Resistance training and combined resistance and aerobic training as a treatment of depression and anxiety symptoms in young people: A systematic review and meta-analysis

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REVIEW

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Resistance training and combined resistance and aerobic training as a treatment of depression and anxiety symptoms in young people: A systematic review and meta-analysis

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Abstract

Aim: To determine the treatment effect of resistance training in reducing symptoms of anxiety and depression in young people.

Methods: We searched MEDLINE, PsychINFO, and PubMed for articles published in English from January 1980 to September 2023 for randomized controlled trials (RCT) that included at least 4 weeks of resistance training, with participants aged 26 years or younger with clinically elevated anxiety and depression symptoms. A random-effects meta-analysis was used to calculate a pooled effect size of resistance training pre-and post-intervention compared to control groups. The quality of evidence was assessed using the Cochrane risk-of-bias 2 (RoB 2) and Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) criteria.

Results: Ten RCTs involving 376 participants (209 females and 127 males) across educational, clinical, and community based setting were eligible for inclusion in the analysis. Resistance training was associated with a significant reduction in depressive (Hedge's $g = -1.06$, 95% CI -1.61 to -0.51, $p < .001$) and anxiety (Hedge's $g = -1.02$, 95% CI -1.50 to -0.54, $p < .001$) symptoms. Substantial heterogeneity was observed in the analysis of depression symptoms ($I^2 = 79\%$) and anxiety symptoms ($I^2 = 66\%$). Six trials had a low risk of bias, four trials showed some concerns. The GRADE analysis demonstrated a high level of certainty for depressive symptoms and a moderate level for anxiety symptoms.

Conclusion: Resistance training is an effective intervention in reducing depression and anxiety symptoms in young people, delivered across a range of settings. Future trials exploring the effect resistance training interventions with long-term follow up are warranted to understand the outcomes.

KEYWORDS
adolescents, anxiety, depression, mental health treatment, resistance training, strength training, young people

1 | INTRODUCTION

The growing prevalence of mental health disorders is a significant public health concern. The World Health Organization (WHO) estimates that 4.4% of the world's population, or over 320 million people, experience clinically diagnosed depression while 3.6% have anxiety disorders (World Health Organization, 2017). The global prevalence of depressive disorders (major depressive disorder & dysthymia) and anxiety disorders has increased by 18% and 15%, respectively, between 2005 and 2015 (Vos et al., 2016). In Australia, the most common mental disorders in any 12-month period are anxiety disorders and affective disorders (17% and 8% of the population) (Australian Bureau of Statistics, 2022). One in seven children or adolescents experience a mental disorder, globally (Polanczyk et al., 2015) and in Australia (Lawrence et al., 2015), which increases to one in five adults from 18 years old onwards (Australian Bureau of Statistics, 2021). Anxiety and depressive disorders are frequently comorbidities (Schoevers et al., 2005) and failing to address mental illnesses during adolescence can lead to an accumulation of the burden of disease and increased costs on health and wellbeing across the lifespan (Suhrcke et al., 2008). Mental illnesses also increase the risk of chronic metabolic and cardiovascular diseases, mortality, and healthcare treatment difficulties (Correll et al., 2017; Knol et al., 2006; Lett et al., 2004). As a result, chronic preventable health conditions are more prominent and life expectancy is significantly reduced in individuals who have severe mental health conditions, compared to those who do not (Lawrence et al., 2013).

There are multifactorial causes (biological, psychological and social factors) for mental disorders in young people, however protective factors include good physical health and development (Patel et al., 2007). In light of this, aerobic training has demonstrated efficacy in reducing elevated symptoms of depression in adults (McCann & Holmes, 1984) and young people (Bailey et al., 2018). Aerobic training can be used as an independent, or adjunctive, treatment for clinical depression (Cooney et al., 2013) and has been demonstrated to be as effective as pharmacological interventions, such as antidepressant medication (Cooney et al., 2013). Additive benefits have been demonstrated when aerobic training has been implemented in conjunction with pharmacotherapy and other first line depression treatments (Jacquelin et al., 2021). The efficacy of aerobic training in treating anxiety disorders is not as established as depressive disorders. As such, it is a recommended adjunctive treatment for clinical levels of anxiety in adults (Asmundson et al., 2013; Jayakody et al., 2014; Moore et al., 2016) and similarly for adolescents experiencing anxiety (Herring, 2018). However, anxiety is ineffectively treated by first line treatments (pharmacotherapy and psychotherapy) and other treatment choices warrant attention (De Vries et al., 2016; Hofmann & Smits, 2008).

Whilst aerobic training may be effective for certain individuals, depressive disorders are highly heterogenous, with varied symptomology, even for people who have similar scores on depressive outcome measures (Fried & Nesse, 2015). Despite the efficacy of aerobic exercise, it has been demonstrated that over 20%–75% of participants may not achieve remission or response (<50% of baseline score) to an aerobic training intervention (Dunn et al., 2005). Given that aerobic training does not always achieve a successful clinical response, resistance training could be a viable alternative or adjunctive approach. Furthermore, elevated depressive and anxiety symptoms share many similarities often leading to worsened symptoms overall (Schoevers et al., 2005). These include impaired concentration, fatigue, irritability, apprehension, restlessness, and muscle tension. Coupling these symptoms with the necessity for aerobic training to be a continuous activity, commonly undertaken at moderate to vigorous intensities (65%–85% heart rate max) which are not always effective, the need for other exercise interventions that suit an individual's preferences is warranted (Nyström et al., 2015). There have also been notable difficulties in sustaining the required intensity of aerobic training interventions with supervision to induce the training adaptations (Jaworska et al., 2019) and certain types of anxiety (e.g., panic disorder with agoraphobia) may lead to an increased risk of dropout from regular aerobic training interventions based on anxiety symptoms (Martinsen et al., 1989).

