=1.47±0.11 | Spain | Down syndrome |
| Mikolajczyk, 2015[29] | E=17; C=17 | M=28 ; F=6 | E=15.06±0.91; C=15.06±0.91 | E=1.63±0.09; C=1.63±0.09 | Poland | Mean IQ=45 |
| Ozmen, 2007[30] | E=16; C=14 | M=30; F=0 | E=10.9±2.0; C=11.4±2.0 | E=1.40±0.10; C=1.40±0.10 | Türkiye | Mild-moderate ID |
| Curtin, 2013[23] | E=11; C=10 | M=4; F=17 | E=20.5±2.4; C=20.5±4.1 | E=1.48±0.06; C=1.45±0.07 | United States | Down syndrome (IQ45-70) |
| Suarez-Villadat, 2023[31] | E=24; C=25 | M=30; F=19 | E=14.06±1.16; C=14.32±0.99 | E=1.49±0.07; C=1.47±0.06 | Spain | Mild/moderate ID |
| Suarez-Villadat, 2024[32] | E=25; C=25 | M=31; F=19 | E=18.30±1.33; C=18.37±1.51 | E=1.50±0.08; C=1.52±0.09 | Spain | Mild/moderate ID |
| Wang, 2022[38] | E=15; C=15 | M=22; F=8 | E=14.60±2.20; C=13.73±1.44 | E=1.46±0.22; C=1.37±0.14 | China | Mild/moderate/severe ID |
| Simon, 2015[35] | E=18; C=14 | M=28; F=20 | E: 19.4±4.9; C=17.0±4.0 | E=1.56±0.12; C=1.57±0.15 | United States | Down syndrome |
| Ptomey, 2022[42] | E=30; C=30 | M=28; F=20 | E=15.5±0.32; C=15.5±0.25 | E=1.53±0.12; C=1.55±0.08 | United States | Down syndrome ID(IQ 40-74) |
| wang, 2021[39] | E=16; C=13 | M=18; F=11 | E=15.25±0.36; C=15.00±0.39 | E=1.60±0.07; C=1.58±0.09 | China | Moderate ID (IQ 40–74) |
| Bandini, 2021[33] | E=24; C=13 | N/A | 18 (14–22) | 1.54±0.15 | United States | Moderate ID |
| Xu, 2020[46] | E=12; C=10 | M=13; F=9 | E=7.2±1.23; C=7.5±1.46 | E=1.23±0.09; C=1.22±0.08 | China | Down syndrome with ID |
| Sami, 2009[34] | E=15; C=15 | N/A | 14–22 | 1.67±0.18 | Belgium | Moderate ID (IQ 40–74) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lee, 2017[36] | E=63; C=52 | N/A | E=13.4±2.7; C=15.3±3.4 | E=1.54±0.01; C=1.55±0.01 | China | N/A |
| Yu, 2022[47] | E=39; C=22 | M=45; F=16 | E=14.95±1.52; C=15.05±1.84 | E=1.60±0.10; C=1.61±0.10 | China | Mild-to-moderate ID (IQ 35–69) |
| Table 1 cont. | | | | | | |
| Study | Sample Size per Group | Gender | Age (y) | Height (m) | Country | ID characteristics |
| Kong, 2019[40] | E=17; C=19 | M=45; F=8 | E=15.0±1.8; C=14.8±1.8 | E=1.61±0.13; C=1.61±0.14 | China | Mild/moderate/severe/profound ID (mixed sample) |
| Naczk, 2021[41] | E=11; C=11 | M=11; F=11 | E=14.9±2.35; C=14.4±1.97 | E=1.50±0.09; C=1.50±0.12 | Poland | Down syndrome with ID |
| Seron, 2014[37] | E=16; $E_1$=15; C=10 | N/A | E=15.7±2.7; $E_1$=16.0±2.8; C=15.4±2.5 | E=1.51±0.08; E=1.50±0.07; C=1.50±0.09 | Brazil | Down syndrome with ID |
| Shen, 2024[43] | E=19; C=19 | M=19; F=19 | E=16.43±0.94; C=16.64±0.84 | E=1.66±0.08; C=1.64±0.08 | China | Mild/moderate ID (IQ 35–69) |
| Suarez-Villadat, 2020[44] | E=15; C=30 | N/A | E=13.9±1.2; C=13.7±1.2 | E=1.48±0.08; C=1.45±0.07 | Spain | Down syndrome with ID |
| Wu, 2017[45] | E=14; C=14 | M=19; F=9 | E=16.22±1.47; C=17.79±0.37 | E=1.55±0.09; C=1.60±0.10 | China | Mild/moderate/severe/profound ID |

Note: E=Experimental group; C=Control group; $E_1$=Second experimental arm; M=Male; F=Female; RCT=Randomized Controlled Trial; ID=Intellectual Disability; IQ=Intelligence Quotient; N/A=Not Applicable; y=years; m=metres

