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REVIEW

# Effect of exercise as adjuvant to energy-restricted diets on quality of life and depression outcomes: a meta-analysis of randomized controlled trials

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## Abstract

**Background and aim** Obesity and related co-morbidities lead to a decrease in health-related quality of life (HRQOL) and mood. Lifestyle strategies may improve these outcomes. However, the efficacy of exercise in conjunction with a weight-loss diet on HRQOL and mood is unclear. The aim of this systematic review and meta-analysis of randomized controlled trials (RCTs) was to examine whether the addition of exercise to energy-restricted dietary programs improves HRQOL and mood status when compared with energy-restricted diets alone in overweight and obese adults.

**Methods** Eligible RCTs were identified by searching PubMed/MEDLINE, EMBASE, ISI (Web of sciences), Scopus, and Google Scholar up to April 2021. Summary effects were derived using a random-effects model. The quality of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology.

**Results** The meta-analysis revealed that an energy-restricted diet plus exercise compared with an energy-restricted diet alone had no significant effects on depression ($n=6$, hedges'g = − 0.04, 95% CI: − 0.28,0.20), MOS 36-Item Short-Form Health Survey (SF-36)-physical component summary scores ($n=8$, weighted mean difference (WMD) = 1.51, 95% CI: − 0.16, 3.18), SF36-mental component summary scores ($n=7$, WMD = 0.64, 95% CI: − 1.00, 2.28), and HRQOL disease-specific questionnaire scores ($n=5$, hedges'g = 0.16, 95% CI: − 0.09, 0.40). The GRADE revealed that the quality of evidence was low for disease-specific HRQOL scores, and depression status; and high for physical and mental health assessed by SF-36.

**Conclusion** In our sample of overweight and obese adults, no beneficial effect of adding exercise to an energy-restricted diet was found in terms of HRQOL and Depression.

**Keywords** Exercise · Diet · Resistance · Aerobic · Quality of life · Depression,mood · Weight loss · Adults · Overweight · Obese · IVhet model · Randomized controlled trial · Meta-analysis · Systematic review

**Abbreviations**

| | |
|---|---|
| HRQOL | Health-related quality of life |
| RCTs | Randomized control trials |
| GRADE | Grading of Recommendations Assessment, Development, and Evaluation |
| SF-36 | MOS 36-Item Short-Form Health Survey |
| WMD | Weighted mean difference |
| NWCR | National Weight Control Registry |
| PRISMA | Preferred reporting items for systematic reviews and meta-analyses |

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| | |
|---|---|
| PROSPERO | International prospective register of systematic reviews |
| MeSH | Medical Subject Headings |
| SDs | Standard deviations |
| IVhet | Inverse variance heterogeneity |
| SF36-MCS | SF36-Mental component summary |
| SF36-PCS | SF36-physical component summary |
| $I^2$ | I-squared |
| POMS | Profile of Mood States |
| HADS | Hospital Anxiety and Depression Scale |
| GDS | Geriatric Depression Scale |
| T2DM | Type 2 Diabetes Mellitus |
| PCOS | Polycystic ovarian syndrome |
| BDI | Beck Depression Inventory |
| BSI-18 | Brief Symptom Inventory-18 |
| CES-D | Center for Epidemiologic Studies Depression Scale |
| KCCQ | Kansas City Cardiomyopathy Questionnaire |
| IWQOL | Impact of Weight on Quality of Life–Lite |
| AQLQ | Juniper Asthma Quality of Life Questionnaire |


## Plain English summary

Obesity leads to a decrease in health-related quality of life (HRQOL) and mood. Lifestyle strategies may improve HRQOL and mood. However, the efficacy of adding exercise to a weight-loss diet on HRQOL and mood is unclear. Determining combined effects of weight-loss diet and exercise compared with weight-loss diets alone on mood status will help physicians, researchers, and policy makers in prescribing optimal lifestyle to improve HRQOL and depression. In this study, we assess the effects of weight-loss diet plus exercise compared with weight-loss diets alone on HRQOL and depression. Our findings did not reveal any beneficial effects of adding exercise to a weight-loss diet on HRQOL and depression in overweight and obese adults. Further studies are needed to investigate the benefits of exercise plus diet intervention on mood status. Given the well-known benefits of exercise on different aspects of health, exercise should be recommended as an important component of lifestyle strategies for obesity management.


## Introduction

Obesity remains a global health challenge [1] as prevalence has nearly tripled since 1975 [2]. Obesity and related comorbidities (such as cardiovascular diseases, type 2 diabetes mellitus, fatty liver disease, certain cancers, Alzheimer, and depression) [3] are associated with a reduction in health-related quality of life (HRQOL) [4, 5]. Both direct and indirect costs of impaired HRQOL and depression (such as the costs related to diagnosis, treatment, unemployment, and loss of income) are considerable [6–9].

Given that obese individuals are at a higher risk for depression and mood disorders [10], managing obesity is critical. Adopting lifestyle interventions (such as diet, physical activity, or behavioral therapy) that are cost-effective and have few side effects are initial non-pharmacological approaches for obesity management [11]. Data from the National Weight Control Registry (NWCR) demonstrates that both changes in diet and physical activity are key strategies for obesity treatment [12]. Dietary weight-loss interventions are effective for body composition changes; however, systematic reviews and meta-analyses assessing the effects of weight-loss diets on depression [13, 14] and HRQOL [15] are inconsistent. Adopting a calorie-restricted diet might reduce some aspects of HRQOL, including social and economic benefits [15]. Systematic reviews and meta-analyses assessing the effects of exercise during weight-loss interventions on the HRQOL [16, 17] and depression [18, 19] have shown beneficial effects.