Muscular fitness (size, strength and power) improvements with resistance training are well established across all age groups for preventing and treating physical health conditions (US Department of Health and Human Services, 2018), yet resistance training remains underutilized across the life span (Australian Institute of Health and Welfare, 2018). Other benefits of resistance training are an increase in self-esteem, reduced symptoms of fatigue, anxiety and depression, and pain and improved sleep quality in various clinical and healthy populations, however the specific social, psychological and/or neural mechanisms for these changes remain unclear (O'Connor et al., 2009). Resistance training trials investigating the treatment of depression are limited to middle-aged or older adults (Herring, 2018; Meyer & Schuch, 2018), despite resistance training (Gordon et al., 2018) or combined resistance and aerobic training interventions (Cooney et al., 2013; Danielsson et al., 2013; Meyer & Schuch, 2018; Schuch et al., 2016) resulting in equal or greater depressive symptom management. A recent review of exercise interventions to treat anxiety and depression in both depressed and non-depressed youths, yielded positive effects from resistance training, however these findings were limited to two resistance only training trials (Zhang et al., 2023). Therefore, the effect of resistance training to treat clinically elevated symptoms of depression and anxiety in young people is not clear. The aims of this systematic review and meta-analysis were to: (1) determine the effect of resistance training interventions, over 4 weeks in duration, on depressive and anxiety symptoms in young people (≤26 years old) with clinically elevated depressive and/or anxiety symptoms; and (2) undertake an investigatory analysis of RT prescription (frequency, intensity, time, type, volume, progression, rest, supervision) that are associated with improving anxiety or depressive symptoms.

2 | METHODS

2.1 | Protocol and registration

The systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). The review was

prospectively registered with the International Prospective Register for Systematic Reviews (PROSPERO) CRD42022297881.

2.2 | Eligibility criteria

Participant, Intervention, Comparison, and Outcomes (PICO) were used for this systematic review. PICO is a specialized framework used by most researchers to formulate a question and to facilitate a literature review for quantitative based trials (Eldawlatly et al., 2018). Briefly, included studies involved participants with a mean age of ≤26 years with elevated depression or anxiety symptoms assessed using a validated outcome measure, where an explicitly stated minimum threshold on a self-report or observer-rated symptom measure exists, or a diagnostic criteria for established nosology was utilized (e.g., DSM-V), pre-and post-intervention. Other diagnoses of primary health conditions, and trials that included depressive or anxiety symptoms as a primary or secondary outcome measure of the study were included. The interventions utilized any form of randomized allocation to resistance training and a non-first line or exercise treatment control/comparison group. Dissertations and studies published prior to 1980 were excluded, as youth mental health was not a discrete field prior to 1980 (Hetrick et al., 2010; Rutter et al., 1976). We included exercise interventions of a minimum of 4-weeks, that included resistance training for the whole training intervention, or combined with other training interventions (aerobic training and/or flexibility training) within the same session or throughout the duration of the intervention. Resistance training was defined as an activity that requires the muscle to exert force, with the aim to increase muscular fitness (strength, power, volume, or endurance) with or without external resistance and relying on the anaerobic energy system (American College of Sports Medicine, 2013; Zhao et al., 2020). Comparison groups included no-treatment (NT), treatment as usual (TAU), and attention/activity placebo (AP). Comparison groups could not include another known exercise based treatment (e.g., aerobic training) since this would not allow the effect of resistance training on depressive and/or anxiety symptoms to be determined.

2.3 | Search strategy and data extraction

We performed a systematic search of the literature from January 1980 to February 2022 via EBSCOhost (PsychInfo & Medline) and PubMed. An updated search for recently published articles was performed in September 2023, however no additional eligible articles were found. The search was limited to peer reviewed, published, English language articles. The full list of search terms modified to each database is available in Table S1. The search strategy used age limiters to include population groups ≤26 years old. The reference lists of recently published, narrative reviews, scoping reviews, systematic reviews, and meta-analyses which consisted of exercise based interventions for anxiety and depression in general and clinical populations were searched to identify other potential eligible studies (Asmundson et al., 2013; Bailey et al., 2018; Barahona-Fuentes et al., 2021; Bartley et al., 2013; Carneiro et al., 2020; Carter et al., 2016; Cooney et al., 2013; Danielsson et al., 2013; Gordon et al., 2017; Gordon et al., 2018; Herring, 2018; Jayakody et al., 2014; Mammen & Faulkner, 2013; Nyström et al., 2015; Pascoe et al., 2020; Radovic et al., 2017; Schuch et al., 2016; Strickland & Smith, 2014; Stubbs et al., 2017). After the removal of duplicates, two reviewers (RM & MW) independently screened abstracts of identified articles. Any discrepancies were checked by a third reviewer (RP) and resolved by consensus. Subsequently, the same reviewers completed full-text screening. After full-text screening data were extracted from included studies onto an excel template by RM cross-checked for inter-observer reliability by MW and MB. Data extracted included participant and trial characteristics, outcomes measures and reported results of anxiety or depressive symptoms pre-and post-intervention, resistance training intervention characteristics (frequency, intensity, type, time, volume, progression, program length, and supervision).

2.4 | Assessment of risk of bias and GRADE in included studies

RM and MW assessed the risk of bias for each outcome measure using the Cochrane RoB 2 (Sterne et al., 2019). Disagreements were resolved by consensus. In addition to the risk of bias, inconsistency, indirectness, imprecision, and publication bias were assessed using the GRADE approach which evaluated the overall quality of the evidence. GRADE provides four levels of recommendations (very low, low, moderate, high) based on the certainty of the quality of evidence, with RCTs beginning at high and authors grading the outcome measures used against each criteria, mentioned previously, to rate the quality of evidence (Guyatt et al., 2008).

