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Systematic review

Is supervised exercise training safe in patients with anorexia nervosa? A meta-analysis

L.W.C. Ng *, D.P. Ng, W.P. Wong

Department of Physiotherapy, Singapore General Hospital, Singapore

Abstract

Background Anorexia nervosa is an eating disorder that is often preceded by excessive physical activity. As such, exercise is not often prescribed in the clinical management of individuals with anorexia nervosa.

Objective To examine the effects of supervised exercise training in patients with anorexia nervosa.

Data sources Five databases were searched from their inception to Week 14 of 2011 using the subject headings 'anorexia' and 'exercise' to identify relevant studies.

Eligibility criteria PRISMA guidelines were followed. Studies that investigated the effects of inclusion of supervised exercise training in clinical management with usual management in patients diagnosed with anorexia nervosa were included in this review. Case reports were excluded.

Data extraction and synthesis Two reviewers independently extracted data using a standardised assessment form. Quality assessment was rated for the controlled trials and single-group studies using the PEDro scale and Downs and Black scale, respectively. Fixed or random effect approaches were used to determine effect size, depending on the heterogeneity of the studies.

Results Pooled randomised controlled trials and quasi-randomised studies showed no significant effect of supervised exercise training on selected anthropometric measurements, while the single-group studies showed significant improvement in weight and body fat. Although Short Form-36 revealed no training effect, distorted feelings about food and exercise were reduced. Cardiovascular fitness also improved with no decrease in weight.

Limitations Heterogeneity of exercise training programmes, small sample size ($n \leq 20$) for 67% of the trials, and inability to exclude publication bias.

Conclusions Inclusion of supervised exercise training in the comprehensive management of patients with anorexia nervosa appears to be safe, as no detrimental effect was observed in anthropometry. Strength and cardiovascular fitness were also shown to improve.

Keywords: Eating disorder; Anorexia; Exercise; Meta-analysis

Introduction

Anorexia nervosa is an eating disorder associated with emaciation, often accompanied by a marked increase in physical activity [1]. The diagnosis of anorexia nervosa is established based on criteria from the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) [2], and is characterised by a refusal to maintain minimal weight or a great fear of gaining weight, a distorted body image and amenorrhoea in postmenarcheal females [2]. Many patients with anorexia nervosa are at risk of medical complications such as bone fractures and hormonal imbalances, which may be caused or exacerbated by extreme amounts of exercise [3]. The prevalence of anorexia nervosa is approximately 0.2% to 0.9% [4], with 40% to 80% of individuals with anorexia nervosa exercising excessively [5]. Given the complexity of eating disorders, estimation of the burden of anorexia nervosa is challenging. In Singapore, the disease burden of anorexia and bulimia accounted for 2.1% of total disability-adjusted life years in those aged 15 to 34 years, and was ranked one of the top 10 causes of disease burden in 2004 [6].

* Corresponding author at: Department of Physiotherapy, Singapore General Hospital, Block 1 Level 1, Outram Road, S169608 Singapore.
Tel.: +65 81252960/+61 0430866033; fax: +65 62234526.
E-mail address: cindy.ng.l.w@sgh.com.sg (L.W.C. Ng).

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Management of anorexia nervosa involves treatment of physical, cognitive and behavioural aspects of the condition [7]. Usual management recommended by the American Psychiatric Association includes nutritional rehabilitation, psychosocial interventions (e.g. cognitive behavioural therapy and family-based treatment) and medications (e.g. antidepressants such as fluoxetine) [8]. Such treatments have been studied in both adolescents and adults with anorexia nervosa, but findings are inconclusive [9] and exercise training may be a useful modality with beneficial physical and psychological effects [10]. A review by Hausenblas *et al*. revealed that exercise for patients with anorexia nervosa did not affect weight gain and had positive effects, such as improved body perception, positive mood and quality of life [11]. However, according to a more recent literature review, few studies included exercise training as part of the overall treatment for patients with anorexia nervosa [3].

Exercise is not often prescribed for hospital inpatients with anorexia nervosa, which may be due to a lack of understanding that exercise can be moderated under appropriate conditions, such as during refeeding and stabilisation of body weight [11]. Exercise training may play an important role in the management of anorexia nervosa through lean body mass gain, provision of an outlet for the patient's inclinations towards exercise [12], reduction in anxiety and depression, having a better body image, and improved social behaviour [11]. Although intensive aerobic training would be inappropriate due to its association with overindulgence or high energy expenditure [12], other forms of exercise that are aimed at increasing muscle mass and helping to regulate excessive behaviours would be beneficial [10,13]. Too much exercise has often been implicated in the pathogenesis and progression of anorexia nervosa [14]. As such, it is important to monitor body weight or body mass index (BMI) when exercises are prescribed. Although a narrative review was published recently [3], the studies selected were limited to those with weight restoration using any exercise or structured physical activity programme, and so the review was unable to offer any guidelines on exercise prescription for patients with anorexia nervosa. Thus, the aim of this review was to search the literature systematically and undertake a meta-analysis of data from studies that evaluated the effect of supervised exercise training on anthropometry, as well as describe the psychological and other physiological outcomes in patients with anorexia nervosa after training. This has important implications in a clinical setting to determine if supervised exercise training is safe and beneficial in the management of anorexia nervosa.

