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SYSTEMATIC REVIEW

Lifting Limits: The Impact of Strength Training in Down Syndrome—A Systematic Review and Meta-Analysis

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ABSTRACT

Background: People with Down syndrome (DS) may exhibit several musculoskeletal disorders, including alterations in muscle tone and activation. Strength training could mitigate the loss of muscle strength and, therefore, improve strength values in this population. Additionally, it may influence health-related outcomes such as physical function, body composition and biochemical markers.

Objective: This systematic review and meta-analysis of randomised controlled trials (RCTs) aimed to analyse the characteristics and effects of strength training in people with DS.

Methods: A search was conducted from inception to 22 April 2025. The methodological quality of the included RCTs was assessed using the 15-item Tool for the assEssment of Study qualiTy and reporting in EXercise (TESTEX). In addition, the risk of bias was assessed using the Cochrane's risk of bias 2 (RoB2).

Results: A total of 10 RCTs ($n = 233$ participants) were included in the systematic review, of which three ($n = 111$ participants) could be meta-analysed. The pooled effect showed statistically significant benefits for upper (mean difference [MD] = 5.66 kg, 95% CI 2.42–8.91) and lower (MD = 20.43 kg, 95% CI 1.76–39.10) body strength. The TESTEX scores for most RCTs ranged from 3 to 12 points. The risk of bias analysis indicated that eight RCTs had a low risk of bias, whereas the remaining studies were classified as high risk.

Conclusion: Strength training may significantly improve muscle strength in people with DS. However, further research is needed to assess the long-term effects on physical function, body composition and biochemical markers.

1 | Introduction

Down syndrome (DS), the most common chromosomal disorder, caused by a complete or partial trisomy of chromosome 21, is the most common cause of intellectual disability worldwide. The World Health Organisation (WHO) estimates the global prevalence at 1 in 1000 births (Díaz-Cuéllar et al. 2016). Nowadays, the life expectancy of people with DS is 60 years (Glasson et al. 2014; Seron et al. 2017), which has increased significantly in recent decades, although it remains much lower than that of the general population (i.e., 72.5 years) (World Health Organisation 2025). The mortality rate increases considerably after the age of 40, with the main causes being complications related to heart problems, pneumonia, circulatory diseases, the decline in functional capacity and behavioural problems due to characteristic diseases, especially Alzheimer's disease

(Bull 2020). Additionally, several conditions appear with age, such as sensory impairments (hearing and vision), musculoskeletal disorders (osteoporosis and sarcopenia) and lung problems (Pitetti et al. 2013).

DS is characterised by musculoskeletal features, including reduced muscle strength, muscle hypotonia, joint hypermobility, delayed muscle activation latency and deficits in postural control (Guzman-Muñoz et al. 2017). Some of these factors may be exacerbated by obesity, which has a prevalence of 61% in adolescents and 72% in adults with DS (Shields 2021) and is associated with a sedentary lifestyle commonly observed in this population (Seron et al. 2014). The reasons why people with DS tend to lead a sedentary lifestyle are varied. However, it can be considered that the physical limitations inherent to DS make it difficult to participate in physical activities (Shields and Taylor 2015).

Strength is the key factor for achieving effective and functional movements and is essential for both people with and without disabilities, as it is vital for overall health, productivity and independence in daily life activities (Howat et al. 1997). In people with DS, muscle strength in the upper and lower limbs is reduced by 50% compared to typically developing individuals or those with intellectual disabilities, but without DS, this reduced muscle strength can greatly impact their ability to perform daily activities (Shields and Taylor 2010). Children with DS have reduced hip abductor and knee extensor strength compared to children without DS (Mercer and Lewis 2001). Furthermore, children and adolescents with DS have reduced quadriceps strength compared to their peers without DS, and they do not show the typical muscle development associated with this stage of life (Cioni et al. 1994). The decrease in muscle strength may be related to deficits in both the quality and quantity of muscle tissue associated with the hypotonia characteristic of people with DS and their predominantly sedentary lifestyle (Tsimaras and Fotiadou 2004). This condition not only affects gross and fine motor skills but also limits functional capacity in occupational and social domains by impairing hand-eye coordination, laterality, visuomotor control and reaction time (Gupta et al. 2011; Lin and Wuang 2012).

Regular physical training is a nonpharmacological therapy approach to improve quality of life and support independence by increasing work capacity and physical performance, such as autonomic cardiac regulation, cardiorespiratory fitness, muscle strength and functionality (Bahiraei et al. 2023). A previous systematic review demonstrated that physical exercise significantly improves muscle strength, balance, flexibility, functional capacity and body composition (Montalva-Valenzuela et al. 2024). Indeed, neuromuscular training could enhance maximal strength in children and young adults with DS (Sugimoto et al. 2016).

Moreover, performing resistance training could enhance muscle strength (Stojanović et al. 2024) and physical fitness (Kuo et al. 2024) in people with DS. However, one of these studies (Stojanović et al. 2024) combined randomised controlled trials (RCTs) and non-RCTs, which may affect the reliability of the conclusions (Hariton and Locascio 2018). To address this limitation, the present study conducted a systematic review and meta-analysis of RCTs to assess the characteristics, methodological quality and effects of strength training programmes in people with DS.

Therefore, given the potential benefits of this type of exercise in people with DS, the main aim of this systematic review and meta-analysis was to summarise the effects of strength training in muscle strength, handgrip strength, work task performance, physical activity (PA) levels, body composition, molecular and inflammatory markers, bone mineral density, muscle endurance and physical function. Both scientific and clinical practice could benefit from a comprehensive review summarising the effects of strength training in people with DS.

2 | Methods

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al. 2021) (Supporting Information S1), and the protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under Registration Number CRD42024571291.

2.1 | Data Sources and Search Strategy

To identify eligible studies, a literature and systematic search was conducted in three databases (i.e., PubMed, Web of Science [WOS] and Scopus) using the following search strategy: (Down Syndrome) AND ('strength training' OR 'resistance training' OR 'strength exercise' OR 'resistance exercise'). No filters were applied. The search was conducted from inception to 22 April 2025. The search was supplemented by a manual review of reference lists of included studies and relevant publications.