There are a large number of systematic reviews and meta-analyses directly comparing the effects of diet alone or in conjunction with exercise on the improvement of health outcomes [20–24]. However, to the best of our knowledge, only one systematic review compares energy-restricted diets and combined energy-restricted diet and exercise on HRQOL [25]; and no meta-analysis was performed. The authors indicated that a definitive conclusion was not feasible based on existing evidence, and a more detailed and comprehensive systematic review and meta-analysis was needed. Moreover, previous clinical trials examining the effect of adding exercise to energy-restricted diets on HRQOL [26–32] or depression [27, 33–36] were also inconsistent. Although some studies found a beneficial effect on depression [28, 33] and HRQOL [26, 29, 30, 34], others reported null or negative effects [5, 27, 34, 35, 37]. For instance, Thomson et al. stated that the emotional response to diet plus exercise interventions might reduce over time, negatively affecting depressive symptoms. Highly perceived time pressure induced by work and family responsibilities can be a major barrier to healthy eating and participation in physical activity [5]. In addition, Bowen et al. found that intensive exercise may harm some important aspects of HRQOL (body or joint pain, social interactions, and mood), especially in initially sedentary individuals [38]. Determining the combined effects of diet and exercise interventions compared with energy-restricted diets alone on mood status will assist physicians, researchers, and policymakers in prescribing optimal lifestyle modifications to improve HRQOL and depression [33]. Therefore, the objective of the present meta-analysis was to critically assess whether the addition of exercise to energy-restricted dietary programs in adult populations has a greater beneficial effect on HRQOL and mood status when compared with energy-restricted diets alone.

## Methods

The current study followed the preferred reporting guidelines for systematic reviews and meta-analyses (PRISMA) [39], and was registered in the international prospective register of systematic reviews (PROSPERO, www.crd.york.ac.uk/PROSPERO; identifier: CRD4202173434). The detailed design and rationale have been described in detail elsewhere [40].

### Literature search

PubMed/MEDLINE, EMBASE, ISI (Web of sciences), Scopus, and Google Scholar were searched up to Apr 2021 by using Medical Subject Headings (MeSH) and non-MeSH keywords outlined in Supplementary Table 1. No language restriction was applied for searching the databases. The reference lists of all relevant studies were checked to identify any additional studies.

### Eligibility criteria

Titles, abstracts, and full texts were screened and cross-checked by six reviewers (Z.Y, S.S, SH.R, S.B, S.MT, and T.Z) based on the following pre-defined inclusion criteria:

(i) Studies conducted in overweight or obese adults (age ≥ 18 years and BMI ≥ 25 kg/m$^2$);
(ii) Studies published as original articles using randomized or non-randomized controlled clinical trial study designs (either parallel or cross-over);
(iii) If there were multiple published reports from the same study, we included the publication with the longest follow-up or a greater number of included participants;
(iv) Studies that compared a weight-loss diet plus any type of exercise (i.e., aerobic or resistance) with an isocaloric weight-loss diet;
(v) Studies reporting mean baseline, after the intervention, or change values, and their corresponding standard deviations (SDs) for depression, SF36-MCS (SF36-mental component summary), SF36-PCS (SF36-physical component summary), or total scores of disease-specific HRQOL questionnaires.

Studies were excluded from the systematic review if they:

(i) Were conducted on animals, children, adolescents, professional athletes, and pregnant, or lactating women;
(ii) Were published as reviews, observational studies, or study protocols;
(iii) Were single arm in design;
(iv) Included different types of weight-loss diets in both arms;
(v) Included non-isocaloric diets in both arms;
(vi) Included follow-up durations of less than two weeks because the time interval would be too short for effective weight-loss diets;

The consensus opinion of the reviewers resolved any disagreement about study selection.

### Data extraction and management

As duplicating the data extraction process reduces both the risk of making mistakes and a single person's biases [41], the data were extracted by two independent investigators (SH.R, T.Z) from eligible studies and any disagreement was resolved by discussion with the principal investigator (A.S-A).

Study and participants' characteristics: the study design (parallel/cross-over), geographical location and duration; the number of participants in each arm, the participants' age, sex, health condition, and being physically active or sedentary at baseline; Intervention details: The characteristics of the exercise program (including exercise duration, intensity, frequency, and being conducted under supervision or not); Comparison details: The characteristics of the weight-loss diet (including the amount of calorie-restriction, type of diet, and macronutrient distributions); Outcome measures: The type of questionnaire; assessing HRQOL and depression as primary outcomes or not; baseline, post-intervention, or change from baseline mean ± standard deviation (SD) for depression or quality of life scores, *P*-values for within-group and between-group comparisons.