Methods

Data sources

Study identification began with electronic searching of computerised databases, namely PubMed, EMBASE, CINAHL, Physiotherapy Evidence Database (PEDro) and Cochrane Central Register of Controlled Trials from inception to Week 14 2011 (Table A, see supplementary online material). The subject headings used in the search were 'anorexia' and 'exercise'. Secondary searches included hand searching the reference lists of all identified studies and the PubMed 'related articles' function.

Study selection

Studies were eligible for inclusion if they: (1) recruited patients with anorexia nervosa diagnosed on the basis of DSM-III-R (1987) or DSM-IV (1994) criteria (Table B, see supplementary online material); (2) investigated the effects of supervised exercise training against usual management recommended by the American Psychiatric Association; and (3) measured changes in selected anthropometric (body weight, BMI, percentage body fat or lean body mass), physiological (muscle strength or endurance) or psychological (quality of life or depression) variables. Where necessary, authors were contacted for those studies that did not report values in absolute terms. Case reports were excluded. Anthropometric data from randomised controlled trials (RCTs) and quasi-randomised trials with a control arm were included for meta-analysis. Psychological data were included for systematic review. All data from single-group studies were also included in the systematic review. There were no articles prior to 1987 that examined the effects of supervised exercise in the treatment of anorexia nervosa.

Quality assessment

Two reviewers (LWCN and DPN) independently extracted data using a standardised assessment form. Quality assessment for the RCTs and non-randomised trials with a control arm was rated using the 10-point PEDro scale [15]. This scale uses criteria related to blinding, intention-to-treat and loss to follow-up, with a higher score indicative of superior internal validity [15]. Quality assessment for the single-group interventional studies was rated using a modified Downs and Black tool [16], which comprised 27 questions, relating to study description, external validity, internal validity and statistical power [17]. Disagreements were resolved by discussion between the two reviewers and, where necessary, a third person (WPW) was consulted.

Data extraction and analysis

Consistency between reviewers for both quality assessment methods was calculated using Kappa (κ) statistics. The I^2 test was used to quantify statistical heterogeneity of all studies with a control arm [18]. A value of $\geq$75% represents high heterogeneity [19]. A fixed or random-effect approach was used. If $I^2 \leq 25\%$, a fixed-effect model was used to estimate the effect size. Hedges' g or standardised mean difference (SMD) was preferred over Cohen's d in this meta-analysis, as the former would adjust for small sample bias [20]. For effect size, ≤0.2 is considered small, 0.5 moderate and ≥0.8 large [21]. Sensitivity or subgroup analysis was chosen for BMI as it was more frequently measured and reported. Sensitivity analysis was conducted to ensure that the results pooled in the meta-analysis were robust. Comprehensive Meta Analysis Version 2.2.050 (Biostat, Englewood, New Jersey, USA) was used for all analyses. The single-group interventional studies were included in the systematic review but not the meta-analysis. Funnel plots for all four measures of anthropometry were examined for publication bias.

Results

The search strategy yielded 1184 records, of which nine studies met the inclusion criteria: four RCTs, three quasi-randomised trials and two single-group interventional studies (Fig. A, see supplementary online material). The author of one study was contacted.

Quality assessment

Table 1 presents the PEDro scores for all trials with a control arm, as well as the Downs and Black scores for the single-group interventional studies. Reviewers agreed on 93% of all PEDro items with a κ statistic of 0.86. The median PEDro scores for the RCTs and quasi-randomised trials were 5 (range 3 to 7) and 5 (range 4 to 5) points, respectively. Reviewers agreed on 74% of all Downs and Black items with a κ statistic of 0.56, which indicates moderate agreement. The Downs and Black score was 15 (range 14 to 16) points. The quality of all the trials was poor to fair, with 44% of the studies lacking randomisation and all the trials lacking blinding.

Subject characteristics

Table 1 presents the characteristics of all the trials. The sample size of the RCTs ranged from five to 26, the sample size of the quasi-randomised trials ranged from eight to 127, and the sample size of the single-group studies ranged from 14 to 32. Collectively, participants in these studies were Caucasians, predominantly females ($n = 430$, 99%) with an average age of 21 years.