2.2 | Study Selection

The systematic review included RCTs published in English or Spanish that met the selection criteria based on the Population, Intervention, Outcomes and Context (PICO) framework (Schardt et al. 2007). Specifically, the criteria included (i) population: people with DS without any restriction on age; (ii) intervention: any type of isolated strength exercise; (iii) comparison: usual care or nonexercise control group; (iv) outcomes: primary outcomes included upper and lower body strength and secondary outcomes included handgrip, work task performance, PA levels, body composition, molecular and inflammatory markers, bone mineral density, muscle endurance and physical function; (v) any form of isolated strength exercise, both supervised and unsupervised programmes.

The reason for including only RCTs was that RCTs are prospective studies that evaluate the effects of an intervention and are considered the standard of reference for studying causal relationships of such interventions (Hariton and Locascio 2018).

Duplicate documents were removed, and RCTs that used the same physical exercise intervention in all study groups or that combined strength exercise with other types of exercise were excluded. Two researchers (L.I.-D. and C.G.-C) selected the studies independently. Discrepancies were resolved by consulting a third researcher (J.G.-L.).

2.3 | Data Extraction

After screening the literature, data were extracted by two researchers (L.I.-D. and C.G.-C.). For each included study, the following information was extracted when available: main author, year of publication, sample characteristics (age, sample size and intellectual disability range), type of intervention and exercise intervention protocol (intensity, volume and study duration), outcomes and preintervention and postintervention results or difference within groups (expressed as mean difference [MD] ± standard deviation [SD] when available).

2.4 | Methodological Quality and Risk of Bias

The methodological quality of the included RCTs was independently assessed by two researchers (L.I.-D. and J.G.-L.) using the 15-item Tool for the assEssment of Study qualiTy and reporting in EXercise (TESTEX) for exercise training studies. In cases of disagreement between the scores, a third author (C.G.-C.) made the final decision. The TESTEX scale comprises 12 criteria, whereby more than 1 point is possible for some criteria, so that a maximum of 15 points can be achieved (5 points for study quality and 10 points for reporting) (Smart et al. 2015).

The risk of bias was independently assessed by two researchers (L.I.-D. and J.G.-L.) using the Cochrane's risk of bias 2 (RoB2) (Sterne et al. 2019). In cases of disagreement between the scores, a third author (C.G.-C.) made the final decision. The RoB2 tool is structured into a fixed set of domains of bias, focusing on different aspects of trial design, conduct and reporting. Five domains were assessed: (D1) bias arising from the randomisation process; (D2) bias due to deviations from intended interventions; (D3) bias due to missing outcome data; (D4) bias in the measurement of the outcome; and (D5) bias in the selection of the reported results. These categories were classified as having a 'high risk of bias', 'low risk of bias' or 'some concerns' (Sterne et al. 2019).

2.5 | Statistical Analysis

The data were analysed using Review Manager (RevMan) 5.4 software (The Nordic Cochrane centre The Cochrane Collaboration, Copenhagen). When at least three RCTs assessed the same outcome with the same measurement tool, the pooled effect of strength exercise on DS was estimated using a random-effects model (i.e., DerSimonian and Laird method). In this type of analysis, each study is weighted by the inverse of its variance, which includes both the within-study variance and the between-study variance (Hodkinson and Kontopantelis 2021).

Only studies that specified the mean effect of exercise (baseline and posttreatment data or difference within groups) or provided data that allowed calculation of the mean effect of exercise were included in the meta-analyses. The significance level was established at $p < 0.05$ (Higgins and Green 2008).

MD with a corresponding 95% confidence intervals (95% CI) was calculated for continuous outcomes when the same assessment tool was employed for the same outcome across studies. The results were expressed in the units used for each specific measurement instrument. To perform the meta-analysis, the MD and SD between baseline and postintervention assessments were extracted from each individual RCT. Statistical heterogeneity was evaluated using a chi-square test (χ^2), and any inconsistency was quantified using the I^2 statistic ($I^2 = [(Q - \text{df}) / Q] \times 100\%$, where Q is the χ^2 statistic and df is the degrees of freedom) (Higgins et al. 2003). I^2 values were interpreted as follows: 0%–40% indicated low heterogeneity, 30%–60% indicated moderate heterogeneity, 50%–90% indicated substantial heterogeneity and values greater than 75% were considered indicative of considerable heterogeneity (Higgins et al. 2003).

3 | Results

Initially, 335 documents were retrieved from the three databases and list of publications. A total of 125 duplicated documents were removed, and 210 documents were screened (Supporting Information S2). Finally, 10 RCTs (Diaz et al. 2021; Fornieles et al. 2014; Ortiz-Ortiz et al. 2019; Reza et al. 2013; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2008, 2013; Shields and Taylor 2010) met the inclusion criteria ($n = 233$ participants) and were included in the systematic review (Table 1), of which three were included in the meta-analysis (Figure 1).

3.1 | Characteristics of the Included Studies

The included RCTs were conducted in children (Ortiz-Ortiz et al. 2019; Reza et al. 2013), adolescents, (Shields et al. 2013; Shields and Taylor 2010) or adults with DS (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2008) (Table 1). The sample size of the included studies ranged from 20 (Shields et al. 2008) to 68 (Shields et al. 2013) participants. In total, two (Diaz et al. 2021; Rosety-Rodriguez et al. 2021) and three (Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014) RCTs were conducted with the same sample and/or with the same exercise protocol. Most RCTs included only men in their study design (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021), whereas three were conducted in both men and women (Shields et al. 2008, 2013; Shields and Taylor 2010). In other RCT, the gender of the participants was not specified (Reza et al. 2013). Regarding the grade of intellectual disability, although it was not reported in the studies conducted in children with DS (Ortiz-Ortiz et al. 2019; Reza et al. 2013), two RCTs included adolescents (Shields and Taylor 2010) or adults (Shields et al. 2008) with a mild to severe grade. The other RCTs were conducted in adolescents or adults with mild to moderate grade of intellectual disability (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2013).