2.5 | Data analysis

The primary outcomes analysed were depressive and anxiety symptoms. Data were extracted and entered into a Microsoft Excel spreadsheet. The mean and standard deviation (SD) of the anxiety or depressive outcome measure score were recorded as well as study demographics. Where necessary, the SD was calculated from the reported 95% confidence interval and ample size. The standardized mean differences (SMD) were calculated as the difference in change scores for outcome measures (baseline and post-intervention) between the intervention and control group divided by the pooled standard deviation at baseline (Morris, 2008). When outcome data was obtained in a remission percentage format, the log odds ratio (LOR) for treatment effectiveness was calculated. The variance for continuous outcomes was estimated using a known equation for effect sizes with continuous data (Borenstein & Hedges, 2009). For the single study that reported using remission rate, the log odds ratio was divided by 1.81 to convert it to a SMD and the variance of the log odds ratio was divided by 3.28 (Murad et al., 2019). All SMDs

were corrected for the upward bias of small sample sizes (i.e., Hedge's) and calculated so that symptom improvement resulted in a negative effect size (Hedges, 1981). The SMD effect size was interpreted as small (≥ − 0.2), moderate (≥ − 0.5), or large (≥ − 0.8) (Cohen, 2013).

A meta-analysis was conducted on the change in depression and anxiety symptoms pre-and post-intervention. A random effects meta-analysis with generic inverse variance weights was used to calculate the pooled effect size using the meta package in R (version 4.1.2) (Balduzzi et al., 2019). The restricted maximum likelihood method was used to estimate between-study heterogeneity (Harville, 1977). Between study heterogeneity (quantified as *I* measure) was characterized as low if it was less than 25%, moderate if between 25% and 50%, and substantial if it was greater than 50%, and $p < .05$ was considered statistically significant. The cut off of 10 effect sizes for each analysis was set for a minimum number to conduct an analysis of publication bias or subgroup analyses (Higgins et al., 2019). A small study effect would be evaluated using visual inspection of funnel plots to assess for publication or reporting bias. Importantly, funnel-plot asymmetry does not always equate to publication bias and consideration of true heterogeneity (intensity of duration, differences in baseline risks) and data irregularities were considered (Sterne & Harbord, 2004).

Statistical analyses on intervention characteristics were unable to be completed due to an insufficient number of studies. Instead, the pooled effect of trials including only resistance training in their interventions was calculated and a narrative synthesis of resistance training variables was collated for any publications reporting an effect size of ≥ − 1.0.

3 | RESULTS

The search strategy identified 1916 articles (Figure 1) which were uploaded to Covidence, an online systematic review tool. A total of 416 duplicate articles were automatically removed, leaving 1500 articles remaining to be screened by title and abstract. Of these, 39 were identified as being eligible for a full-text review. Following this review, a total of 11 articles were included, of which three contained both a depressive and anxiety measure (ElDeeb et al., 2020; Hilyer et al., 1982; Woolery et al., 2004), four included only an anxiety measure (Carter et al., 2015; Herring et al., 2011; Nazari et al., 2020; Williams & Cash, 2001) and four included only a depressive measure (Carter et al., 2015; Hughes et al., 2013; Vizza et al., 2016; Wunram et al., 2018).

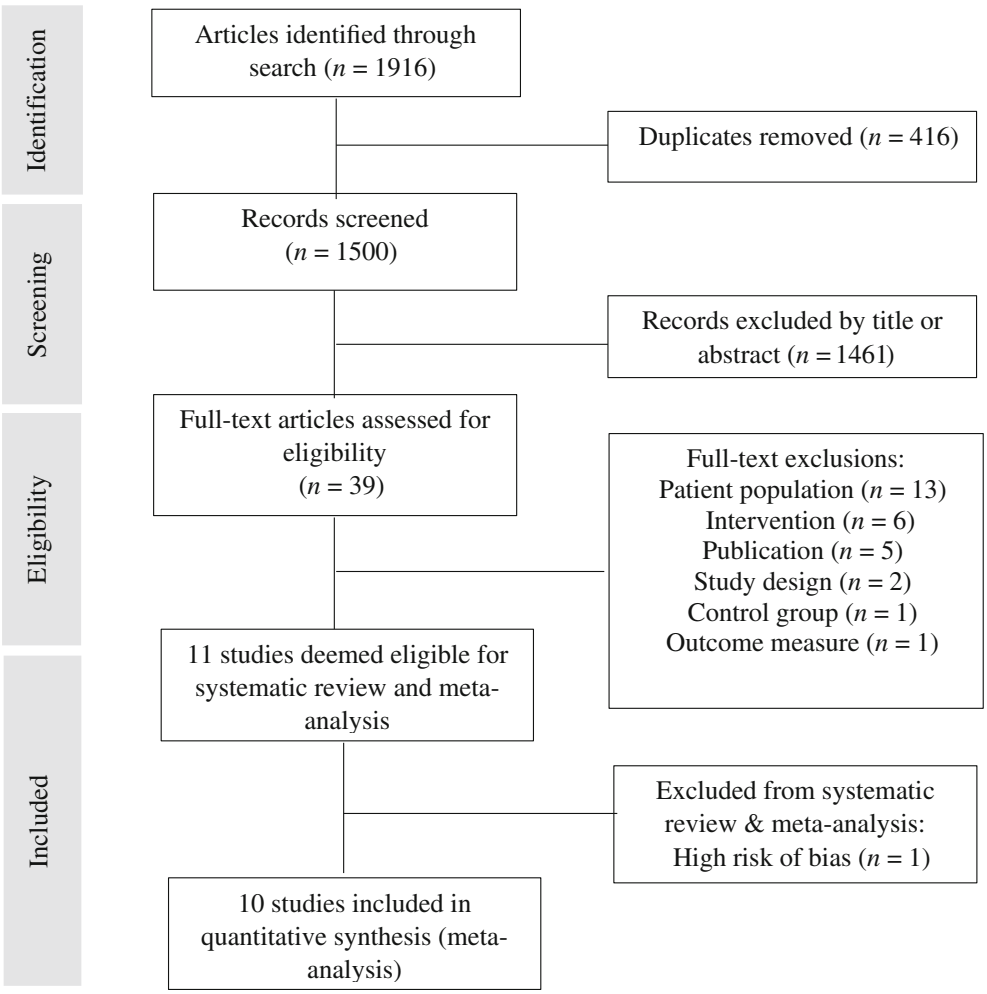

FIGURE 1 Flow diagram of records identified and included. [Correction added on 14 June 2024, after first online publication: The 'full-text exclusions' in Figure 1 has been updated with simplified wording for better clarity.]