Effects of exercise training on anthropometry

All four RCTs showed no significant change in body weight and BMI regardless of the mode of exercise (Table 2) [22–25]. There was no change in percentage body fat [22–24] or lean body mass [23,24]. In the quasi-randomised trials, Touyz *et al.* found no change in body weight and lean body mass in the group that performed supervised exercise [26]. Tokumura *et al.* reported no change in percentage body fat but an increase in BMI {from 18.8 [standard deviation (SD) 0.5] to 21.7 (SD 0.5) kg/m^2; $P < 0.001$} for the group that included 30 minutes of cycling at anaerobic threshold after a mean period of 10 months [27]. Significant weekly body weight gain of at least 1.69 kg ($P < 0.05$) was observed in the study by Calogero and Pedrotty, where a combination of different types of exercises were performed by the experimental group [28].

Meta-analysis was conducted for both the RCTs and quasi-randomised trials. Since statistical heterogeneity was observed for body weight and BMI, a random effect model was used for pooling the findings. The pooled SMD for body weight was 0.40 ($P = 0.11$) (Fig. 1). The sensitivity analysis for BMI showed that the quasi-randomised trials had a significant SMD of 1.14, while that of the RCTs was small and insignificant (SMD −0.13, $P = 0.67$) (Fig. 2). The pooled SMD for BMI was also not significant (SMD 0.50, $P = 0.10$) (Fig. 3). No heterogeneity was observed for percentage body fat or lean body mass, and the pooled SMD was small and insignificant (Figs. 4 and 5).

The two single-group intervention studies significantly improved body weight, BMI and percentage body fat (Table 2) [29,30]. In one study, a significant improvement was also demonstrated in lean body mass [from 35.4 (SD 3.4) kg to 39.7 (SD 3.6) kg] [29].

Effects of exercise training on psychological outcomes

Participants in one study undergoing Viniyoga, defined as a programme of exercises comprising strength building, posture and relaxation, flexibility and large muscle movements [30], were significantly less pre-occupied with food after every exercise session [25]. Exercise commitment (describing negative effect of exercise), exercise involvement (describing frequency and type of exercise habits) and exercise rigidity (addressing missing exercise sessions) are three dimensions of the Obligatory Exercise Questionnaire, an assessment tool that has been used in some studies involving patients with anorexia nervosa. Participation in an exercise programme during treatment reduced emotional commitment to exercise and exercise involvement compared with the control arm; however, exercise rigidity did not reduce in those who did not participate in the exercise programme (Table 3) [28]. No significant effect of exercise training on health-related quality of life was demonstrated, as determined by Short Form-36 (SF-36; group × time interaction effect, $P > 0.05$ for all subscales of SF-36) [24]. Similar findings were found in older patients (>29 years, see Table 3) with anorexia nervosa ($P \geq 0.05$) [22].

Effects of structured exercise on other physiological outcomes

Chantler *et al.* demonstrated a significant increase in knee extensor and knee flexor peak torque [change of 25.6 (SD 11.4) N m and 17.3 (SD 4.7) N m, respectively] in patients

Table 1
Description of trials.

Study	Randomised controlled trials									
	PEDro	Setting and duration	Experimental				Control			
			Sample size	Gender (M/F)	Mean (SD) age (years)	Protocol	Sample size	Gender (M/F)	Mean (SD) age (years)	Protocol
Thien 2000 [22]	3	Eating disorder outpatients follow-up clinic, Canada; 3 months	5	0/5	29 (4.4)	Graded exercise protocol dependent on patient's percentage ideal body weight and percentage body fat. Ranged from Level 1 to Level 7. Level 1 is stretching exercises in sitting and lying while Level 7 is stretching exercises, resistive strengthening and low impact cardiovascular exercise. Three times per week	7	1/6	36 (7.9)	Usual care and encouraged to limit exercise as much as possible
Chantler 2006 [23]	6	Eating disorder unit, South Africa; 8 weeks	7	0/7	20 (5.0)	2.5-kg dumb-bells for back, chest, calf, shoulder and arm exercises; and elastic thera-bands or body weight for back, thigh, hip and abdominal exercises. 2 to 3 sets × 8 to 15 repetitions. Twice per week; 1 hour each	7	0/7	22 (6.0)	Usual care
del Valle 2010 [24]	6	Outpatient clinic, Spain; 12 weeks	11	1/10	15 (0.6)	Warm up (10 to 15 minutes), stretching, 11 strength exercises involving major muscle groups of 1 set × 10 to 15 repetitions, isometric contractions of large muscle groups of 6 sets × 3 repetitions of 20 to 30 seconds and cool down (10 to 15 minutes). Twice per week; 60 to 70 minutes each	11	1/10	14 (1.2)	Usual care
Carei 2010 [25]	7	Adolescent outpatient clinic, USA; 8 weeks	15	0/15	17 (2.5)	1 hour Viniyoga. Twice per week	11	2/9	16 (1.9)	Usual care