The studies compared strength training with a control group that continued their daily life activities (Diaz et al. 2021;

TABLE 1 | Systematic review and meta-analysis: Characteristics of the included studies.

Author (year)	Sample characteristics	Sample size	Intervention	Outcome	Main results
Shields et al. (2008)	Participants: Adults with DS Age (mean ± SD): 25.8 ± 5.40 (EG); 27.6 ± 9.5 (CG) Intellectual disability grade: Mild, moderate and severe Other: Ability to follow simple verbal instructions	20 (65% male)	EG ($n = 9$) *Type of exercise*: Progressive strength training *Intensity*: Increased when 3 sets of 12 repetitions of an exercise could be completed *Volume*: 2 weekly sessions; 6 exercises (weight machines); 2–3 sets; 10–12 repetitions of each exercise until fatigue *Total duration*: 10 weeks CG ($n = 11$) *Intervention*: Daily life activities *Total duration*: 10 weeks	• Upper and lower body strength (*chest press and leg press 1RM test*) • Muscle endurance (*number of repetitions at 50% of 1RM*) • Physical function (*timed stairs test and grocery shelving task*)	↑ Upper body muscle endurance and upper body muscle strength in the EG ↑ Physical function in the EG
Shields and Taylor (2010)	Participants: Adolescents with DS Age (mean ± SD): 15.9 ± 1.5 (EG); 15.3 ± 1.7 (CG) Intellectual disability grade: Mild, moderate and severe Other: Ability to follow simple verbal instructions	23 (74% male)	EG ($n = 11$) *Type of exercise*: Progressive strength training *Intensity*: Increased when 3 sets of 12 repetitions of an exercise could be completed *Volume*: 2 weekly sessions; 6 exercises (pin-loaded weight machines); 3 sets; 12 repetitions of each exercise or until fatigue *Total duration*: 10 weeks CG ($n = 12$) *Intervention*: Daily life activities *Total duration*: 10 weeks	• Upper and lower body strength (*chest press and leg press 1RM test*) • Physical function (*Timed Up and Down Stairs Test and Grocery Shelving Task*)	↑ Lower body muscle strength in the EG
Reza et al. (2013)	Participants: Children with DS Age (mean ± SD): 9.33 ± 1.61 (EG); 9.42 ± 1.62 (CG) Intellectual disability grade: NS Other: NA	24 (gender NS)	EG ($n = 12$) *Type of exercise*: Strength training *Intensity*: NS *Volume*: 3 weekly sessions; 45 min each session. *Total duration*: 4 months *Others*: NA CG ($n = 12$) *Intervention*: No exercise intervention *Total duration*: 4 months *Others*: NA	• BMD (g/cm^2) of the right proximal femoral neck (*dual-energy-X-ray absorptiometry*)	↑ BMD in the EG

(Continues)

TABLE 1 | (Continued)

Author (year)	Sample characteristics	Sample size	Intervention	Outcome	Main results
Rosety-Rodríguez et al. (2013)	Participants: Adults with DS Age (mean ± SD): 23.7 ± 3.1 Intellectual disability grade: Mild Other: NA	40 (100% male)	EG ($n = 24$) *Type of exercise*: Progressive strength training *Intensity*: 40%–65% 8RM *Volume*: 3 weekly sessions; 6 exercises (pin-loaded weight machines); 2 sets; 10 repetitions of each exercise (Weeks 1–4), 8 repetitions (Weeks 5–8), 6 repetitions (Weeks 9–12). *Total duration*: 12 weeks. *Others*: NA CG ($n = 16$) *Intervention*: Daily life activities *Total duration*: 12 weeks *Others*: NA	• Work task performance (*Timed Get Up and Go*) • Body composition (*fat free mass*, *waist circumference*) • Inflammatory cytokines (*plasma levels of leptin, adiponectin*, *tumour necrosis factor-α and interleukin 6*)	↓ Wrist circumference and fat free mass in the EG ↓ Fat free mass in the EG ↓ Leptin, interleukin 6, and tumour necrosis factor-α levels in the EG
Shields et al. (2013)	Participants: Adolescents or young adults with DS Age (mean ± SD): 17.7 ± 2.4 (EG); 18.2 ± 2.8 (CG) Intellectual disability grade: Mild and moderate Other: Able to follow simple verbal instructions	68 (56% male)	EG ($n = 34$) *Type of exercise*: Progressive strength training *Intensity*: 60%–80% 1RM *Volume*: 2 weekly sessions; 7 exercises (pin-loaded weight machines); 3 sets; 12 repetitions of each exercise *Total duration*: 10 weeks *Others*: follow-up (Week 24) CG ($n = 34$) *Intervention*: Social programme with a student mentor once a week *Total duration*: 10 weeks *Others*: follow-up (Week 24)	• Work task performance (*weighted box stacking test and weighted pail carry test*) • Upper and lower body strength (*chest press and leg press 1RM test)* • Physical activity levels (*accelerometer RT3 activity monitor*)	↑ Upper (postintervention) and lower body (postintervention and Week 24 follow-up) strength in the EG ↑ Physical activity levels in the EG (Week 24 follow-up)
Fornieles et al. (2014)	Participants: Adults with DS Age (mean ± SD): 23.7 ± 3.1 Intellectual disability grade: Mild Other: NA	40 (100% male)	EG ($n = 24$) *Type of exercise*: Progressive strength training *Intensity*: 40%–65% 8RM *Volume*: 3 weekly sessions; 6 exercises (pin-loaded weight machines); 2 sets; 10 repetitions of each exercise (Weeks 1–4), 8 repetitions (Weeks 5–8), 6 repetitions (Weeks 9–12). *Total duration*: 12 weeks. *Others*: NA CG ($n = 16$) *Intervention*: Daily life activities *Total duration*: 12 weeks *Others*: NA	• Work task performance (*weighted box stacking tests*) • Salivary evaluation (*testosterone*, *cortisol*, *immunoglobulin A*)	↑ Work task performance in the EG ↑ Testosterone and immunoglobulin A in the EG

(Continues)

TABLE 1 | (Continued)