3.1 | Assessment of risk of bias and GRADE in eligible studies

Out of the 11 studies analysed, six had an overall low risk of bias (Carter et al., 2015; ElDeeb et al., 2020; Matthew P Herring et al., 2011; Hughes et al., 2013; Vizza et al., 2016; Wunram et al., 2018), four had some concerns (Gordon et al., 2022; Hilyer et al., 1982; Nazari et al., 2020; Woolery et al., 2004), and one was found to be high risk caused by improper randomization, and was removed from the analysis (Williams & Cash, 2001), leaving 10 studies in total. The overall quality of evidence was high for depressive symptoms and moderate for anxiety symptoms (Table S2).

3.2 | Summary of articles

The total number of participants in all included studies was 376 (209 females and 127 males); sex was not reported in one study (Nazari et al., 2020). The mean age across all trials was 19 years, with the intervention groups ranging from 11 to 26 years old. Three trials included participants with clinically diagnosed depression (Carter et al., 2015; Hughes et al., 2013; Wunram et al., 2018) and one with clinically diagnosed anxiety (Matthew P Herring et al., 2011). The remaining six trials included participants with clinically elevated symptoms of depression or anxiety (ElDeeb et al., 2020; Matthew P Herring et al., 2011;Hilyer et al., 1982; Nazari et al., 2020; Vizza et al., 2016; Woolery et al., 2004). Four trials recruited a sample not meeting any physical activity guidelines (ElDeeb et al., 2020; Hughes et al., 2013) or deemed sedentary (Matthew P Herring et al., 2011; Wunram et al., 2018), two trials had participants not meeting the resistance training guidelines (Gordon et al., 2022; Vizza et al., 2016) and four trials did not report any baseline physical activity (Matthew P Herring et al., 2011; Hilyer et al., 1982; Nazari et al., 2020; Woolery et al., 2004).

Seven trials reported depressive symptoms, with five involving resistance training and aerobic training or flexibility training (Carter et al., 2015; Hilyer et al., 1982; Hughes et al., 2013; Vizza et al., 2016; Woolery et al., 2004), and two with resistance training only (ElDeeb et al., 2020; Wunram et al., 2018). Traditional resistance training (machines, free weights, or bodyweight) was used in 9 trials (Carter et al., 2015; ElDeeb et al., 2020; Gordon et al., 2022; Matthew P Herring et al., 2011; Hilyer et al., 1982; Hughes et al., 2013; Nazari et al., 2020; Vizza et al., 2016; Woolery et al., 2004) and whole body vibration as the sole intervention in one trial (Wunram et al., 2018) and a comparison to traditional resistance training in one trial (ElDeeb et al., 2020). In the seven trials measuring anxiety symptoms, four trials used resistance training and aerobic training or flexibility (Hilyer et al., 1982; Nazari et al., 2020; Vizza et al., 2016; Woolery et al., 2004) and three utilized resistance training only (ElDeeb et al., 2020; Gordon et al., 2022; Matthew P Herring et al., 2011). All trials prescribed the intensity, with only one trial allowing a self-selection of intensity and rest (Carter et al., 2015). The duration of trials ranged from five to 20 weeks, and the weekly session frequency ranged between two to four sessions per week. The duration of each training session varied from six to 90 min. Seven trials reported supervised exercise sessions, of which two included home exercise programs. Control groups included waitlist or treatment as usual (TAU).

Six out of seven depressive symptom outcome measures were self-report questionnaires and one was a clinician-rated instrument. Six of seven anxiety symptom outcome measures were self-report questionnaires and one trial reported Number Needed to Treat (NNT)/Remission percentage. A detailed summary of each outcome measure is in Table S3. All investigatory data on intervention setting, adjunct treatments, frequency, intensity, duration, type, time, volume, progression, rest, supervision, sex differences, symptom severities, adjunctive treatments being received, adherence and baseline physical activity levels were recorded (Table 1).

3.3 | Meta-analysis of depressive symptoms

RT was associated with a large reduction ($g = -1.06$, 95% CI -1.61, -0.51, $p < .001$) in depressive symptoms in young people (Figure 2). There was substantial heterogeneity between trials ($I^2 = 79.0\%$). Visual inspection of funnel plots did not indicate that publication bias (Figure 3). The pooled effect for the two studies that involved exclusively resistance training was similar to that of the overall pooled effect ($g = -1.32$, 95%CI $= -2.47, -0.16$, $p = .025$).

3.4 | Meta-analysis of anxiety symptoms

RT was associated with a large reduction ($g = -1.02$, 95% CI $= -1.50, -0.54$, $p < .001$) in anxiety symptoms in young people (Figure 4). There was substantial heterogeneity between trials ($I^2 = 66\%$). Visual inspection of funnel plots did not indicate a publication bias (Figure 5). The magnitude pooled effect for the three studies that involved exclusively resistance training was smaller to that of the overall pooled effect, however, the effect was still significant ($g = -0.63$, 95%CI $= -1.18, -0.09$, $p = .023$).

3.5 | Narrative synthesis of intervention characteristics

The RT intervention characteristics across four trials with an effect size less than -1 were summarized in Table 2. Three of the four included trials included results for both depression and anxiety symptoms, therefore the characteristics have been combined.

4 | DISCUSSION

The current study examined the effect of resistance training on young people with clinical levels of anxiety and depression. We reported that resistance training, independently, or combined with aerobic training

TABLE 1 Characteristics of included trials.