Study	Quasi-randomised trials									
	PEDro	Setting and duration	Experimental				Control			
			Sample size	Gender (M/F)	Mean (SD) age (years)	Protocol	Sample size	Gender (M/F)	Mean (SD) age (years)	Protocol
Touyz 1993 [26]	4	Inpatient treatment, Australia; 4 weeks	19	N/A	16 (2.5)	Behavioural programme. Anaerobic exercise programme consisting of stretching, posture enhancement, weight training and occasional social sport or aerobic activity. 3 hours per week	20	N/A	20 (5.3)	Behavioural programme
Tokumura 2003 [27]	5	Japan; 6 to 12 months (mean 10 months)	9	0/9	14 (median)	30 minutes stationary bicycle exercise at anaerobic threshold. 5 times per week	8	0/8	14 (median)	Usual care
Calogero 2004 [28]	5	Residential eating disorders treatment facility, USA; 2.5 to 5 weeks	127 43 (R) 20 (BP)	0/127	22 (8.0)	Warm up, exercise activities (stretching, posture, yoga, Pilates, partner exercises, strength training, balance, exercise balls, aerobic activity and recreational games) and cool down 2 to 4 times per week; 60 minutes each	127 39 (R) 13 (BP)	0/127	23 (8.7)	Usual care

Study	Single-group studies					
	Downs and Black tool	Setting and duration	Sample size	Gender (M/F)	Mean (SD) age (years)	Protocol
Russell 1993 [29]	14	Eating disorders programme, Australia; 10 to 15 weeks	32	0/32	19 (41.0)	Graded supervised structured exercises consisting of aerobic and non-aerobic activity
Szabo and Green 2002 [31]	16	Eating disorders unit, South Africa; 8 weeks	14	N/A	20 (mean)	2.5-kg dumb-bells for upper body exercises, and therapeutic elastic bands and body weight for lower body exercises

M, male; F, female; R, restricting subtype; BP, binge–purge subtype; SD, standard deviation; N/A, not available.

Table 2
Outcomes of controlled trials and single-group studies (raw data).

Study	Measures	Pre		Post	
		Intervention group	Control group	Intervention group	Control group
Thien 2000 [22]	Body weight (kg)	–	–	–	–
	BMI (kg/m^2)	20.3 (1.8)	17.2 (1.6)	Δ1.0 (1.3)	Δ0.8 (1.1)
	Body fat (%)	21.0 (2.9)	16.7 (4.9)	Δ0.9 (2.1)	Δ0.5 (2.6)
	Lean body mass (kg)	–	–	–	–
Chantler 2006 [23]	Body weight (kg)	40.3 (4.5)	43.5 (4.4)	46.3 (3.9)	46.8 (3.9)
	BMI (kg/m^2)	15.1 (1.1)	16.5 (1.3)	17.4 (1.3)	17.8 (1.1)
	Body fat (%)	10.0 (2.2)	12.2 (2.7)	12.6 (3.6)	14.1 (3.1)
	Lean body mass (kg)	36.2 (3.6)	38.1 (3.6)	40.4 (3.0)	40.2 (3.1)
del Valle 2010 [24]	Body weight (kg)	48.2 (8.8)	46.6 (5.5)	47.0 (8.6)	47.2 (5.3)
	BMI (kg/m^2)	18.7 (1.7)	18.2 (1.5)	18.2 (2.2)	18.3 (1.6)
	Body fat (%)	14.8 (2.9)	13.8 (2.6)	13.7 (3.3)	13.9 (2.4)
	Lean body mass (kg)	20.7 (4.7)	19.8 (3.0)	20.8 (3.1)	20.4 (3.0)
Carei 2010 [25]	Body weight (kg)	–	–	–	–
	BMI (kg/m^2)	17.9 (2.0)	17.8 (2.0)	18.2 (2.2)	18.8 (2.6)
	Body fat (%)	–	–	–	–
	Lean body mass (kg)	–	–	–	–
Touyz 1993 [26]	Body weight (kg)	39.1 (3.1)	37.2 (4.3)	Δ4.1 (2.3)	Δ3.85 (2.4)
	BMI (kg/m^2)	14.8 (1.0)	14.3 (1.3)	–	–
	Body fat (%)	–	–	–	–
	Lean body mass (kg)	–	–	–	–
Tokumura 2003 [27]	Body weight (kg)	–	–	–	–
	BMI (kg/m^2)	18.8 (0.5)	19.6 (0.7)	21.7 (0.5)	20.2 (0.5)
	Body fat (%)	27.7 (0.8)	27.8 (1.4)	30.3 (0.5)	29.1 (1.2)
	Lean body mass (kg)	–	–	–	–
Calogero 2004 [28]	Body weight (kg)	–	–	Δ2.7 (0.9) (R)	Δ1.8 (1.6) (R)
	BMI (kg/m^2)	18.5 (5.2)	20.5 (6.0)	Δ3.6 (1.9) (BP)	Δ2.1 (1.0) (BP)
	Body fat (%)	–	–	–	–
	Lean body mass (kg)	–	–	–	–
Russell 1993 [29]	Body weight (kg)	42.0 (0.9)		51.9 (4.4)	
	BMI (kg/m^2)	15.4 (1.3)		19.1 (1.2)	
	Body fat (%)	15.2 (5.0)		23.4 (3.8)	
	Lean body mass (kg)	35.4 (3.4)		39.7 (3.6)	
Szabo 2002 [31]	Body weight (kg)	40.3 (4.5) (E)/43.5 (4.4) (NE)		46.3 (3.9) (E)/46.8 (3.9) (NE)	
	BMI (kg/m^2)	15.1 (1.1) (E)/16.5 (1.3) (NE)		17.4 (1.3) (E)/17.8 (1.1) (NE)	
	Body fat (%)	10.1 (2.2) (E)/12.3 (2.7) (NE)		12.6 (3.6) (E)/14.1 (3.1) (NE)	
	Lean body mass (kg)	36.2 (3.6) (E)/38.1 (3.6) (NE)		40.4 (3.0) (E)/40.2 (3.1) (NE)	