Author (year)	Sample characteristics	Sample size	Intervention	Outcome	Main results
Rosety-Rodriguez et al. (2014)	Participants: Adults with DS Age (mean ± SD): 23.7 ± 3.1 Intellectual disability grade: Mild Other: NA	40 (100% male)	EG (n = 24) *Type of exercise*: Progressive strength training *Intensity*: 40%–65% 8RM *Volume*: 3 weekly sessions; 6 exercises (pin-loaded weight machines); 2 sets; 10 repetitions of each exercise (Weeks 1–4), 8 repetitions (Weeks 5–8), 6 repetitions (Weeks 9–12). *Total duration*: 12 weeks. *Others*: NA CG (n = 16) *Intervention*: Daily life activities *Total duration*: 12 weeks *Others*: NA	• Handgrip muscle strength (*electronic dynamometer*) • Oxidative damage markers (*MDA*, *and urinary level of 80 HdG*)	↓ MDA in the EG ↓ 80HdG in the EG
Ortiz-Ortiz et al. (2019)	Participants: children with DS Age (mean ± SD): 12.2 ± 1.9 (EG); 12.4 ± 2.3 (CG) Intellectual disability grade: Mild (supongo) Other: NA	22 (59% male)	EG (n = 13) Type of exercise: progressive resistance training Intensity: NA Volume: 5 weekly sessions; strength circuit and 'tabata' exercises (weight discs, tension ropes, dumbbells, medicine ball and handgrip) Total duration: 16 weeks CG (n = 9) Intervention: Daily life activities Total duration: 16 weeks Others: NA	• Handgrip strength (*hydraulic dynamometer*) • Body weight (*Tanita*), body height (*stadiometer*), triceps and calf skinfolds (*calliper*)	↑ Handgrip strength in the EG ↓ Medial calf skinfold and BMI in the EG
Diaz et al. (2021)	Participants: Adults with DS Age (mean ± SD): 28.4 ± 3.6 (EG); 27.8 ± 3.0 (CG) Intellectual disability grade: Mild Other: NA	36 (100% male)	EG (n = 18) *Type of exercise*: Progressive strength training *Intensity*: 40%–65% 8RM *Volume*: 3 weekly sessions; 6 exercises (pin-loaded weight machines); 2 sets; 10 repetitions of each exercise (Weeks 1–4), 8 repetitions (Weeks 5–8), 6 repetitions (Weeks 9–12). *Total duration*: 12 weeks. *Others*: NA CG (n = 18) *Intervention*: Daily life activities *Total duration*: 12 weeks *Others*: NA	• Work task performance: (*weighted pail carry test*) • Body composition (*BMI*, *musculoskeletal index*, *weight*, *wrist circumference*, *muscle mass*, *fat mass*) • Markers of muscle damage: (*creatin kinase activity*, *myoglobin concentration*, *lactate deshydrogenase*)	↑ Work task performance in the EG ↑ Muscle mass and musculoskeletal index in the EG

(Continues)

Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2008; Shields and Taylor 2010); attended a social programme of recreational activities such as watching movies, crafts or social activities (Shields et al. 2013); or received no additional intervention or advice (Reza et al. 2013). The study duration ranged from 10 weeks (Shields et al. 2008, 2013; Shields and Taylor 2010) to 4 months (Ortiz-Ortiz et al. 2019; Reza et al. 2013).

Regarding the characteristics of strength training, participants performed from two (Shields et al. 2008, 2013; Shields and Taylor 2010) to five weekly sessions (Ortiz-Ortiz et al. 2019). All the studies used a work volume of two (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2008) or three (Shields et al. 2008, 2013; Shields and Taylor 2010) sets of each exercise with an adjusted intensity of 40%–65% of eight-repetition maximum (8RM) (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021) or 60%–80% of one-repetition maximum 1RM (Shields et al. 2013). Two RCTs were designed following the recommendations of the American College of Sports Medicine, and the intensity was increased when the participants could complete two (Shields et al. 2008) or three (Shields and Taylor 2010) sets of 12 repetitions of an exercise. In the studies conducted in children with DS, the intensity and sets were not specified (Ortiz-Ortiz et al. 2019; Reza et al. 2013).

3.2 | Methodological Quality Assessment and Risk of Bias Results

The overall methodological quality of the 10 RCTs included had a score ranging from 8 to 12 points, except for two studies (Ortiz-Ortiz et al. 2019; Reza et al. 2013) that presented a low quality with a score of 3 points. Six studies (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2013) reported information about all exercise parameters including session duration, frequency, intensity and modality. However, any study specified the PA levels in the control groups (Supporting Information S3).

Risk of bias assessment is displayed in Figure 2. The risk of bias analysis revealed that eight (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013, 2014, 2021; Shields et al. 2008, 2013; Shields and Taylor 2010) of the 10 studies presented a low risk and two (Ortiz-Ortiz et al. 2019; Reza et al. 2013) had some concerns in dimension one (bias derived from the randomisation process).

The proportion of studies identifying bias in one or more design elements is presented, which shows the percentage obtained by judgement in each evaluated item (low risk, some concerns and high risk) (Figure 3). The main concerns regarding potential bias stemmed from issues related to the deviations from intended interventions, such as unclear blinding procedures (e.g., whether participants and investigators were aware of intervention assignments during the trial). Another important concern is related to the risk of bias arising from measurement of the outcome. No differences were observed in the rest of the dimensions (D2–D5), with the risk being low.