Author	Participant (mean age ± SD) intervention setting adjunct treatments (number of participants)	Control group treatments	Type intervention duration frequency	Session duration volume intensity (progression) rest	Adherence supervision baseline PA	Depression/anxiety symptom outcome
(Hilyer et al., 1982)	23 males (17.01 ± 0.91 years) Elevated depressive symptoms (BDI) and trait anxiety (STAI) Educational setting (state school) Counselling TAU (all)	20 males (16.90 ± 0.75) Counselling TAU	Circuit training (F + AT+RT) 20 weeks 3 days/week	90 min (F 10 min, R + AT 65 min, F + GS 10–15 min) 2 sets × 8 reps 8RM (as able) N/A	N/A Yes (Group) N/A	D & A—Significantly reduced symptoms.
(Carter et al., 2015)	44 (11male/33 female) (15.4 ± 1.0 years) Depression diagnosed and elevated on CDI 2 Clinic based (referred from public services) Psychological therapy (35), PCT (4).	43 (35 females/8 males)(15.4 ± 0.9) TAU (psych therapy 33 & PCT 8)	Circuit training (F + AT+RT) 6 weeks 2 days/week	45 min (5 min F & 40 min AT/RT) N/A Self-selected intensity monitored with rating of perceived exertion (self-selected) 1 min rest & rest as needed	70% Yes (Group) N/A	D—No significant difference.
(Hughes et al., 2013)	14 (7 male/7female) (17 ± 0.9 years) MDD criteria met via interview and elevated score on CDRS-R. Clinic based (referred from health professionals) PCT (1).	12 (4 females/8 males) (17 ± 0.6) PCT (1)	Self-Selected training type (AT or RT + F) 12 weeks 2 days/week then 3 days/week (1 session/W in person)	30–40 min (self-selected AT or RT) N/A 1/3 to 1/4 calorie target (increase energy expenditure weekly 8 > 10 > 12 KKW) N/A	77% Yes & No Not meeting guidelines.	D—Significantly reduced symptoms (pre vs. post)
(Wunram et al., 2018)	18 (6 male/12 female) (15.9 ± 1.2 years) MDD criteria met via interview & DIKJ score elevated Clinic based (hospital inpatients) TAU—therapy inpatient schedule (psychotherapy, exercise, art, music therapies).	17 (13 females/4 males) (15.7 ± 1.1 years) TAU	Whole body vibration (RT) 6 weeks 3 days/week	12 min 6 × 2 min per exercise (add 1 min per session) 20 Hz (amplitude of 2 mm) 2–3 min rest	100% Yes Deemed sedentary.	D—No significant difference.
(Nazari et al., 2020)	20 (N/A) (11.22 ± 1.90 years) Anxiety elevated on RCMAS	20 (N/A) (11 ± 2.67 years) Control	Circuit training (F + AT+RT) 16 weeks 3 days/week	75 min (10 min WU, 20 min Pilates, 20 min body weight RT, 20 min AT, 5 min CD)	N/A	A—Significantly reduced symptoms pre versus post & against controls.

TABLE 1 (Continued)

Author	Participant (mean age ± SD) intervention setting adjunct treatments (number of participants)	Control group treatments	Type intervention duration frequency	Session duration volume intensity (progression) rest	Adherence supervision baseline PA	Depression/anxiety symptom outcome
	Clinic based (hospital inpatients) Prescribed diet intervention.			1–2 sets at 8–12 reps (2–3 sets of 10–12 last 8 weeks) 8–12RM 30s rest		
(ElDeeb et al., 2020)	20 (females) (17.7 ± 1.17 years) Depression & anxiety elevated on PMSQ Clinic based (referred by gynaecologist). B6 and Magnesium supplementation	20 (females) (17.9 ± 1.16 years) Control	Whole body vibration (RT) 12 weeks 3 days/week	6 min 3 sets × 1 min 20 Hz (1 set each session and + 2 Hz every 2 weeks) 1 min rest	N/A N/A Not meeting guidelines.	D + A—Significantly reduced.
(ElDeeb et al., 2020)	20 (females) (17.3 ± 1.41 years) Adj: Dietary intervention (Vitamin B6 and Magnesium supplementation)		Circuit training (RT) 12 weeks 3 days/week	40 min (10 min WU, 20–25 min RT circuit, 5–10 min CD) 1 × 3–4 reps (increase to 12 gradually) 60%–70%1RM 2 min rest	N/A N/A Not meeting guidelines	D + A—Significantly reduced.
(Gordon et al., 2022)	11 (4 males/7 Females) (26 ± 5.6 years) Analogue GAD scored via interviewer and state anxiety measured on STAI-Y1 Community based (Instructed to maintain current level of physical activity)	13 (8 females/5 males) (27.1 ± 5.6 years) Waitlist (acute quite rest)	Traditional RT 8 weeks 2 days/week	25 min 2 sets × 8 reps of 8 exercises (increase to 12 reps gradually and then increase load 5%) 8–12RM Rest 1 min	99% Yes Not meeting RT guidelines.	A—Significantly reduced state anxiety (pre week 1 vs. post week 8)
(Matthew P Herring et al., 2011)	10 (females) (25.6 ± 7.1 years) Primary GAD diagnosis Community based PCT (3)	10 (females) (24.2 ± 6.3 years) Waitlist	Traditional RT (lower body only) 6 weeks 2 days/week	46 min 7 sets × 10 reps (add 5% of 1RM weekly) 10RM Rest 80 s	100% Yes Sedentary	A—60% remission rate for RT, compared to 30% for WL
(Woolery et al., 2004)	13 (3 males/10 females) (21.5 ± 3.23 years) Mild depression on BDI Community based.	15 (12 females/3 males) (21.5 ± 3.23 years) Wait list	Calisthenic (RT) 5 weeks 2 days/week	60 min (combined calisthenic and relaxation postures) N/A Intensity not defined N/A	N/A Yes N/A	D + A—Significantly reduced
(Vizza et al., 2016)	7 (females) (26 ± 7 years)	6 (females) (29 ± 3 years)	Traditional RT 12 weeks	60 min (5 min WU, 50 min RT)	76% (43% HEP)	D + A—Significantly reduced

(Continues)

TABLE 1 (Continued)

Author	Participant (mean age ± SD) intervention setting adjunct treatments (number of participants)	Control group treatments	Type intervention duration frequency	Session duration volume intensity (progression) rest	Adherence supervision baseline PA	Depression/anxiety symptom outcome
	Moderate to severe depression and anxiety symptoms (DASS-21) Community based.	TAU	4 day/week (2 in person +2 HEP)	2 sets × 8 reps (3 × 8–12 with load increasing with strength) + HEP (3 × 10 for all exercises) 8–12RM N/A	Yes and No Not meeting RT guidelines.	