Δ, change; BMI, body mass index; R, restricting subtype; BP, binge–purge subtype; E, anorexic exercisers; NE, anorexic non-exercisers.
Data are mean (standard deviation).

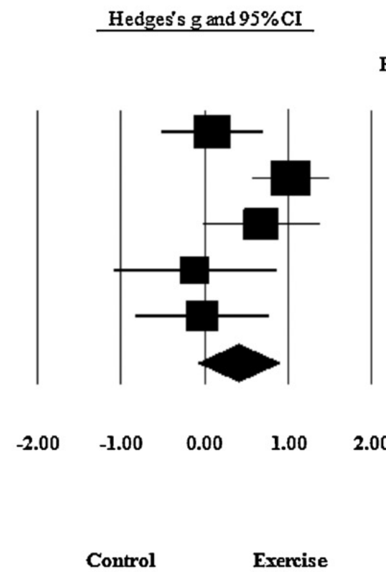
Table 3
Description of psychological and quality-of-life outcomes.

Study	Intervention group	Control group	Comparison between groups
Thien 2000 [22]	SF-36 improved by 6.6 (7.0). Social function improved by 5.0 (18.9)	SF-36 decreased by 12.0 (25.5). Social function decreased by 19.6 (27.8)	$P = 0.07$ $P = 0.05$
Chantler 2006 [23]	N/A	N/A	
del Valle 2010 [24]	SF-36 score: improvement in physical role, general health, social function and mental component scale	SF-36 score: improvement in all domains and physical component scale and mental component scale	No significant interaction effect and no significant training effect
Carei 2010 [25]	Reduction in weight and shape concerns of the Global Eating Disorder Examination score at Week 12. Reduction in anxiety and depression score at Week 12	The Global Eating Disorder Examination score decreased slightly at Week 9 but returned to baseline at Week 12. Reduction in anxiety and depression score at Week 12	No difference between groups
Touyz 1993 [26]	N/A	N/A	
Tokumura 2003 [27]	N/A	N/A	
Calogero 2004 [28]	Emotional commitment to exercise (R) (pre) 25.9 (8.5) (post) 23.0 (6.3). Emotional commitment to exercise (BP) (pre) 23.8 (6.1) (post) 19.2 (7.2). Exercise involvement (R) (pre) 8.8 (3.3) (post) 7.8 (2.4). Exercise involvement (BP) (pre) 8.2 (2.9) (post) 7.1 (1.7). Exercise rigidity (R) (pre) 5.7 (1.9) (post) 4.3 (1.4). Exercise rigidity (BP) (pre) 5.6 (1.7) (post) 4.1 (1.1)	Emotional commitment to exercise (R) (pre) 24.2 (8.9) (post) 25.0 (9.5). Emotional commitment to exercise (BP) (pre) 26.5 (9.8) (post) 27.5 (9.2). Exercise involvement (R) (pre) 8.6 (3.4) (post) 9.0 (2.7). Exercise involvement (BP) (pre) 8.9 (3.6) (post) 9.3 (3.4). Exercise rigidity (R) (pre) 5.9 (2.1) (post) 6.0 (1.7). Exercise rigidity (BP) (pre) 5.7 (1.8) (post) 5.8 (2.0)	No significant difference between exercise and control group or between diagnostic groups. ANCOVA (exercise vs control): Emotional commitment to exercise, M = 23.23 vs M = 24.7, F = 15.7, $P < 0.0001$. Exercise involvement, M = 8.0 vs M = 8.3, F = 8.5, $P = 0.004$. Exercise rigidity, $M = 4.1$ *vs* M = 5.6, $F = 55.4$, $P < 0.0001$

Study	Single group
Russell 1993 [29]	N/A
Szabo 2002 [31]	Beck Depression Index (E) decreased by 11.8 (18.6) ($P = 0.219$) Beck Depression Index (NE) decreased by 15.2 (11.5) ($P = 0.012$) Eating Disorder Inventory (E) decreased by 22.0 (2.7) ($P = 0.002$) Eating Disorder Inventory (NE) decreased by 25.5 (2.7) ($P = 0.011$)

SF-36, Short Form-36; R, anorexic nervosa, restricting subtype; BP, anorexic nervosa, binge–purge subtype; E, anorexic exercisers; NE, anorexic non-exercisers; N/A, not available.
Data are mean (standard deviation).