TABLE 1 | (Continued)

Author (year)	Sample characteristics	Sample size	Intervention	Outcome	Main results
Rosety-Rodriguez et al. (2021)	Participants: Adults with DS Age (mean ± SD): 28.4 ± 3.6 (EG); 27.8 ± 3.0 (CG) Intellectual disability grade: Mild Other: NA	36 (100% male)	EG ($n = 18$) *Type of exercise*: Progressive strength training *Intensity*: 40%–50% 8RM *Volume*: 3 weekly sessions; 6 exercises (pin-loaded weight machines); 2 sets; 10 repetitions of each exercise (Weeks 1–8), 8 repetitions (Weeks 9–12). *Total duration*: 12 weeks. *Others*: NA CG ($n = 18$) *Intervention*: Daily life activities *Total duration*: 12 weeks *Others*: NA	• Handgrip muscle strength (*electronic dynamometer*) • Lower body strength (*dynamic torque of knee flexors and extensors*) • Antioxidant activity (*plasma total antioxidant status and GSH*) • Oxidative damage markers (*MDA, carbonyl*)	↑ Plasma total antioxidant status in the EG ↑ Erythrocyte glutathione reductase and GSH plasma levels in the EG ↓ Oxidative damage and carbonyl groups markers in the EG

Abbreviations: 1RM, one-repetition-maximum; 8RM, eight-repetition maximum; BMD, bone mineral density; BMI, body mass index; CG, control group; EG, experimental group; GSH, reduced glutathione; HdG, hydroxydeoxyguanosine; MDA, malondialdehyde; NA, not applicable; NS, not specified.

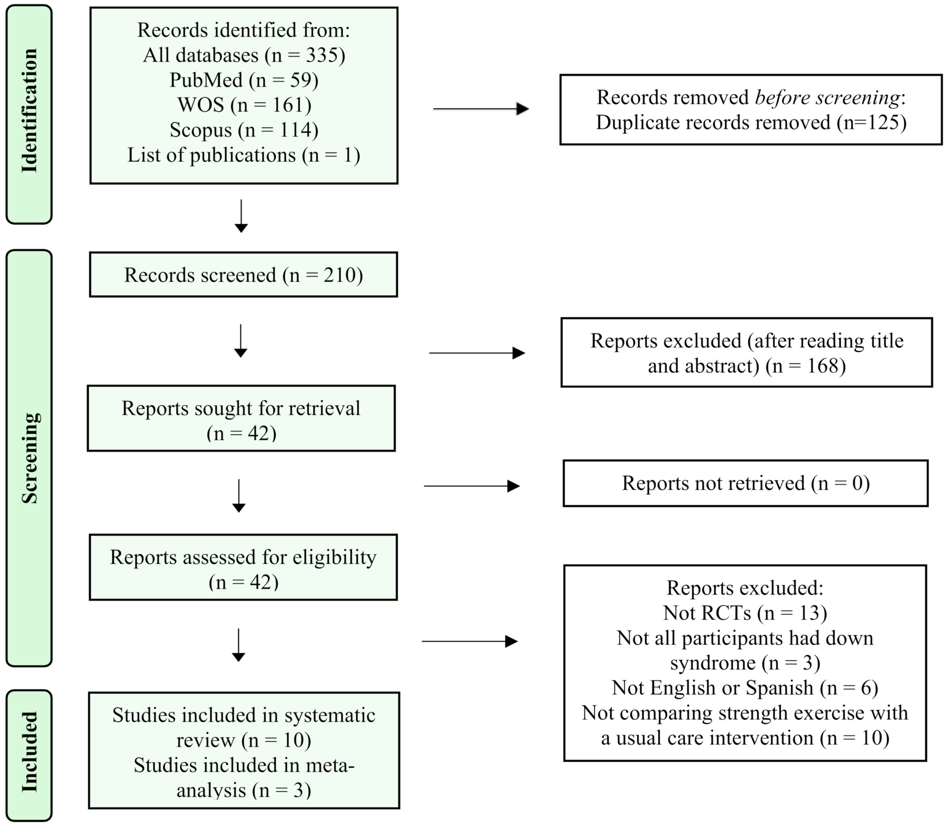

FIGURE 1 | Systematic review and meta-analysis: PRISMA search flowchart. The 335 documents were retrieved from the three databases and additional list of publications.

3.3 | Systematic Review Results

A total of three RCTs investigated the effects of strength training on upper and lower body strength using the 1RM test for chest and leg press (Shields et al. 2008, 2013; Shields and Taylor 2010). In another RCT, the measurement of dynamic torques produced by knee flexors and extensors was assessed through a motor-driven dynamometer (Rosety-Rodriguez et al. 2021). Handgrip strength was also included in three RCTs (Ortiz-Ortiz et al. 2019; Rosety-Rodriguez et al. 2014, 2021). In the experimental groups, statistically significant results were reported for upper (Shields et al. 2008, 2013) and lower body strength (Shields et al. 2013; Shields and Taylor 2010) and for handgrip strength (Ortiz-Ortiz et al. 2019). Similarly, four RCTs (Diaz et al. 2021; Fornieles et al. 2014; Rosety-Rodriguez et al. 2013; Shields et al. 2013) assessed changes in work task performance through Time Get Up and Go and weighted box stacking and weighted pail carry tests, with significant results in the experimental group in two (Diaz et al. 2021; Fornieles et al. 2014) of these studies. Physical function, evaluated using a timed stairs test and a grocery shelving task, also showed a significant benefit in the experimental group in one RCT (Shields et al. 2008), and PA levels were increased in another RCT in the group that performed strength training (Shields et al. 2013). In terms of body composition, statistically significant improvements were reported for bone mineral density (Reza et al. 2013), fat free mass (Rosety-Rodriguez et al. 2013), muscle mass and musculoskeletal index (Diaz et al. 2021) and calf skinfold (Ortiz-Ortiz et al. 2019). The results for body mass index showed significant results in one RCT (Ortiz-Ortiz et al. 2019).

Regarding oxidative stress, a significant improvement in the concentration of malondialdehyde (Rosety-Rodriguez et al. 2014, 2021) and urinary levels of 8-hydroxydeoxyguanosine (Rosety-Rodriguez et al. 2014) was observed. Similarly, plasma levels of carbonyl groups were also reduced in the group that performed strength training (Rosety-Rodriguez et al. 2021). In the case of antioxidants, strength training increased plasma total antioxidant status, glutathione reductase and plasma levels of reduced glutathione (Rosety-Rodriguez et al. 2021). Another RCT that evaluated the concentration of inflammatory cytokines also found improvements in plasma levels of leptin, interleukin 6 and tumour necrosis factor in the experimental group (Rosety-Rodriguez et al. 2013). Testosterone and immunoglobulin A showed significant increases in the salivary evaluation of adults with DS who performed the strength training programme (Fornieles et al. 2014). Markers of muscle damage were also examined. However, the results did not show significant results for this outcome (Diaz et al. 2021).