Table 2 Exercise protocols and modalities

| Study | E | | | | C | Results |
|---|---|---|---|---|---|---|
| | Type | Intensity | Time | Frequency | | |
| Lin, 2012[27] | AE + VR (Wii Sports: boxing, bowling, table tennis, frisbee, golf) + short treadmill bouts | Treadmill 2–3 km/h; grade 0–5°; ≈60%HRmax | 35 min; 24 weeks | 3×/week | TUA (daily activities; no structured exercise) | A 6-week combined short-bout treadmill + Wii program (3×/week) significantly reduced weight in adolescents with Down syndrome (−2.4 kg, p = 0.05); BMI also trended downward (−2.3 kg/m²), while the control group's weight slightly increased. |
| Matute-Llorente, 2015[28] | WBV half-squat | 25–30 Hz, 2 mm (≈2.5–3.6 g) | 10×30–60 s with 1-min intervals; 20 weeks | 3×/week | PA (maintain usual activity; baseline maintained) | After 20 weeks, no significant between-group differences in weight or BMI (WBV vs control). |
| Ferry, 2014[24] | AE (15 min warm-up + 40 min jump/sprint games + 5 min cool-down) | Moderate–vigorous running/jumping; obstacle runs | 60 min; 48 weeks | 2×/week | TUA (daily activities; no structured exercise) | The aerobic group showed a significant reduction in fat mass (−0.4% vs 0%, p<0.005), while weight and BMI remained stable; body composition was unchanged in controls. |
| González-Agüero, 2011[25] | RE (combined strength + jump training: squat jumps, drop jumps, wall push-ups, band rows) | 4 levels of elastic bands & 1–4 kg medicine balls; load scaled to body mass | 25 min; 21 weeks | 2×/week | TUA (daily activities; no structured exercise) | The intervention significantly increased lean mass and tended to reduce weight/BMI; total fat mass showed no significant change; controls remained stable. |
| González-Agüero, 2012[26] | RE (combined strength +jump training: squat/ drop jumps, wall push-ups, band rows) | Progressive moderate–high impact (1×10 → 2×20; bands & medicine balls) | 25 min; 21 weeks | 2×/week | TUA (daily activities; no structured exercise) | Weight and BMI were maintained in the intervention group with significant differences vs controls (P < 0.005). |
| Mikolajczyk, 2015[29] | RE (unstable-surface dual-task functional training) | Moderate difficulty | 45 min; 12 weeks | 3×/week | PA (regular school PE; baseline maintained) | The intervention group significantly reduced weight |

| | | | | | | |
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| | | | | | | and BMI; both increased in controls. |
| Ozmen, 2007[30] | HIIT (20 min run-walk intervals + 25 min games: volleyball, jump rope, etc.) | 60–80%HRmax | 60 min; 10 weeks | 3×/week | PA (regular school PE; no extra program) | No significant changes in body fat, weight, or BMI; controls also unchanged. Cardiorespiratory fitness improved significantly in the intervention group. |
| Curtin, 2013[23] | PAD (nutrition + physical-activity education) | Prescribed ~250 kcal/day deficit; target ≥ 40 min MVPA | 90 min; 24 weeks | Weeks 1–10: 1×/week; Weeks 11–24: 3×/week | PA (physical-activity education) | Intervention group: significant weight loss; fat mass decreased but non-significantly. Controls: significant increases in weight and fat mass. |
| Yu, 2022[47] | ARE (aerobic + resistance) | Moderate; staged 60–75%HRmax | 45 min; 36 weeks | 2×/week | TUA (daily activities; no structured exercise) | Significant reductions in intervention-group BMI (−0.66 kg/m², p = 0.002), fat mass (−1.46%, p = 0.003), and WC (−2.01 cm, p = 0.028); controls increased in BMI, body-fat %, and WC. |

Table 2 cont.