Abbreviations: A, anxiety symptoms; AT, aerobic training; CD, cool down; D, depressive symptoms; F, flexibility training; GAD, generalized anxiety disorder; GS, goal setting; HEP, home exercise program; KKW, kilocalories per week; MDD, major depressive disorder; PA, physical activity; PCT, pharmacotherapy; Psych, psychotherapy; RM, repetition maximum; RT, resistance training; SS, self-selected; TAU, treatment as usual; WU, warm up, (this is should be listed as Table S3).

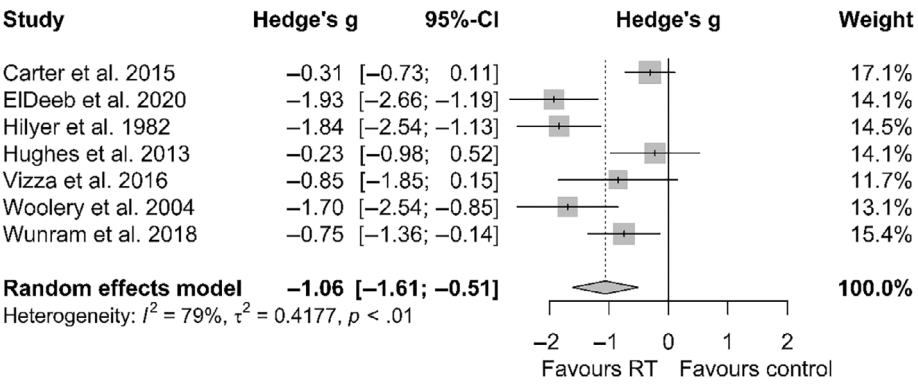

FIGURE 2 Forest plot on the Hedge's g of resistance training interventions on symptoms of depression compared to control groups.

can significantly reduce symptoms of depression and anxiety in individuals 26 years old and younger who are experiencing clinically elevated depressive or anxiety symptoms. As such, resistance training should be incorporated as an integral part of treatment for young people with symptoms of depression and anxiety.

The findings indicated a large clinical effect in the reduction of depressive symptoms following resistance training. This finding provides strong support for the use of resistance training in the management of clinical depression in adolescents and young people. Exploration into resistance training and evidence of the significant effect has been lacking for young people with clinically elevated depressive or anxiety symptoms (Bailey et al., 2018; Barahona-Fuentes et al., 2021; Radovic et al., 2017; Rodriguez-Ayllon et al., 2019). This meta-analysis builds upon the previous evidence that indicated the effectiveness of resistance training to reduce depressive symptoms in predominantly adult populations (Gordon et al., 2018) by focusing on young people. While the majority of literature has focused on the benefits of aerobic training, herein we demonstrate that resistance training, and resistance training combined with aerobic training, may promote a similar or even greater reduction in depressive symptoms. Radovic et al. (2017) reported a significant reduction in depressive symptoms in clinically depressed adolescents (g = −0.61, 95%CI = −1.06, −0.16) with only one trial including any form of resistance training. Similarly, Larun et al. (2006) reported a significant effect (g = −0.66, 95%CI = −1.25, −0.08) comprising of predominantly aerobic training (12 compared to 4 studies) in healthy and clinically depressed adolescent populations. Whilst the majority of the trials in this review did not strictly include only resistance training as part of their interventions, when analysing the studies that only included resistance training the clinical effect remained large (g = −1.32, 95%CI = −2.47, −0.16) (ElDeeb et al., 2020; Wunram et al., 2018).

A significant reduction in anxiety symptoms following resistance training was also demonstrated. Previous reviews have focused primarily on adult cohorts (middle age and older), with very little data on individuals ≤26 years of age (Strickland & Smith, 2014). While prior resistance training based interventions in adults have shown small to moderate treatment effects for clinical anxiety (Carneiro et al., 2020; Gordon et al., 2017), herein we report a large effect in young people with elevated anxiety symptoms. The effect of resistance training only interventions was smaller and indicates that there may be a complementary effect of including both resistance training and aerobic training for anxiety symptoms (ElDeeb et al., 2020; Vizza et al., 2016; Woolery et al., 2004). These findings highlight the need to provide

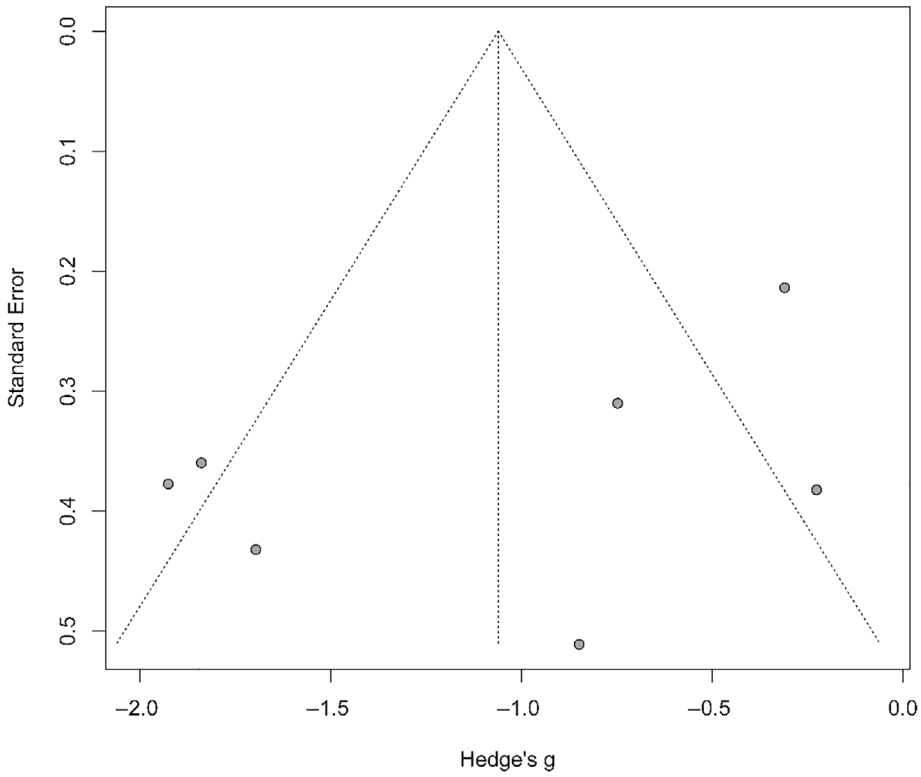

FIGURE 3 Funnel plot on Hedge's g and standard errors for trials with depression outcomes.