3.4 | Meta-Analysis Results

Three RCTs (Shields et al. 2008, 2013; Shields and Taylor 2010) were included in the meta-analysis, and two outcomes were meta-analysed: upper and lower body strength.

3.4.1 | Upper Body Strength

Three RCTs ($n = 111$ participants) (Shields et al. 2008, 2013; Shields and Taylor 2010) analysed the effects of strength

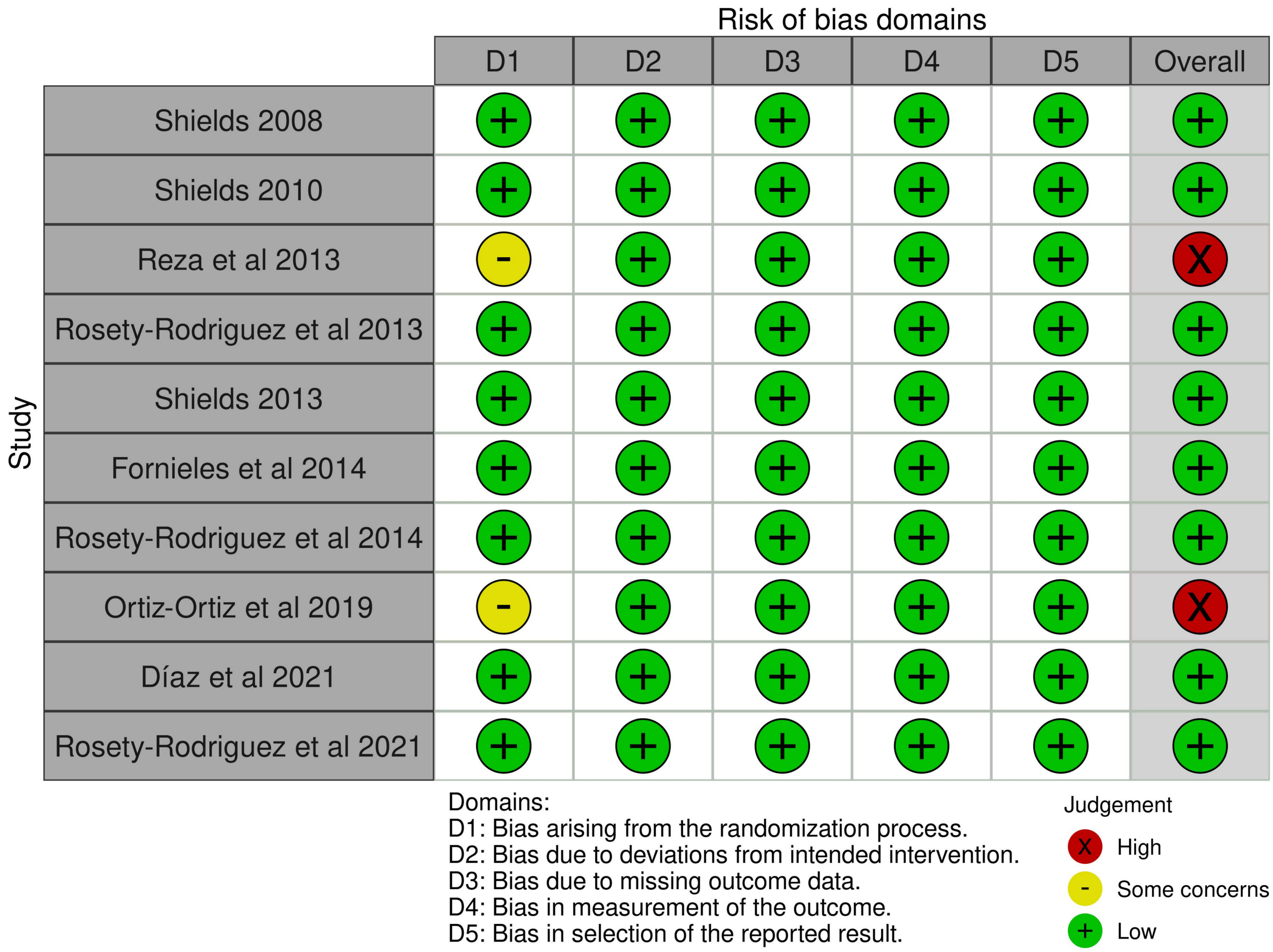

FIGURE 2 | Assessment of risk of bias based on the Cochrane risk of bias tool.

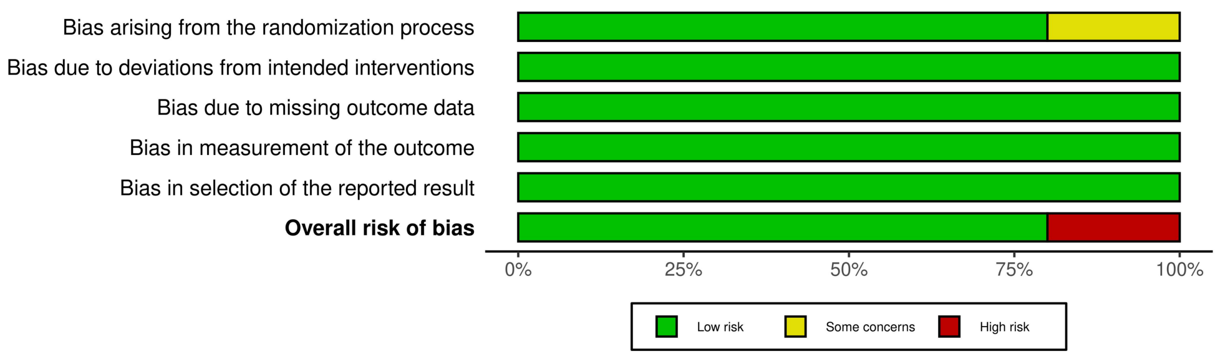

FIGURE 3 | Risk of bias graph.

exercise on upper body strength through a 1RM chest press test. The pooled effect (Figure 4A) showed statistically significant benefits in favour of the exercise group, with no heterogeneity between studies (MD = 5.66 kg, 95% CI 2.42–8.91, $p < 0.001$; $I^2 = 0\%$; $p = 0.990$).