### Risk of bias assessment in individual studies

The quality of included articles was assessed using the Cochrane collaboration risk of the bias assessment tool [42] considering seven domains: (i) random sequence generation, (ii) allocation concealment, (iii) blinding of participants and personnel, (iv) blinding of outcome assessment, (v) incomplete outcome data, (vi) selective reporting, and (vii) dietary compliance. Studies were categorized as low risk of bias, high risk of bias, or unclear risk of bias for each domain. To obtain the overall quality of studies, we did not take the "blinding of participants and personnel domain" into account because of the difficulty in blinding participants and personnel in lifestyle modification trials. Considering the remaining domains (random sequence generation, allocation concealment, blinding of outcome assessment, incomplete outcome data, selective reporting, and dietary compliance) as key domains, the studies were categorized as low risk (low risk for all domains), unclear risk (unclear risk for at least one domain), and high risk (high risk for at least one domain). Any disagreement was resolved through discussion with the principal investigator (A.S.A).

### The overall quality of evidence

The quality of evidence for each outcome was assessed using The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach based on the following domains: assessed risk of bias, inconsistency, indirectness, imprecision, and publication bias [43–45]. The quality of evidence was categorized as high, moderate, low, and very low.

### Statistical analyses

The difference in mean changes and their standard deviations (SDs) between the two arms of each study was used as the effect size for SF36-MCS and SF36-PCS quantitative synthesis. Depression and HRQOL disease-specific questionnaire scores were assessed using different tools in different studies. For this reason, standardized mean differences are calculated and Hedges'g statistic is used.

Two [35, 46] out of six [5, 27, 33–35, 46] studies reported the mean change values for depression. Therefore, the SDs for mean change values were calculated using correlation *r* of studies [35, 46] that reported baseline, after intervention and change values ($r = 0.57$ for depression).

Because none of the studies provided data on changes in SF36 and HRQOL disease-specific scores, the SDs for change values were calculated by using a correlation coefficient of 0.5. The meta-analysis was repeated using correlation coefficients of 0.2 and 0.8 to check the sensitivity of the meta-analysis to selected correlation coefficients. The overall estimates were calculated using both the DerSimonian and Laird random-effects model [47] and the inverse variance heterogeneity (IVhet) model [48] which has more coverage likelihood compared to DerSimonian and Laird random-effects model.

Between-study heterogeneity was assessed using Cochran's $Q$-test and $I$-squared ($I^2$) statistic [49]. The Cochran's $Q$ test with a $P$-value of $< 0.05$ was considered a statistically significant heterogeneity, and $I^2$ with values of greater than 75% was considered the between-study heterogeneity [40].

To explore the potential source of heterogeneity, several subgroup analyses were performed based on: country (Astralia/ Canada/ Iran/ USA/ Netherlands), sex of participants (male / female / both), intervention duration (≤ 12 weeks / > 12 weeks), type of questionnaire [Hospital Anxiety and Depression Scale (HADS), Geriatric Depression Scale (GDS)], outcome (primary / secondary), intervention under supervision (yes / no / partially / not mentioned), risk of bias assessment (low / unknown / high), baseline physical activity status (not mentioned / sedentary), additional weight management program (not mentioned / behavior modification / routine classes), type of exercise program (strength / aerobic / strength plus aerobic / not mentioned), type of dietary intervention (diet / education / guideline), and reporting data (complete / incomplete). In addition, meta-regression analysis was performed to evaluate if prespecified factors can explain the variation between studies.

Publication bias for each outcome was assessed by inspecting funnel plots and conducting statistical asymmetry tests (Egger's regression asymmetry test [50] and Begg's adjusted rank correlation test [51]), if there were at least ten studies accessible for meta-analysis [42]. Sensitivity analysis was performed to assess the robustness of overall effects by sequentially removing individual studies from the meta-analysis [52]. All of the analyses were performed using STATA, version 11.2 (Stata Corp, College Station, TX), and two-sided $P$ values $\leq 0.05$ were considered statistically significant.

## Results

### Literature search

A total of 42,189 publications were identified during the initial database literature search; of those, 469 articles were included in the full-text screening stage. Out of these, 454 articles were excluded (119 studies were repeated publications on the same study; the energy deficit of diets was not equal in the diet alone and diet plus exercise groups for 34 trials; the full texts of 17 articles were not accessible; the outcomes of 148 publications were not relevant; 76 trials did not conduct a weight-loss program; 1 study represented the data after a follow-up period; 4 studies did not report total scores for depression, SF36-PCS; SF36-MCS or HRQOL disease-specific tools and 55 articles were removed for other reasons). Sixteen arms from fifteen articles were included in the present systematic review. Of those, one study did not provide sufficient data based on each arm of the intervention [37]. Thus, this trial was not included in the quantitative synthesis for depression. Therefore, fifteen arms from fourteen studies were included in the meta-analysis (Fig. 1).