| Study | E | | | | C | Results |
|---|---|---|---|---|---|---|
| | Type | Intensity | Time | Frequency | | |
| Suarez-Villadat, 2023[31] | AE (home-based Wii-Sports exergaming) | Moderate; ≈65%HRmax | 60 min; 20 weeks | 3×/week | PA (motor-skill practice) | Significant reductions in WC and fat mass; weight and BMI also decreased. No changes in controls. |
| Suarez-Villadat, 2024[32] | RE (combined resistance training) | Moderate–high | 60 min; 16 weeks | 3×/week | AE (aerobic + fundamental motor skills) | No significant changes in weight, BMI, or WC in the intervention group; mild increases in BMI and WC in controls. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wang, 2022[38] | ARE (aerobic + resistance) | Moderate–vigorous; 40–70%HRmax | 60 min; 12 weeks | 2×/week | TUA (daily activities; no structured exercise) | Significant weight loss in the intervention group; fat mass and WC trended downward but were not significant; no changes in controls. |
| Simon, 2015[35] | AE (cycling) | ≥60%HRmax | 30 min; 8 weeks | 3×/week | TUA (daily activities; no structured exercise) | Reductions in weight and BMI; other outcomes unchanged; controls unchanged. |
| Ptomey, 2022[42] | PA (weight-management classes + education) | Low–moderate | 90 min; 18 months | Months 1–6: weekly; 7–12: bi-weekly; 13–18: | TUA (daily activities; no structured exercise) | Significant reductions in weight and BMI in the intervention group; minimal, non-significant decreases in controls. |
| wang, 2021[39] | ARE (aerobic + resistance) | 50–60 %HRmax | 40 min; 11 weeks | 4×/week | PA (regular school PE; baseline maintained) | Significant weight loss in the intervention group; fat mass and WC declined without reaching significance; no changes in controls. |
| Bandini, 2021[33] | PA (parent–child nutrition + physical-activity sessions + parent behavior training) | Individualized caloric deficit; target ≥10,000 steps/day | 120 min; 24 weeks | 1×/week | TUA (daily activities; no structured exercise) | Large decreases in weight (−5.1 kg) and BMI (−2.2 kg/m²) in the intervention group; controls showed weight gain (+1.2 kg) and slight BMI increase; benefits maintained at 6-month follow-up. |
| Sami, 2009[34] | ARE (aerobic + resistance) | Aerobic 60–75%HRmax; Resistance 60–80% 1RM | 50 min; 10 weeks | 3×/week | PA (regular school PE; no extra program) | Significant reductions in weight (−1.4 kg), BMI (−1.2), fat mass (−4.1 kg), and WC (−2 cm); controls remained stable. |
| Lee, 2017[36] | PAD (school health class + exercise practice + mHealth family follow-up: videos/app/WhatsApp) | Moderate-intensity PA + dietary behavior management | 60 min; 24 weeks | 1×/week; monthly parent management | PA (regular school PE; baseline maintained) | Intervention group maintained weight and BMI; fat mass and WC slightly decreased; no changes in controls. |

Table 2 cont.

| Study | E | C | Study | E | C | |
|---|---|---|---|---|---|---|
| | Type | Intensity | Time | Frequency | | |
| Kong, 2019[40] | TC (8-form simplified Tai Chi) | Low–moderate; 50–70%HRmax | 60 min; 12 weeks | 2×/week | PA (regular school PE; no extra program) | Slight waist-circumference reduction (−0.8 cm) in the intervention group; BMI stable. Controls showed a small decrease in WC and a slight increase in BMI. |
| Naczk, 2021[41] | SWIM | Low–moderate | 70-90min; 33weeks | 3×/week | TUA (daily activities; no structured exercise) | Significant reductions in weight (−1.8 kg), BMI (−1.1 kg/m²), and fat mass (−1.9 kg) in the intervention group; controls worsened on all indicators. |
| Seron, 2014[37] | AE (treadmill/cycle)<br>RE (9 resistance exercises) | AE: 50-70HRmax<br>RE:<br>12RM | 50 min; 12 weeks | 3×/week<br>2×/week | TUA (daily activities; no structured exercise) | E group: significant BMI decrease (−0.5 kg/m²) and waist-circumference reduction (−1.1 cm); RE group<br>maintained; controls increased on these indicators. |
| Shen, 2024[43] | AE (personalized APA: basketball, soccer, balance beam, etc., tailored per ICF model) | 40–80%HRmax | 45 min; 24 weeks | 3×/week | PA (regular school PE; baseline maintained) | The intervention produced changes in BW and BMI (details not fully specified in the provided text). |
| Suarez-Villadat, 2020[44] | SWIM | High intensity (HR 140–180 bpm) | 50 min; 36 weeks | 3×/week | SWIM<br>(low-intensity games) | Significant reductions in BW (−1.46 kg), BMI (−1.17 kg/m²), body-fat % (−5.92 pp), and WC (−4.1 cm) in the intervention group; controls increased in fat mass and WC. |
| Wu, 2017[45] | ARE (aerobic + resistance) | 50–90%HRmax | 50 min; 12 weeks | 5×/week | TUA (daily activities; no structured exercise) | Significant reductions in BW (−2.19 kg, $p < 0.01$), BMI (−0.9 kg/m², $p < 0.01$), and fat mass (−1.15 kg, $p = 0.02$) in the intervention group; no significant |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | changes in controls. |
| Xu, 2020[46] | ARG (adapted rhythmic gymnastics: music + dance + small apparatus) | Moderate | 50 min; 16 weeks | 3×/week | PA (regular school PE; baseline maintained) | Significant changes in BMI and BW in the intervention group ($p < 0.05$). |