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Touyz 1993	0.09	0.31	0.10	-0.53	0.70	0.28	0.78	22.02
Calogero 2004 (R)	1.03	0.23	0.05	0.57	1.48	4.40	0.00	26.17
Calogero 2004 (BP)	0.68	0.36	0.13	-0.03	1.38	1.89	0.06	19.94
Chantler 2006	-0.12	0.50	0.25	-1.10	0.86	-0.24	0.81	14.25
del Valle 2010	-0.03	0.41	0.17	-0.83	0.78	-0.07	0.95	17.62
	0.40	0.25	0.06	-0.09	0.89	1.62	0.11	



I^2=61%, p=0.04

Fig. 1. Forest plot for body weight. R, restricting subtype; BP, binge–purge subtype; CI, confidence interval.

Group by Study Type	Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Non-RCT	Tokumura 2003	2.85	0.67	0.45	1.53	4.16	4.24	0.00	16.47
Non-RCT	Calogero (R) 2004	0.74	0.28	0.08	0.20	1.28	2.68	0.01	44.52
Non-RCT	Calogero (BP) 2004	0.88	0.33	0.11	0.24	1.52	2.68	0.01	39.01
Non-RCT		1.14	0.31	0.10	0.53	1.75	3.64	0.00	
RCT	Thien 2000	0.16	0.54	0.29	-0.91	1.22	0.29	0.77	20.05
RCT	Chantler 2006	-0.31	0.50	0.25	-1.30	0.68	-0.62	0.54	22.02
RCT	Carei 2010	-0.25	0.39	0.15	-1.01	0.50	-0.65	0.51	29.89
RCT	del Valle 2010	-0.05	0.41	0.17	-0.85	0.75	-0.12	0.90	28.04
RCT		-0.13	0.30	0.09	-0.71	0.45	-0.43	0.67	

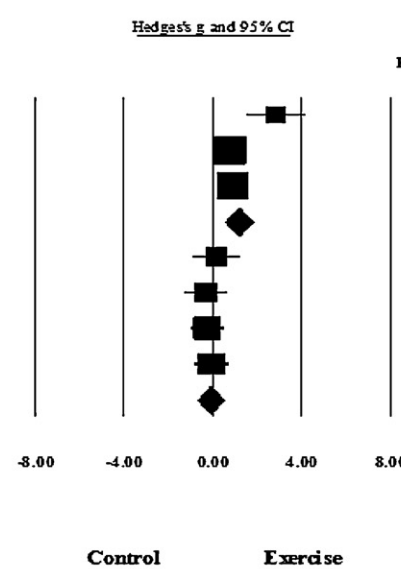
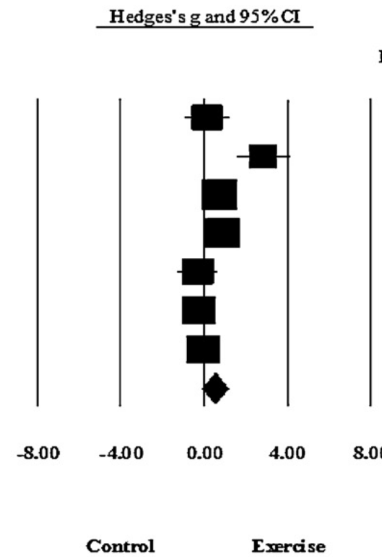


Fig. 2. Forest plot for body mass index analysed based on study type (sensitivity analysis). RCT, randomised controlled trial; R, restricting subtype; BP, binge–purge subtype; CI, confidence interval.

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Thien 2000	0.16	0.54	0.29	-0.91	1.22	0.29	0.77	12.43
Tokumura 2003	2.85	0.67	0.45	1.53	4.16	4.24	0.00	10.28
Calogero (R) 2004	0.74	0.28	0.08	0.20	1.28	2.68	0.01	17.44
Calogero (BP) 2004	0.88	0.33	0.11	0.24	1.52	2.68	0.01	16.49
Chantler 2006	-0.31	0.50	0.25	-1.30	0.68	-0.62	0.54	13.11
Carei 2010	-0.25	0.39	0.15	-1.01	0.50	-0.65	0.51	15.36
del Valle 2010	-0.05	0.41	0.17	-0.85	0.75	-0.12	0.90	14.89
	0.50	0.31	0.09	-0.10	1.10	1.63	0.10	