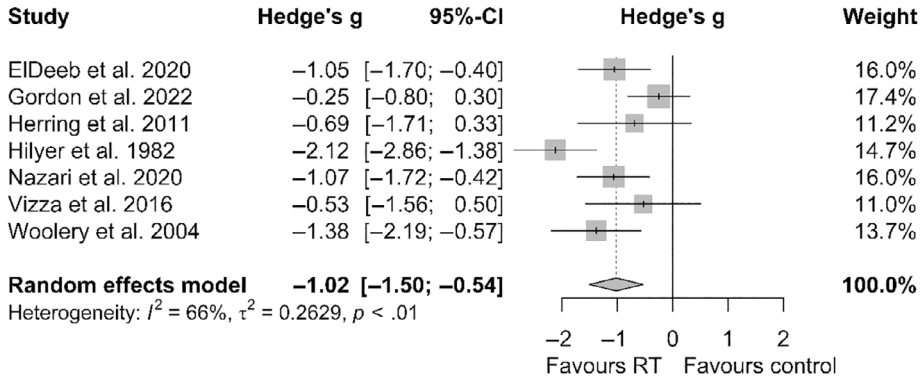

FIGURE 4 Forest plot on the Hedge's g of resistance training interventions on symptoms of anxiety compared to control groups.

clinical guidance that tailors resistance training interventions for specific developmental stages as the effects on anxiety symptoms and suitable interventions may vary across the lifespan. The only previous review to analyse resistance training in young individuals diagnosed with anxiety or depressive symptoms found a significant large effect in the reduction of symptoms (Barahona-Fuentes et al., 2021). This previous review limited the search to those diagnosed with anxiety or depression and adolescents aged <18 years old, a search period (2010–2020), and included a high level of publication bias (Barahona-Fuentes et al., 2021). The current review aimed to broaden the search criteria for all available evidence since 1980 and include trials with patients that have clinically elevated symptoms and diagnoses across a greater age range (≤26). This is due to the accumulating evidence of increased mental health disorders across this transitional phase into modern adulthood (Patel et al., 2007) and commonly grouping adolescents and young adults for prevalence of mental disorders in national reports (Australian Instutute of Health and Welfare, 2023). Consequently, this review has resulted in more trials and a reduced publication bias to support the findings.

The specific mechanisms through which combined resistance and aerobic training may improve mental health symptoms, more than aerobic training alone, remain unclear. Anxiety and depressive disorders alter the hypothalamic pituitary adrenal axis, via hypoactivity or hyperactivity (Strickland & Smith, 2014; Wegner et al., 2020) and it is proposed that resistance training may positively modulate cortisol levels (Crewther et al., 2011). Resistance training may also stimulate different neurobiological effects, for example insulin-like growth factor 1 is significantly increased (Cassilhas et al., 2010), however the different neurobiological mechanisms between various exercise modalities requires further investigation. Resistance training improves cognitive abilities as effectively as aerobic training (Nagamatsu et al., 2012) and when combing both modes of training there is

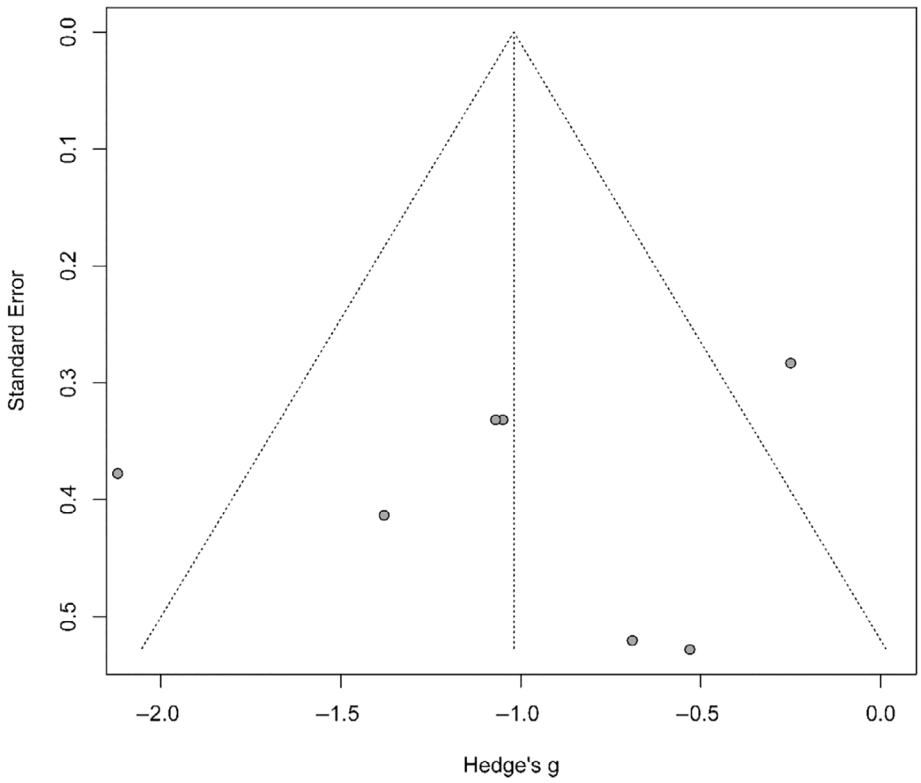

FIGURE 5 Funnel plot on Hedge's g and standard errors for trials with anxiety outcomes.