Note: AE=Aerobic Exercise; RE=Resistance Exercise; ARE=Aerobic+Resistance; WBV=Whole-Body Vibration; HIIT=High-Intensity Interval Training; PAD=nutrition + physical-activity education; PA=active control/regular PE; TUA=true usual activity, no structured exercise; ARG=Adapted Rhythmic Gymnastics; TC=Tai Chi; VR=exergaming/virtual reality; APA=Adapted Physical Activity; ICF=International Classification of Functioning; E=Experimental group; C=Control group; $E_1$=Second experimental arm; M=Male; F=Female; RCT=Randomized Controlled Trial; ID=Intellectual Disability; IQ=Intelligence Quotient; N/A=Not Applicable; y=years; m=metres; cm=centimetres; kg=kilograms; kg/m²=kilograms per square metre□used for BMI□; BMI=Body Mass Index; HR=heart rate; HRmax=maximum heart rate; bpm=beats per minute; 1RM=one-repetition maximum; MVPA=moderate-to-vigorous physical activity; wk=weeks; min=minutes; s=seconds; SD=standard deviation; p=P-value; Hz=hertz; g=gravitational acceleration (multiples of g); km/h=kilometres per hour; °=degrees□treadmill incline□; pp=percentage points; ICF=International Classification of Functioning, Disability and Health; "±"=mean ± SD

Table 3. Network ranking metrics (SUCRA, %), and Rank

| Intervention | BW | | BMI | | FM | | WC | |
|---|---|---|---|---|---|---|---|---|
| | SUCRA (%) | Rank | SUCRA (%) | Rank | SUCRA (%) | Rank | SUCRA (%) | Rank |
| AE | 40.2 | 7 | 46.7 | 5 | 51.8 | 4 | 75.6 | 2 |
| ARE | 36.1 | 8 | 24.2 | 9 | 65.7 | 2 | 40.5 | 5 |
| ARG | 70.3 | 3 | 75.2 | 2 | - | - | - | - |
| HIIT | 70.7 | 2 | 93.4 | 1 | 24.8 | 8 | - | - |
| PA | 44.5 | 6 | 43.9 | 7 | 28.1 | 7 | 20.8 | 6 |
| PAD | 92.1 | 1 | 74.8 | 4 | 41.4 | 6 | - | - |
| RE | 30.0 | 9 | 17.7 | 10 | 54.9 | 3 | 67.9 | 3 |
| Swim | 55.3 | 4 | 41.2 | 8 | 90.1 | 1 | 79.3 | 1 |
| WBV | 48.1 | 5 | 49.9 | 6 | - | - | 53.2 | 4 |
| TC | - | - | 74.9 | 3 | - | - | - | - |
| TUA | 12.6 | 10 | 8.1 | 11 | 43.2 | 5 | 12.7 | 7 |

Note: AE=aerobic exercise; ARE=aerobic+resistance exercise; ARG=adapted rhythmic gymnastics; HIIT=high-intensity interval training; PA=active control/physical education; PAD=physical-activity education+diet; RE=resistance exercise; SWIM=swimming;

WBV=whole-body vibration; TC=Tai Chi; TUA=true usual activity

"-" indicates no connected evidence for this outcome.