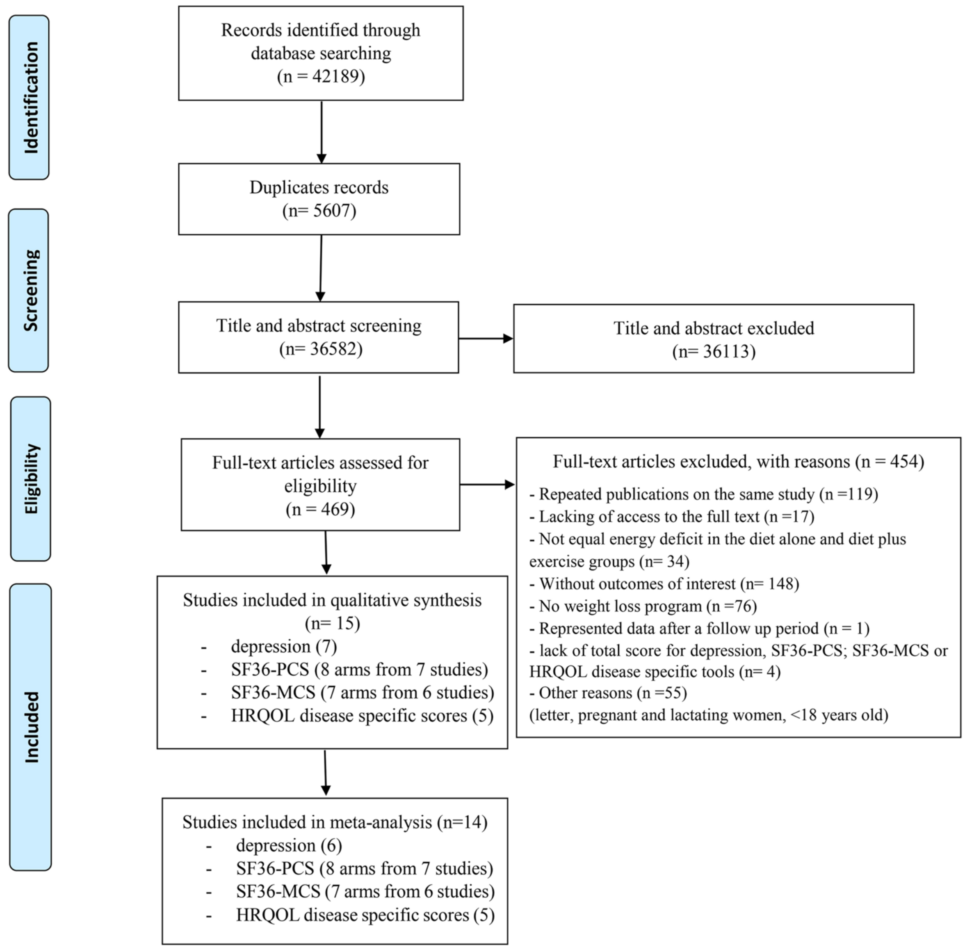


**Fig. 1** Flow diagram of study selection process

## Characteristics of the included studies

Sixteen arms from fifteen articles were included in the systematic review which were published from 1995 to 2016. All trials assessing the effects of exercise as an adjuvant to energy-restricted diets on HRQOL or depression were parallel in design. However, some cross-over studies assessed the effects of adding exercise to energy-restricted diets on the other outcomes that were not included in the current study. The majority of included studies were from the United States of America (10 publications [27, 28, 31–34, 36, 37, 46, 53]), others were from Canada [26], Netherlands [35], Australia [54], and Iran [29]. The duration of the studies ranged from 8 to 72 weeks.

All studies were conducted on overweight/obese individuals. Two studies [33, 36] were conducted in females, two studies were completed on males [27, 29], and others included participants from both sexes [26, 28, 30–32, 34, 35, 46, 53, 54]. The calorie restriction of diets in all studies varied from 200 to 1000 kcal/day, and The exercise programs of included studies were aerobic [26, 29, 30, 32, 33, 35], resistance [53], or both [28, 31, 34, 36, 37, 46, 54].

Two independent couples of arms from the Lalonde et al. study [26] are included in the current study. Moreover, the two Messier et al.'s studies [28, 53] are independent since they are conducted at different times and on different samples with different aims. The characteristics of included studies are provided in Table 1.

## Risk of bias and quality of evidence

A total of 14 trials were included in the quality assessment. Of these, two RCTs [31, 34] RCTs [31, 34] were categorized as low risk of bias, eight studies [26–28, 30, 33, 35, 36, 54] were classified as unclear risk of bias; and four studies [29, 32, 46, 53] were classified as high risk. Approximately 80% of trials [26–28, 30–34, 36, 46, 54] were categorized as low risk of bias for random sequence generation, and three studies [31, 34, 54] reported the approach to conceal their randomization (allocation concealment). As blinding of the participants and personnel is impossible in lifestyle modification trials, the domain of blinding of participants and personnel was not taken into account in the overall score of quality assessment. Seven trials [27, 28, 30, 31, 33, 34, 46] were low risk of bias for