3.4.2 | Lower Body Strength

Three RCTs (nn = 111 participants) (Shields et al. 2008, 2013; Shields and Taylor 2010) analysed the effects of strength exercise on lower body strength through a 1RM leg press test. The pooled effect (Figure 4B) showed statistically significant improvements in the exercise group, however with high heterogeneity between studies (MD = 20.43 kg, 95% CI 1.76–39.10, $p = 0.030$; $I^2 = 71\%$; $p = 0.030$).

4 | Discussion

This systematic review and meta-analysis of RCTs assessed the effects of isolated strength training in people with DS. In

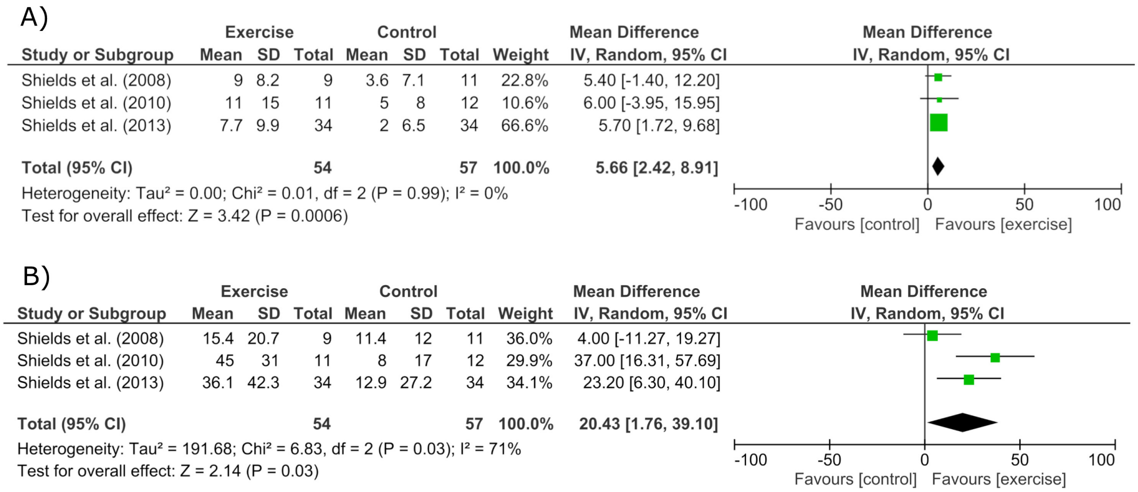

FIGURE 4 | Meta-analysis results. (A) Upper body strength results and (B) lower body strength results.

particular, the results of the meta-analysis show that strength training significantly improved upper and lower body strength compared to usual care or no exercise intervention. The results of the review suggest overall improvements in physical function, body composition and biochemical markers, highlighting the potential benefits of strength training in people with DS.

The WHO recommends that people with disabilities should follow the PA recommendations for adults, adolescents and/or children and that the prescription exercise should be guided by a professional (Bull et al. 2020). However, this population group usually does not fully achieve the recommended PA guideline (Fox et al. 2019; Jacob et al. 2023).

Strength training may be more effective than aerobic training in improving physical fitness-related outcomes in youth with DS (Suarez-Villadat et al. 2024). Evidence indicates that strength training not only increases muscle strength but also improves body composition, balance and inflammatory status in this population (Melo et al. 2022; Paul et al. 2019). Similar benefits have also been reported for adults with intellectual disability (Obrusnikova et al. 2022). The results of our study are consistent with previous research and support the importance of performing strength training (Méndez-Martínez and Rodríguez-Grande 2023). However, the pooled analysis of lower body strength revealed considerable heterogeneity, possible due to variability in effect sizes between the included RCTs studies. Our results are consistent with previous findings that reported increases in lower body strength in individuals with DS after at least 6 weeks of training (Kuo et al. 2024; Sugimoto et al. 2016). However, further research is needed to confirm the effectiveness of this type of training in improving functional outcomes (e.g., walking) (Kuo et al. 2024).

It is also important to note that current guidelines for strength training of people with intellectual disabilities recommend a mesocycle duration of 12 weeks (Jacinto et al. 2021). The RCTs included in the meta-analysis had a duration of 10 weeks, and the intensity was only specified in one RCT (i.e., 60%–80% 1RM) (Shields et al. 2013). Future research should conduct longer intervention periods to ensure a well-documented benefit and to determine the existence of a dose–response effect in this population. Given the statistically significant results observed in the meta-analysis, along with consistency across previous research (Melo et al. 2022; Paul et al. 2019) recommending similar training intensities and methodologies, a progressive strength training programme emerges as a practical and evidence-based application.

In particular, performing two to three weekly sessions emphasising multijoint exercises with two to three sets of 10–12 repetitions at 60%–80% 1RM—under the supervision of trained professionals—can effectively enhance upper and lower body strength in individuals with DS. These programmes should include a gradual increase in workload and adapt to individual abilities, to ensure both safety and optimal outcomes. This approach represents a feasible and effective strategy for improving muscle strength in this population. However, only two RCTs (Shields et al. 2008; Shields and Taylor 2010) included participants with severe intellectual disability, highlighting the need to expand research in this group to better understand their specific needs and responses to interventions.