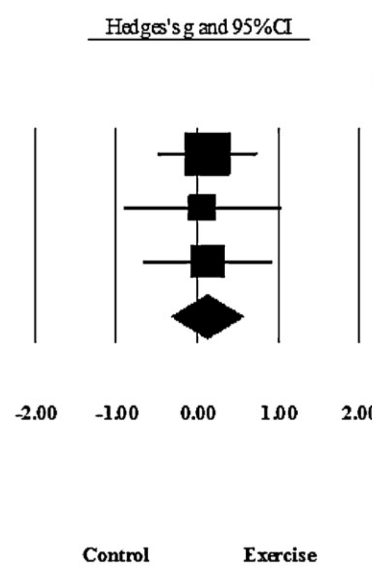


I^2=61%, p=0.04

Fig. 3. Forest plot for body mass index. R, restricting subtype; BP, binge–purge subtype; CI, confidence interval.

who participated in a twice-weekly resistance training programme, whereas no significant change was found in the control group [23]. Muscular strength measured by six repetitive maximum on seated lateral row improved significantly ($P = 0.009$) for the exercise training group; however, no similar significant improvement was observed in other strength tests (bench and leg press) or functional tests (timed up and go test and timed up and down stairs test) [24]. Nine patients who cycled for half an hour five times a week at anaerobic threshold improved their peak volume of oxygen consumed from 31.8 (SD 1.3) ml/kg/min to 46.4 (SD 2.2) ml/kg/min, while oxygen consumption at anaerobic threshold improved significantly from 15.7 (SD 1.1) ml/kg/min to 23.0 (SD 1.4) ml/kg/min ($P < 0.01$) [27].

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Touyz 1993	0.12	0.31	0.10	-0.49	0.74	0.40	0.69	50.53
Chantler 2006	0.06	0.50	0.25	-0.92	1.04	0.12	0.90	19.90
del Valle 2010	0.13	0.41	0.17	-0.68	0.93	0.31	0.76	29.57
	0.11	0.22	0.05	-0.33	0.55	0.50	0.61	



I^2=0%, p=0.99

Fig. 4. Forest plot for lean body mass. CI, confidence interval.

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Thien 2000	0.15	0.54	0.29	-0.91	1.21	0.28	0.78	22.61
Chantler 2006	-0.42	0.51	0.26	-1.41	0.57	-0.83	0.41	24.20
del Valle 2010	-0.07	0.41	0.17	-0.87	0.74	-0.16	0.87	29.15
Tokumura 2003	1.27	0.51	0.26	0.27	2.27	2.49	0.01	24.04
	0.22	0.35	0.13	-0.48	0.91	0.62	0.54	

(Statistics for each study)

I^2=0%, p=0.73

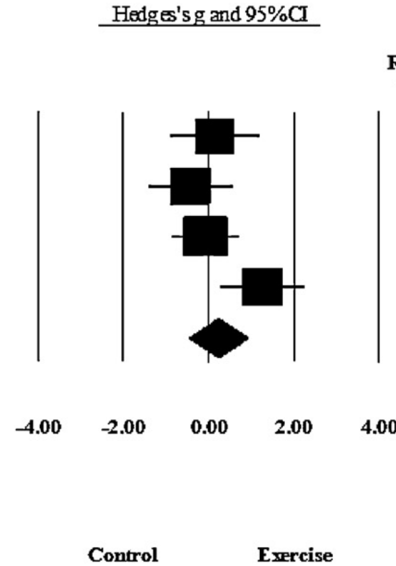


Fig. 5. Forest plot for percentage body fat. CI, confidence interval.

Discussion

Supervised exercise training did not affect anthropometry, as observed in all trials with a control arm. However, significant before–after improvement was noted in all the anthropometric measures after exercise training, as observed in the two single-group studies. Supervised exercise training showed a decrease in concerns about body weight, shape and depression [25,31], as well as perception of exercise [28], although there was no training effect on quality of life as measured by SF-36 [22,24]. Improvement in strength [23] and cardiovascular endurance [27] was also observed despite no significant change in lean body mass. This implied that incorporating a supervised exercise programme into the management of anorexia nervosa did not have a negative impact on weight, and may have psychological and physiological benefits.