## Figures

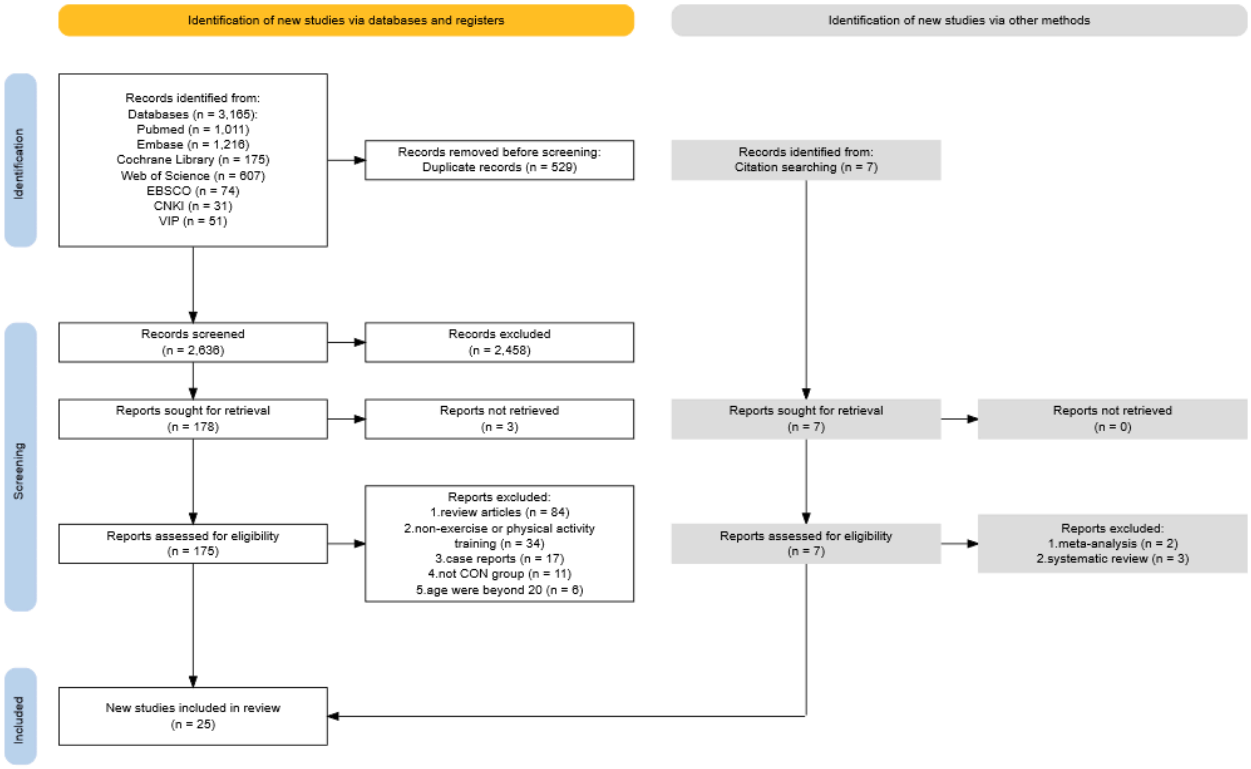
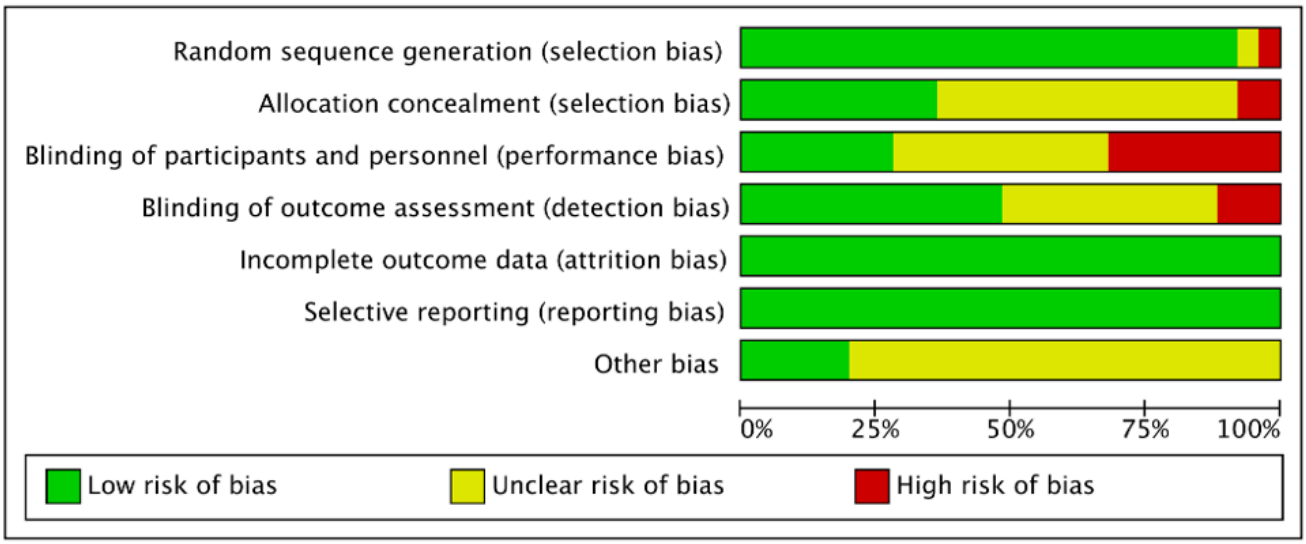