**Table 1** Characteristics of included studies

| Author (Year)/ country | Participants (int/cont) / sex | Mean age (int/cont) | Population characteristics | Duration (week)/ Design | Exercise protocol | Energy restriction protocol | Interested outcome/ assessment | Result |
|---|---|---|---|---|---|---|---|---|
| Geliebter [46] (1997)/ USA | (43/22)/ B | 35/ 36 (int = strength training + diet) 36/ 36 (int = aerobic training + diet) | Healthy | 8/ P | One group: strength exercise (60 min; 3 times/ week) The other group: aerobic exercise (30 min; 3 times/ week) | 70% of RMR | Depression/ BDI | ↔ |
| Imayama [33] (2011)/ USA | (117/118)/ F | 58/ 58.1 | Healthy | 48/ P | Aerobic exercise (45 min; 5 days/week) | 1200- 2000 kcal/day | Depression / BSI-18 | ↔ |
| Kitzman [32] (2016)/ USA | (25/24)/ B | 66.3/ 66.5 | Patients with heart failure with preserved ejection fraction | 20/ P | Walking (3 times/week) | Calorie deficits ~ 350-400 kcal/day | Quality of life/ SF-36, KCCQ | ↔ ↔ |
| Lalonde [26] (NCEP step I) (2002)/ Canada | (10/9) B | 40–60 * | Patients with dyslipidemia | 12/ P | Aerobic exercise (45 min of cardiovascular exercise + 10 min of stretching; 3 times/week) | NCEP step I diet (lose no more than 250 g per week.) | Quality of life/ SF-36 | ↔ |
| Lalonde [26] (NCEP step II) (2002)/ Canada | (10/12)/ B | 40–60 * | Patients with dyslipidemia | 12/ P | Aerobic exercise (45 min of cardiovascular exercise + 10 min of stretching; 3 times/ week) | NCEP step II diet (lose no more than 250 g per week.) | Quality of life/ SF-36 | ↔ |
| Leehey [27] (2016)/ USA | (14/18)/ M | 66.6/ 65.4 | Patients with chronic kidney disease (stages 2–4) | 52/ P | Combined aerobic/ resistance exercise (12-week exercise training = 60 min aerobic plus 20–30 min resistance training; 3 times/ week 40-week home exercise = 60 min; 3 times/ week or 30 min; 6 times/ week) | Calorie deficits = 200–250 kcal | Quality of life / SF-36 Depression/ CES-D | ↔ ↔ |
| Messier [53] (2010)/ USA | (36/71)/ F | 57.2/ 58 | Healthy | 24/ P | Progressive resistance training program (3 days/ week) | Calorie deficits = 500–800 kcal | Quality of life/ 20 item Medical Outcomes Study General | ↔ |

**Table 1** (continued)

| Author (Year)/ country | Participants (int/cont) / sex | Mean age (int/cont) | Population characteristics | Duration (week)/ Design | Exercise protocol | Energy restriction protocol | Interested outcome/ assessment | Result |
|---|---|---|---|---|---|---|---|---|
| Messier [28] (2013)/ USA | (124/124)/ B | 65/ 66 | Patients with knee osteoarthritis | 72/ P | Combined aerobic/ resistance exercise (15 min aerobic walking, 20 min strength training, 15 min a second aerobic phase, and 10 min cool-down); 3 days/ week) | Calorie deficits = 800–1000 kcal | Quality of life/ SF-36 | ↔ |
| Napoli [34] (2014)/ USA | (124/124)/ B | 70/70 | Patients with frailty | 26/ P | Progressive multicomponent exercise training program (15 min flexibility, 30 min aerobic, 30 min resistance training, and 15 min balance exercises; 3 times/week) | Calorie deficits = 500–750 kcal | Quality of life/ IWQOL<br>Depression/ GDS | ↔<br>↑ |
| Nikroo [29] (2015)/ Iran | (12/13)/ B | 40.25/ 34 | Patients with NASH | 12/ P | Aerobic exercise (35-50 min; 3 days/week) | Calorie deficits = 500 kcal | Quality of life / SF-36 | ↔ |
| Scott [54] (2013)/Australia | (13/15)/ B | 33.9/44.7 | Patients with asthma | 12/ P | Combined aerobic/ resistance exercise (Gymnasium membership and a group personal training session; 1 h/week) | 885–1170 kcal/ day | Quality of life/ AQLQ | ↔ |
| Shah [30] (2011)/ USA | (20/8)/ B | 42.4/ 41 | Bariatric surgery patients | 12/ P | Aerobic exercise (The exercise goal was to expend ≥ 2,000 kcal/ week; at least 5 days/ week) | 1,200–1,500 kcal/ day | Quality of life/ SF-36, IWQOL | ↔ ↔ |
| Snel [35] (2012)/ The Netherland | (13/14)/ B | 53/56 | Patients with insulin-dependent T2DM | 16/ P | Aerobic exercise (one hour/week training in hospital and at least four sessions/week training at home) | ~450 kcal per day | Depression/ HADS | ↔ |
| Thomson [36] (2010)/ USA | (35/14)/ F | $29.3 \pm 0.7$ [¥] | Patients with PCOS | 20/ P | Combined aerobic/ resistance exercise (3 walking /jogging and 2 strength training sessions/ week) | high protein meal plan (6,000 kJ/day) | Depression/ CES-D | ↔ |

**Table 1** (continued)

| Author (Year)/ country | Participants (int/cont) / sex | Mean age (int/cont) | Population characteristics | Duration (week)/ Design | Exercise protocol | Energy restriction protocol | Interested outcome/ assessment | Result |
|---|---|---|---|---|---|---|---|---|
| Villareal [31] (2011)/ USA | (28/26)/ B | 70/ 70 | Healthy | 26/ P | Combined aerobic/ resistance exercise (90 min, 3 sessions/ week) | Calorie deficits = 500-750 kcal | Quality of life/ SF-36 | ↔ |
| Wadden [37] (1997)/ USA | (29/29)/ F | 42.8/ 41 | Healthy | 48/ P | Combined aerobic/ resistance exercise (3 sessions/ week for the first 28 weeks and 2 sessions/ week thereafter; 40 min per session) | Weeks 2–17 (~ 880-900 kcal/day and 2 cups of salad per day) Weeks 18–20 (~ 1,250 kcal/day) Weeks 22–48 (~ 1,500 kcal/day) | Depression/ BDI, POMS | ↔ |