Effects of exercise training on anthropometry

Clearly, a supervised exercise programme significantly improves before–after measurements of body weight, BMI, percentage body fat and lean body mass [27,28]. However, adding a supervised exercise programme to the comprehensive management of anorexia nervosa did not further improve these anthropometric measurements. Close scrutiny of these studies reveals a predominance of flexibility exercises [22,24,26,28], which are aimed at increasing muscle length or range of motion rather than muscle mass [32]. Where resistance exercises were included to build muscle mass (for lean body mass and body weight), the resistance or weights prescribed were likely to be 'light' so that they could be tolerated by patients with anorexia nervosa [22–24,26,28,31], and therefore were insufficient to stimulate muscle growth. In most instances, the major goal was to understand that a low level of resistive exercises was required to maintain body shape and tone [26]. Secondly, the anorexic controls could possibly continue to be involved in some form of exercise at the time of the studies. Enforcing complete inhibition of exercise participation could be time consuming [26]. Conversely, those who were not exercising in the control arms may have initiated exercise participation as a result of witnessing favourable changes experienced by those in the supervised exercise training arms; a phenomenon known as 'diffusion or imitation of intervention', thus constituting a form of social threat to internal validity in these studies [33]. Finally, another possible reason for the lack of a significant difference between the supervised exercise training and control groups was type II error due to small sample sizes. Except for one quasi-randomised trial [26], all studies in this review had small sample sizes. In particular, all RCTs included less than 20 patients in each arm (Table 1). Regardless of the reasons for the lack of significantly better anthropometric changes with the addition of supervised structured exercise training, having such a programme may improve compliance with psychotherapy and/or refeeding treatments for anorexia nervosa [31].

Effects of exercise training on psychological outcomes

Exercise is known to have a positive effect on self-esteem, mood and depression that could help to prevent and treat eating disorders [34]. This was noted in one observational study where patients with anorexia nervosa were less depressed after an 8-week supervised resistance training programme [30]. Disordered feelings about food and exercise were reduced in those who participated in supervised exercise [25,28]. However, there was no training effect on quality of life when a generic questionnaire (SF-36) was used [22,24]. Although SF-36 has been used to assess psychosocial deterioration in patients with anorexia nervosa [35], it may not be sensitive to detect change after treatment in patients with anorexia nervosa.

Effects of structured exercise on other physiological outcomes

Exercise training appeared to have other benefits such as a significant increase in muscle strength [23] and cardiovascular endurance [27] without compromising body weight. The improvement in cardiovascular fitness (approximately 46%) for patients with anorexia nervosa [27] was much higher than that reported in similar aged females [36]. However, one study found that resistance exercise had no effect on muscular strength [24], probably because the intensity was inadequate (only one set of 10 to 15 repetitions) and the type of exercise was isometric instead of isokinetic.

Strengths and limitations

This is the first meta-analysis undertaken on the effects of a supervised exercise programme on anthropometry, which is a concern when patients with anorexia nervosa participate in exercise programmes. Although a recent literature review on anorexia nervosa and exercise concluded from its limited empirical data that there was a positive correlation between physical activity and weight restoration, it did not look objectively at the effect of exercise and was unable to provide guidelines on exercise in patients with anorexia nervosa [3]. This is also the first review to examine both psychological and physiological outcomes of supervised exercise training in patients with anorexia nervosa.

However, this systematic review is limited by the heterogeneity of exercise training programmes, which may challenge the validity of the meta-analysis and pooled data as well as the small sample size ($n \leq 20$) for 67% of the trials. The funnel plots for percentage body fat and lean body mass (Fig. B, see supplementary online material) also showed evidence of asymmetries, thus publication bias cannot be excluded. This review also based its data source on established electronic databases, whereas the grey literature (e.g. research thesis) was excluded. The quality of the articles was not excellent, which may explain the minimal results.

Implications for clinical practice and further recommendations

A programme consisting of aerobic exercise alone is not recommended for patients with anorexia nervosa, because this type of exercise expends energy and brings about considerable caloric loss. Indeed, patient education on different exercises to bring about other components of physical fitness (*e.g.* strength, flexibility and balance) should be included. The nine trials in this study included resistance training [23,24,31], stretching or yoga [22,25], combination of anaerobic and low impact aerobic activity [6,28,29], and aerobic exercise at anaerobic threshold [27]. Furthermore, two of these studies had a concurrent refeeding programme [26,29] which involves stabilising and normalising eating and dietary behaviours, which includes meal supervision, tube feeding or supplementation. All of them enforced strict criteria on which patients were eligible for the exercise programme (such as being >71% ideal body weight for at least 24 hours [22,23,28], 1800 to 2500 calories of dietary intake per day [24,31], stable body weight and an increase of body fat by 25% [27], and a resting pulse rate of >44 beats per minute [25]). This meta-analysis showed that including supervised exercise training in the management of anorexia nervosa is safe, as it did not result in additional weight loss and may have benefits in the areas of strength and psychological well-being. Future research is required to establish guidelines for exercise training in individuals with anorexia nervosa, and to determine responders to supervised exercise training, attitudes towards exercise and relapse. Other future studies could include service delivery such as home-based programmes as well as cost-effectiveness.

Conclusion

The addition of supervised exercise training to usual care appeared to have no additional effect on anthropometry; thus, it is safe to incorporate it into clinical programmes. Exercise training seemed to improve strength and cardiovascular endurance despite no change in lean body mass. There also appeared to be no impact on quality of life, although disordered feelings for food and exercise were reduced. Further research is required with larger sample sizes and longer follow-up periods.

Conflict of interest: None declared.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.physio.2012.05.006.

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