**Figure 1**

PRISMA flowchart diagram



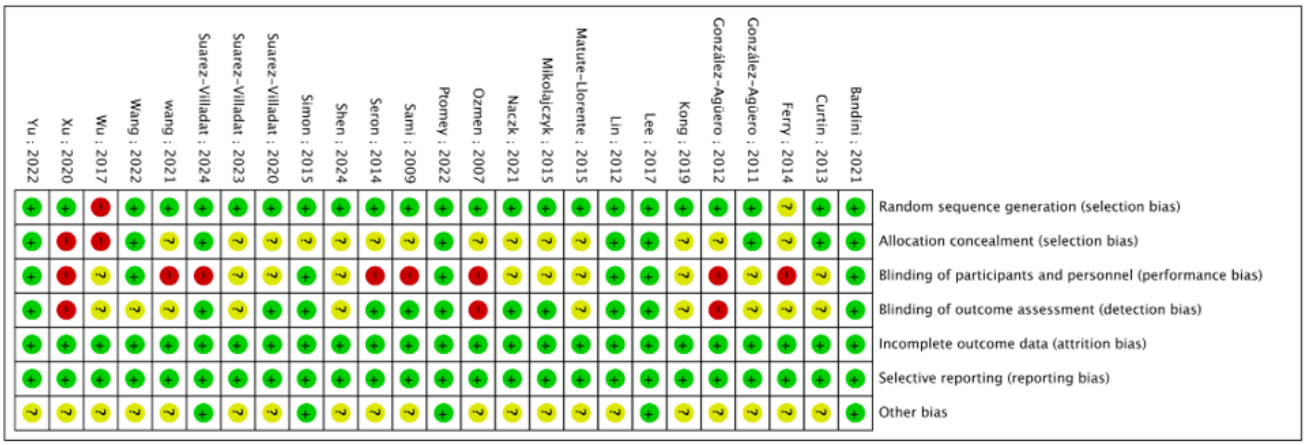




**Figure 2**

Quality and risk-of-bias assessment. Risk-of-bias graph (A): review authors' judgments about each risk-of-bias item presented as percentages across all included studies; and risk-of-bias summary (B): review authors' judgments about each risk-of-bias item for each included study (red, green and yellow circles indicate "high", "low" and "unclear" risk of bias, respectively).

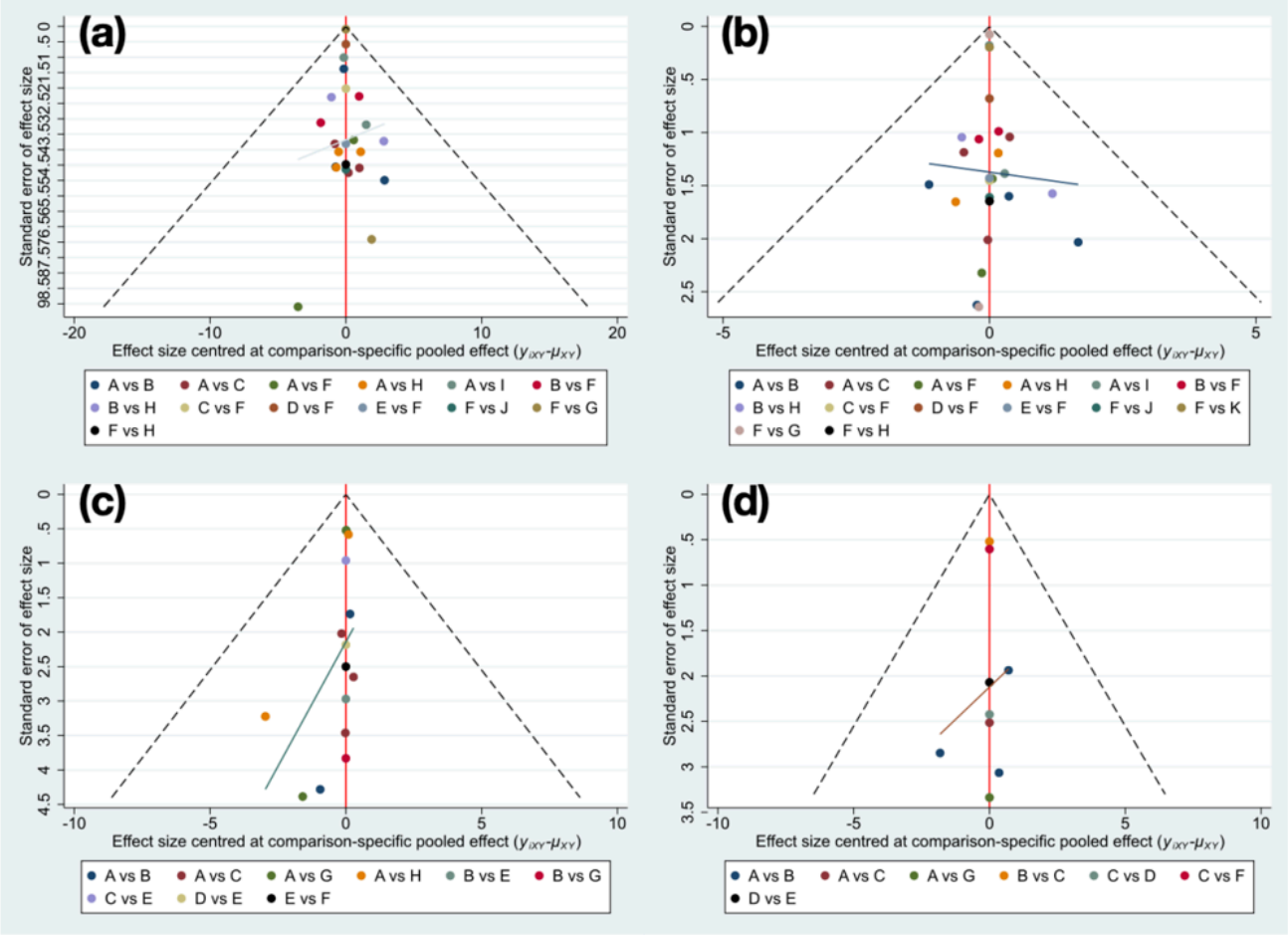



**Figure 3**

Comparison-adjusted funnel plots for small-study effects: (a)BW, (b) BMI, (c) fat mass, (d) WC

Note:(a)A=TUA, B=AE, C=ARE, D=ARG, E=HIIT, F=PA, G=PAD, H=RE, I=SWIM, J=WBV; (b)A=TUA, B=AE, C=ARE, D=ARG, E=HIIT, F=PA, G=PAD, H=RE, I=SWIM, J=WBV, K=TC; (c)A=TUA, B=AE, C=ARE, D=HIIT, E=PA, F=PAD, G=RE, H=SWIM; (d)A=TUA, B=AE, C=ARE, D=PA, E=RE, F=SWIM, G=TC.