Furthermore, the meta-analysis included both adolescents (Shields et al. 2013; Shields and Taylor 2010) and adults with DS (Shields et al. 2008; Shields and Taylor 2010). The heterogeneity of participants' ages may be considered a limitation, as physiological responses to exercise may vary considerably across life stages. This is particularly relevant as people with DS tend to experience progressive deterioration in important health-related variables, including body composition and physical fitness, as shown in a longitudinal study over a 10-year period (Pino-Valenzuela and Benavides-Roca 2023). Regarding sex, as previously mentioned, the pooled RCTs included samples comprising both sexes (Shields et al. 2008, 2013; Shields and Taylor 2010). The effects of strength training on various outcomes, such as muscular strength or muscle mass, may differ between men and women. This could be because young women with DS tend to have higher fat mass and lower lean mass compared to their male peers (González-Agüero et al. 2011). Furthermore, in terms of physical fitness, adolescents with DS typically exhibit higher handgrip strength, jumping ability and cardiorespiratory fitness than young women (Suarez-Villadat et al. 2019). Therefore, future research should examine whether there are differences in the benefits obtained from strength training between males and females.

In terms of training methods, all meta-analysed RCTs used pin-loaded weight machines and implemented progressive overload. The widespread use of machines instead of free weights may be due to their greater safety and the ease of quantifying the load. However, free weights theoretically activate more muscles (Schwanbeck et al. 2020). A systematic review concluded that there were no significant differences between the use of machines or other training methods, particularly in terms of improving maximal strength, jumping performance and hypertrophy. Therefore, the choice between training modalities may be based on personal preference and the combination of both approaches could be beneficial (Haugen et al. 2023).

Controversial results were found for handgrip results, as only one of the three RCTs that assessed this outcome reported a significant benefit (Ortiz-Ortiz et al. 2019). Handgrip strength is considered an important marker of health (Vaishya et al. 2024) and predicts functional performance in children and adolescents with DS (Beqaj et al. 2018). Therefore, future research should study the impact of exercise on this outcome in people with DS, considering their reduced strength levels (Cabeza-Ruiz and Castro-Lemus 2017).

Similarly, significant increases in work task performance (Diaz et al. 2021; Fornieles et al. 2014) and physical function (Shields et al. 2008) can also be associated with improved functional performance. In line with this, a previous meta-analysis examining the effects of aerobic exercise obtained similar results in relation to physical function, assessed by 6-min walk distance, sit-to-stand, and timed up and go (Shields 2021), highlighting the benefits of incorporating aerobic and strength training in the exercise interventions designed for people with DS. A previous nonrandomised study found that participants who performed a progressive resistance training programme for 10 weeks improved their stair climbing ability but did not significantly increase their aerobic capacity (Cowley et al. 2011). In addition, the increase in PA levels, reported in only one RCT (Shields et al. 2013), is crucial in people with DS (Shields 2021), as it may also be associated with better physical function and improved cardiovascular, metabolic, musculoskeletal and psychosocial health (Pitetti et al. 2013).

Improvements in body composition parameters were also reported in several studies included in the systematic review (Ortiz-Ortiz et al. 2019; Reza et al. 2013; Rosety-Rodriguez et al. 2013). Individuals with DS have a high risk of obesity (Oreskovic et al. 2023; Pecoraro et al. 2023). Although this is not necessarily associated with an increased risk of cardiometabolic disease in this population, a positive correlation between BMI, blood lipids and C-reactive protein has been previously reported (Oreskovic et al. 2023), which increases the importance of analysing biochemical markers. Specifically, in people with DS, the increased production of reactive oxygen species may be influenced by a deregulation of gene and protein expression (Reis et al. 2024). A clinical study showed that participants with DS had higher levels of markers of oxidative damage and inflammation than individuals without DS and that a single exercise session may be insufficient to induce molecular and health adaptations (Reis et al. 2024). Previous research has summarised the potential benefits of exercise in oxidative damage and antioxidant capacity (Campos and Casado 2015). Our systematic review results also support the effects of strength training, as significant improvements in marker concentrations (Rosety-Rodriguez et al. 2014, 2021) and a decrease in plasma total antioxidant status were observed (Rosety-Rodriguez et al. 2021). However, future research should focus on investigating the changes in gene expression in people with DS and whether performing strength training improves or alters their expression.

However, the study remains some limitations. The main limitation is that the meta-analysis included only three RCTs and a total sample size of 111 participants, which makes it difficult to draw solid conclusions. In particular, only two outcomes (upper and lower body strength) could be meta-analysed due to the insufficient number of RCTs or the limited data availability for statistical analysis of other outcomes. Although meta-analyses usually increase the predictability in estimating effects compared to individual RCTs (Nordmann et al. 2012) and some evidence suggests that only a few studies may be sufficient to obtain a reasonable effect estimate (Herbison et al. 2011), the inclusion of only three studies may limit the reliability of the meta-analysis, and further research is needed to confirm the obtained results. Furthermore, due to the small number of RCTs included in the meta-analyses, publication bias could not be assessed reliably, as *p* value–based tests may underestimate its presence when fewer studies are available (Furuya-Kanamori et al. 2020). Additionally, a large heterogeneity was found in terms of training parameters (intensity, frequency and duration), and only two of the nine included RCTs included people with severe intellectual disability. Furthermore, the limited number of RCTs examining strength training in this population prevented additional meta-analyses on other outcomes. Expanding research in this area would allow for a more comprehensive assessment of physical, functional and clinical outcomes.

Future research should focus on analysing the effects of long-term strength training interventions in people with DS. Studies with a uniform sample size are also needed. Considering the relationship between the pathogenesis of SD, genetic alterations and involvement in oxidative stress, future studies should include the analysis of molecular variables and changes in gene expression to try to establish correlations. In addition, there is a need to improve the implementation of strength training programmes and promote current PA recommendations in this population to identify additional benefits. Moreover, future subgroup analyses focused on specific subgroups, such as children, adolescents or adults with DS, may help clarify the influence of age on the observed results.

5 | Conclusion

This systematic review and meta-analysis suggests that strength training may significantly improve upper and lower body strength in both adolescents and adults with DS. The study provides novel findings on the effects of this type of exercise across several outcomes and highlights the importance of incorporating it into regular PA programmes to enhance overall health. However, more research is needed on the effects of long-term strength training interventions on other outcomes, such as body composition, physical function and biochemical markers as well as studies that clearly specify all training parameters to confirm the observed benefits. Moreover, there is a lack of studies investigating the effects of this type of training in children, which emphasises the need for further research in younger populations.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.