*AQLQ* The Juniper Asthma Quality of Life Questionnaire, *B* Both sexes, *BMR* Basal Metabolic Rate, *BDI* Beck Depression Inventory, *BDI*-II Beck Depression Inventory II, *BSI-18* Brief Symptom Inventory-18, *CES-D* Center for Epidemiologic Studies Depression Scale, *cont* Control, *F* Female, *GDS* Geriatric Depression Scale, *HADS* Hospital Anxiety and Depression Scale, *IDEA* The Intensive Diet and Exercise for Arthritis study, int Intervention, *IWQOL* Impact of Weight on Quality of Life–Lite, *KCCQ* The Kansas City Cardiomyopathy Questionnaire, *M* Male, *MSE* The Minor Symptoms Evaluation, *NASH* Non-alcoholic Steatohepatitis, *NCEP* National Cholesterol Education Program, *NHP* Nottingham Health Profile, *P* Parallel, *PCOS* Polycystic Ovary Syndrome, *PCOSQ* Polycystic Ovary Syndrome Questionnaire, *POMS* Profile Of Mood States, *RMR* Resting Metabolic Rate, *SF-36* The SF36 36-Item Short-Form Health Survey, *SSA* The Subjective Symptoms Assessment, *T2DM* Type 2 Diabetes Mellitus, *VLCD* Very Low Calorie Diet

↑ Adding exercise to the energy-restricted programs had a positive effect on depression;

↓ Adding exercise to the energy-restricted programs had a negative effect on depression;

↔ Adding exercise to the energy-restricted programs had a null effect on the interested outcome;

* The mean age of intervention and control groups was not reported, thus the range of ages is provided;

¥ The mean age of intervention and control groups was not reported, thus the mean age of total population is provided blinding of outcome assessor, and eleven trials [26–28, 30–34, 36, 53, 54] were low risk of bias for incomplete outcome data. There was no evidence of selective outcome reporting in the included trials, and eight studies were categorized as low risk of bias for dietary compliance [26–28, 30–34]. The details of the risk of bias assessments are shown in Supplementary Table 2.

The GRADE approach was used to assess the quality of evidence. The quality of evidence was low for the effect of adding exercise to the energy-restricted diet on disease-specific HRQOL, and depression status; and high for the effect of adding exercise to the energy-restricted diets on wither SF36-PCS or SF36- MCS (Supplementary Table 3).

## Meta-analyses

### Depression

Meta-analysis of six trials (including 462 participants) [27, 33–36, 46] found that adding exercise to the energy-restricted diet interventions had no significant effect on depression scores neither by using the random effect model (hedges' g = − 0.04, 95% CI: − 0.28, 0.20, $P = 0.73$) (Fig. 2) nor by using the IVhet model (hedges' g = − 0.04, 95% CI: − 0.30, 0.21, $P = 0.73$). Moreover, the between-study heterogeneity was moderate [40] (Q statistic = 6.92, P for heterogeneity = 0.22, $I^2 = 27.8\%$) for both models. The results remained non-significant even after conducting several subgroup analyses (Supplementary Table 4).

### Physical component summary (PCS) scores of SF36 questionnaire

Meta-analysis of eight arms from seven trials (including 467 participants) [26–32] found that adding exercise to the energy-restricted diet interventions had no significant effect on SF36-PCS scores with no evidence of between-study heterogeneity neither by using the random effect model (weighted mean difference (WMD) = 1.51, 95% CI: − 0.16, 3.18, $P = 0.08$; $I^2 = 0.0\%$, $P$ for heterogeneity = 0.78, Fig. 3) nor by using the IVhet model (WMD = 1.51, 95% CI: − 0.16, 3.18, $P = 0.08$; $I^2 = 0.0\%$, $P$ for heterogeneity = 0.78). This result was marginally significant ($P < 0.1$) but not clinically important. The results remained non-significant even after performing several subgroup analyses (Supplementary Table 5).

### Mental component summary (MCS) scores of SF36 questionnaire

The results of meta-analysis of seven arms from six trials (428 participants) [26–31] revealed that adding exercise to the energy-restricted diet interventions had no significant effect on SF36-MCS scores with no evidence of