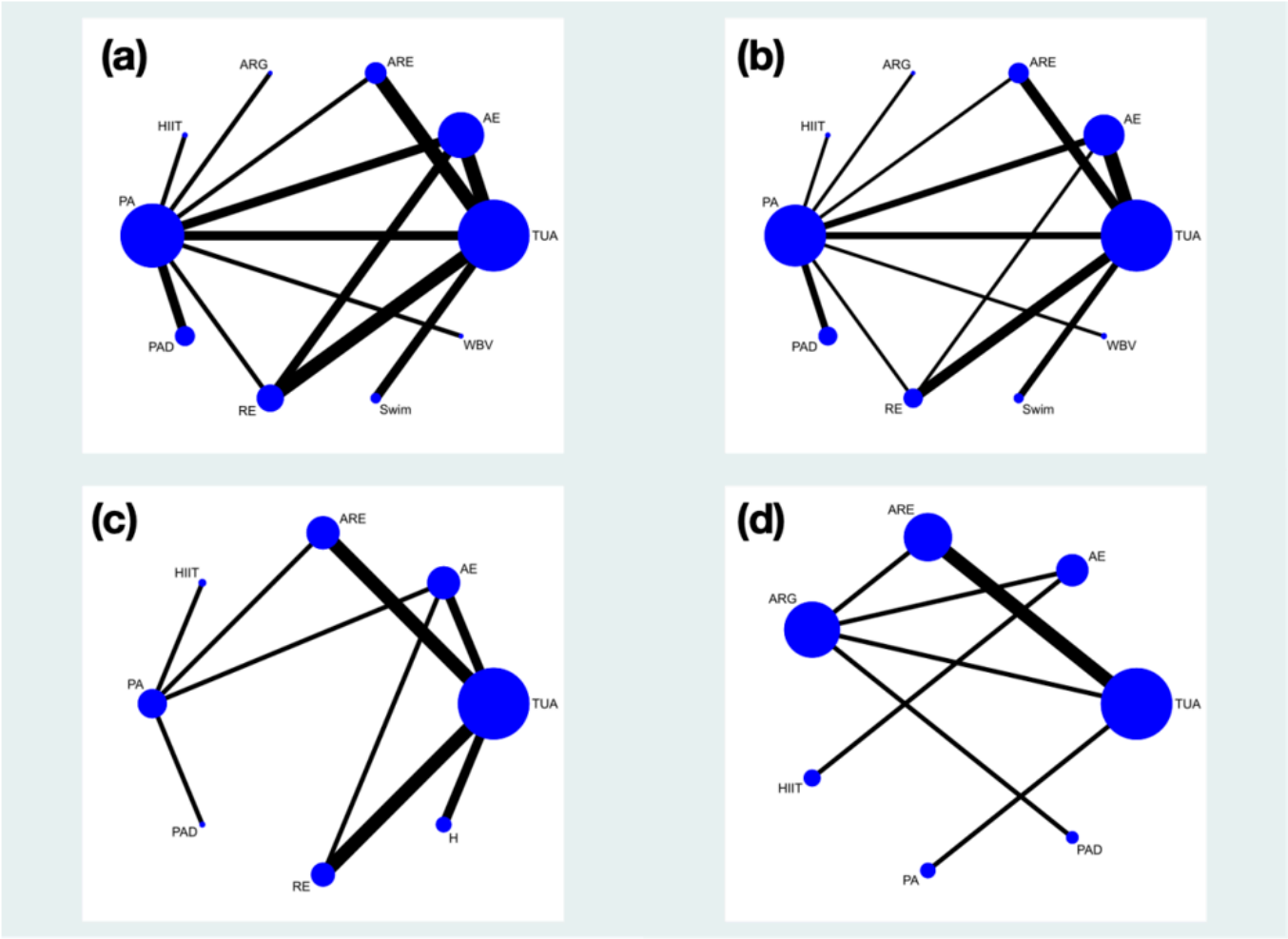



**Figure 4**

Network geometry of the evidence for (a) BW, (b) body mass index (BMI), (c) fat mass, and (d) WC

Note:(a)A=TUA, B=AE, C=ARE, D=ARG, E=HIIT, F=PA, G=PAD, H=RE, I=SWIM, J=WBV; (b)A=TUA, B=AE, C=ARE, D=ARG, E=HIIT, F=PA, G=PAD, H=RE, I=SWIM, J=WBV, K=TC; (c)A=TUA, B=AE, C=ARE, D=HIIT, E=PA, F=PAD, G=RE, H=SWIM; (d)A=TUA, B=AE, C=ARE, D=PA, E=RE, F=SWIM, G=TC.