TABLE 2 Trial intervention characteristics of studies with large effect sizes (>1.0 Hedge's g).

	Resistance training intervention characteristics in large effect size trials
Symptom severity	Mild to moderate
Frequency (weekly)	2–3 sessions
Intensity	8–12RM, 60%–70%1RM.
Time (session duration/weeks)	60–75 min/12–20 weeks.
Type	Traditional RT and AT with FT (free weights, machines, bodyweight)
Volume per exercise	1–3 sets × 8–12 repetitions
Progression	Increase volume (reps, sets) or load gradually with a pre-set plan or as strength improves.
Rest periods	30 s to 2 min
Supervision	Supervised training, with additional HEPs.

Note: Resistance training prescription variables include (%RM, repetition maximum percentage; RT, resistance training; AT, aerobic training; FT, flexibility training; HEP, home exercise program) across all trials with an effect size greater than −1.0 (ElDeeb et al., 2020; Hilyer et al., 1982; Nazari et al., 2020; Woolery et al., 2004).

evidence of a significantly greater effect (Kramer & Colcombe, 2018), however research is predominantly in older adults. There is evidence of self-esteem, a global concept pertaining of one's perception and feelings of themselves (O'Connor et al., 2009), increasing similarly with resistance training or aerobic training (Trujillo, 1983). Furthermore, sub-components, including physical self-esteem, body image (the feeling one has about their appearance or muscular strength), and physical self-efficacy may be augmented with resistance training (Dishman et al., 2006; Hausenblas & Fallon, 2006). Whilst, neural mechanisms that explore aerobic training's effect on the brain has been analysed more recently (Cotman et al., 2007), there remains less evidence on resistance training specific mechanisms (O'Connor et al., 2009). There are numerous differences of strength training's effect on the neuromuscular system based on the training characteristics (muscle and nerve activation, the relative load to capacity on muscles, total time under tension, the velocity of the contraction, the rest periods, the range of motion, and the achievement of volitional fatigue), therefore there could be an extensive range of possible neurophysiological adaptation that differ to aerobic training (O'Connor et al., 2009). Further research is warranted to examine the psychological or physiological changes from resistance training and their effect on mental illness symptoms.

The intention was to further examine the impact of specific resistance training prescription variables (Table 2) on anxiety or depressive symptoms however the sample size was not sufficient for this level of analysis. Previous reviews in adults and young people with anxiety and depressive symptoms have found no significant differences across frequency, intensity, time, duration, and volume, but some differences were evident based on the presence of supervision of training interventions (Gordon et al., 2017; Gordon et al., 2018). While statistical comparisons could not be performed, when comparing the trials with the largest clinical effect to trials with the smallest clinical effects, one notable difference found was that a duration of the resistance training

intervention of more than 12 weeks was more likely to achieve a greater symptom reduction for depression and anxiety symptoms compared to interventions of less than 12 weeks. The majority of trials utilized a similar intensity (60%–70%1RM or 8–12 repetitions) across interventions. This is aligned with prior research demonstrating the anxiolytic effect of resistance training is best achieved with low-moderate intensities (50–65%1RM), compared to higher intensities (75–85%1RM) (Strickland & Smith, 2014). Frequency varied across trials and volume (sets, repetitions and load) was not reported consistently. Adherence rates in the resistance training interventions were similar to previous aerobic training interventions (Bailey et al., 2018) with three resistance training trials achieving over a 99% adherence rate, and the remainder over 70%. Two of these trials utilized short duration training bouts (<25 min), whereas the average time needed was over 60 min for the largest effect. These factors make it difficult to determine the contribution of different intervention characteristics and it is important that future trials clearly distinguish these variables to enable a better understanding of resistance training intervention designs that maximize treatment outcomes.

5 | LIMITATIONS

Notable limitations for this review were the high heterogeneity in effects between studies and study characteristics and the small number of studies precluded further subgroup analyses or meta-regressions. We limited the search to only English language publications. Additionally, three trials included participants with comorbidities which may add confounding medical conditions (ElDeeb et al., 2020; Nazari et al., 2020; Vizza et al., 2016), however in two of these trials, depression and/or anxiety symptoms were a primary outcome rather than management of the alternate medical condition.

6 | CONCLUSION AND FUTURE DIRECTIONS

Whilst many publications include a broad overview of intervention design characteristics, future trials should consider a more thorough reporting of resistance training prescription variables as well as long-term follow up assessments to facilitate a smooth translation to clinical practice. One such example would be to report methodology and results with a TIDieR checklist (Hoffmann et al., 2014). In addition, other factors that influence engagement in exercise, such as enjoyment or positive affect, are not typically considered in exercise guidelines or intervention design. Prescribing exercise that focuses on maximizing the participants' enjoyment of the movement and the affective response during and after exercise, are novel approaches that may be used to promote adherence and long term participation (M C. Pascoe & Parker, 2022; Rhodes & Kates, 2015; Van Landuyt et al., 2000; Woessner et al. 2021). While supervised resistance training can improve depressive and anxiety symptoms in a controlled trial environment, there remains a gap in the implementation of exercise-based interventions in routine mental health care due to accessibility (Lederman et al., 2017) and cultural attitudes towards incorporating physical health interventions within treatments (Suetani et al., 2016). There is a need to explore various delivery options across interventions, such as a gradual reduction in supervision, combination of supervised with unsupervised delivery and collaboration with other professionals (e.g., personal trainers, exercise physiology students, or mental-health staff) to overcome accessibility and feasibility barriers (Lederman et al., 2017).

In summary, this quantitative synthesis of the literature demonstrated the significant positive effect that resistance training can provide, across a range of settings, to young people experiencing clinically elevated depression or anxiety symptoms. Given the low number of trials and high heterogeneity, additional RCT-designed studies are warranted to translate these results into clinical practice. For practitioners, resistance training can be considered an effective clinical exercise intervention in the treatment of young people with clinically elevated symptoms of depression and anxiety.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict 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 at the end of this article.

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