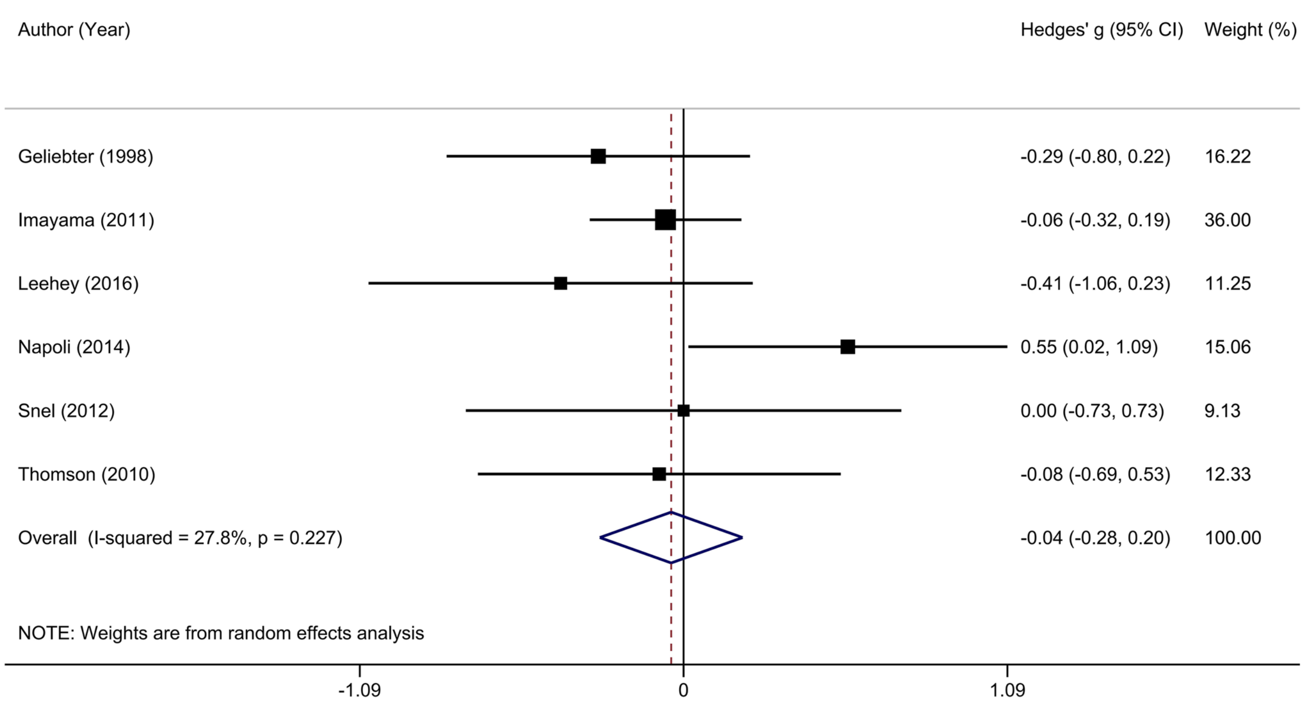


**Fig. 2** Forest plot describing the effect of exercise plus a weight-loss diet compared with a weight-loss diet alone on depression using a random-effects model

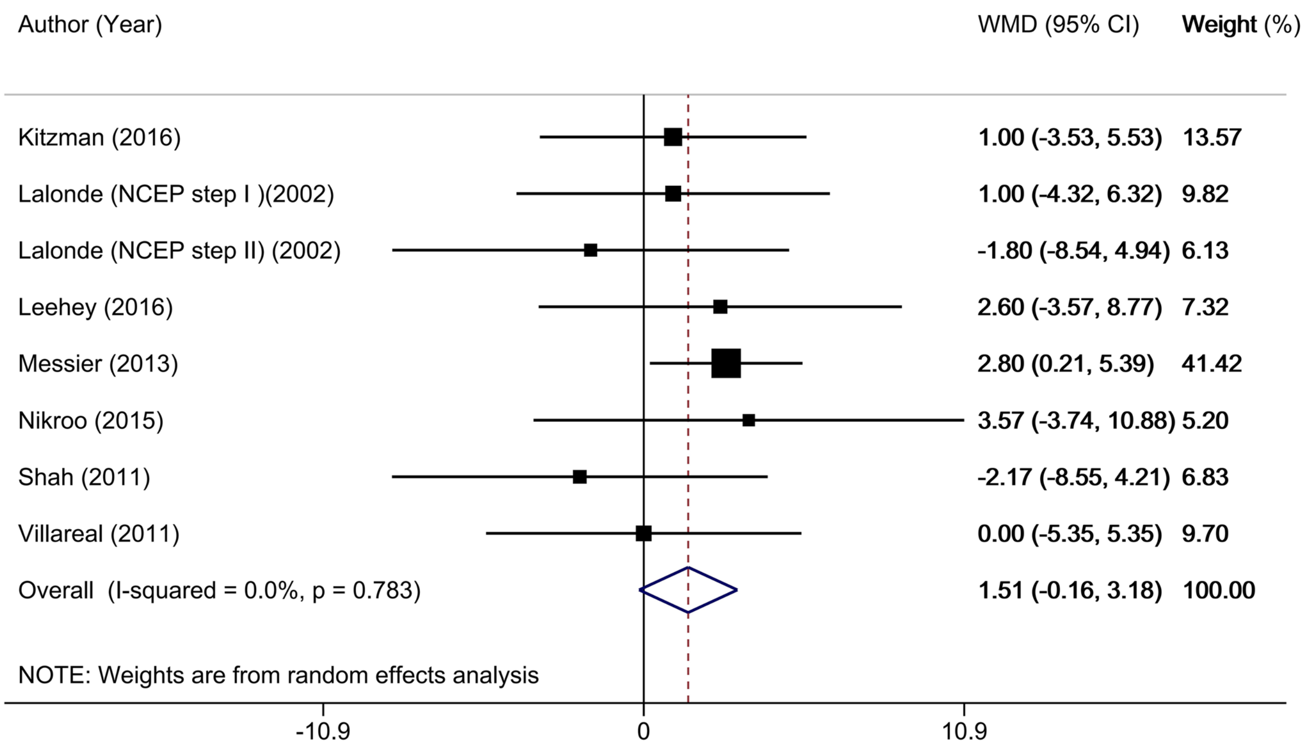


**Fig. 3** Forest plot representing the effect of exercise plus a weight-loss diet compared with a weight-loss diet alone on SF36- PCS using a random-effects model