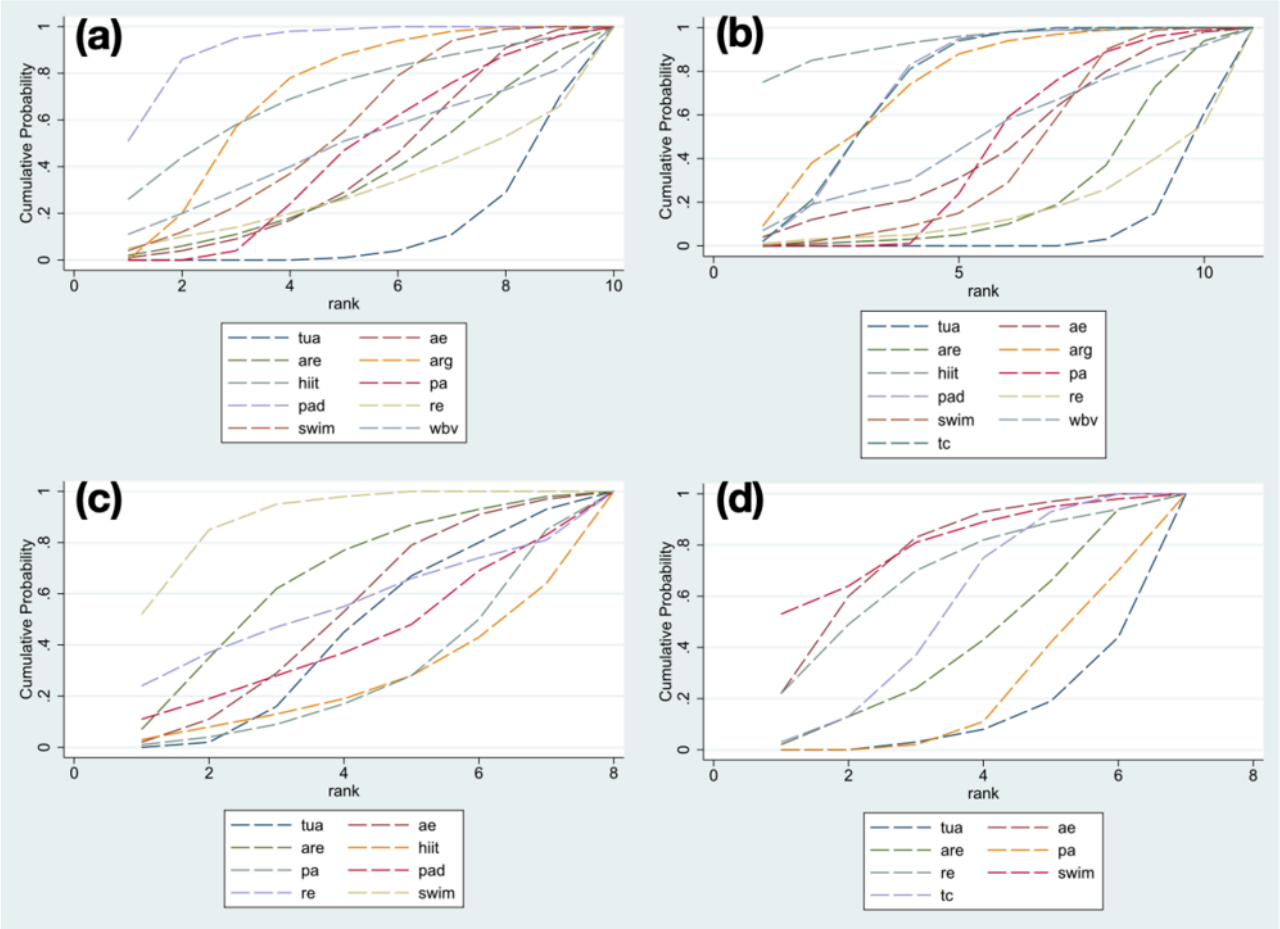



**Figure 5**

Cumulative ranking curves (SUCRA) for competing interventions: (a) BW, (b) BMI, (c) fat mass, (d) WC.

Note: AE=aerobic exercise; ARE=aerobic+resistance exercise; ARG=adapted rhythmic gymnastics; HIIT=high-intensity interval training; PA=active control/physical education; PAD=physical-activity education+diet; RE=resistance exercise;

WBV=whole-body vibration; TC=Tai Chi; TUA=true usual activity

## Supplementary Files

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- SupplementaryID.docx