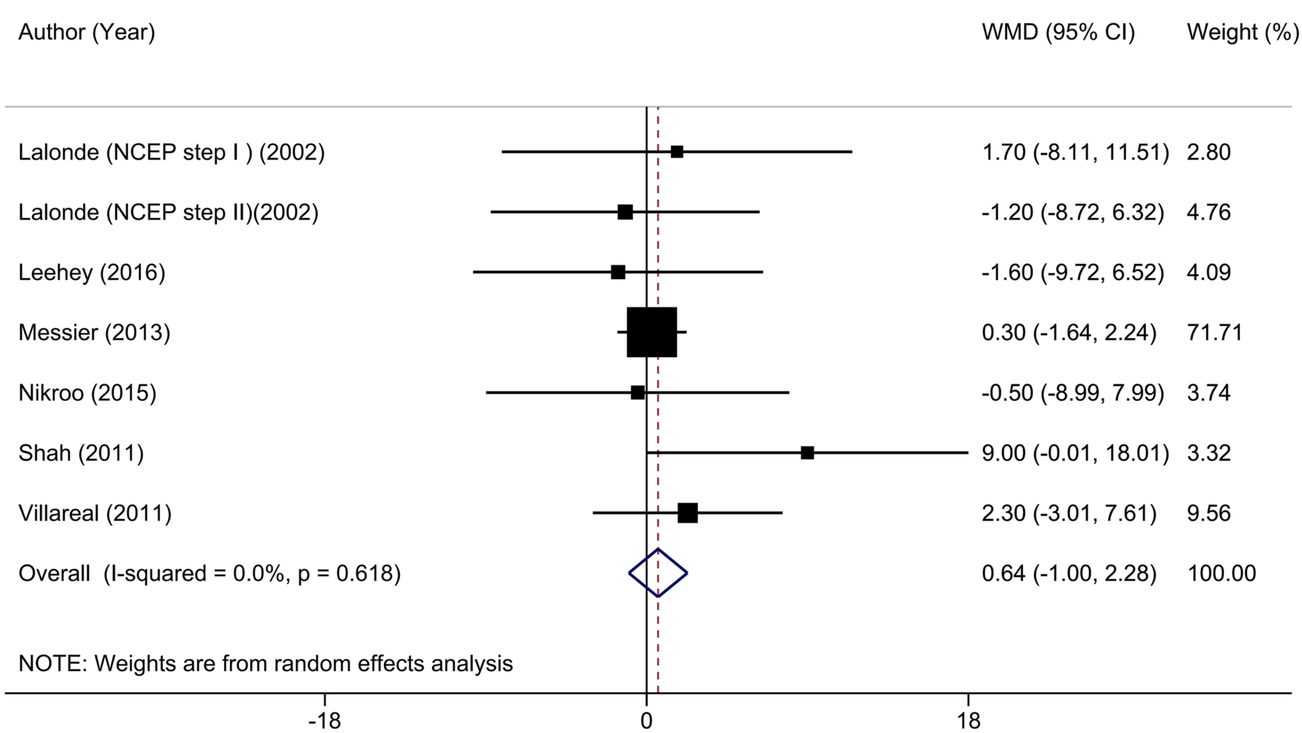


**Fig. 4** Forest plot depicting the effect of exercise plus a weight-loss diet compared with a weight-loss diet alone on SF36- MCS using a random-effects model

between-study heterogeneity neither by using the random effect model (WMD = 0.64, 95% CI: − 1.00, 2.28, $P$= 0.44; $I^2$= 0.0 %, $P$ for heterogeneity = 0.62, Figure 4) nor by using the IVhet model (WMD = 0.64, 95% CI: − 1.00, 2.28, $P$= 0.44; $I^2$= 0.0 %, $P$ for heterogeneity = 0.62). Several subgroup analyses were conducted and no significant effects were found (Supplementary Table 5).

### Disease-specific health-related quality of life questionnaire scores

Meta-analysis of 5 trials (266 participants) [30, 32, 34, 53, 54] found that adding exercise to the energy-restricted diet interventions had no significant effect on disease-specific questionnaire scores with no between-study heterogeneity (hedges'g = 0.16, 95% CI: − 0.09, 0.40, $P$ = 0.20; $I^2$ = 0.0%, $P$ for heterogeneity = 0.91), using neither the random effect model (Fig. 5) nor the IVhet model.

Due to the lack of evidence of between-study heterogeneity and the limited number of included studies, we did not perform subgroup analysis for this outcome.

## Meta-regression

On meta-regressions, no significant associations were found between the effects of energy-restricted diet plus exercise compared with energy-restricted diets alone on depression and HRQOL and following study-level covariates: type of questionnaire, type of dietary intervention, type of exercise program, intervention duration, outcome, intervention under supervision, risk of bias assessment result, sex of participants, baseline physical activity status, additional weight management program (supplementary table 6).

## Sensitivity analysis and Publication bias

With regards to sensitivity analyses, the overall effects of exercise on depression and HRQOL did not change by removing individual studies from the analyses, and visual inspection of the funnel plots revealed no evidence of publication bias (supplementary Fig. 1 [A-C]).

## Discussion

The current systematic review and meta-analysis of RCTs examining the effects of energy-restricted diet plus exercise compared with energy-restricted diets alone did not significantly affect the quality of life and depression. These findings remained non-significant in several pre-defined subgroup analyses. Some studies have reported the beneficial effects of adding exercise to an energy-restricted diet [26, 28–30, 33, 34]. However, a recent systematic review [25] indicated that although four out of nine included studies supported the role of exercise in the improvement of

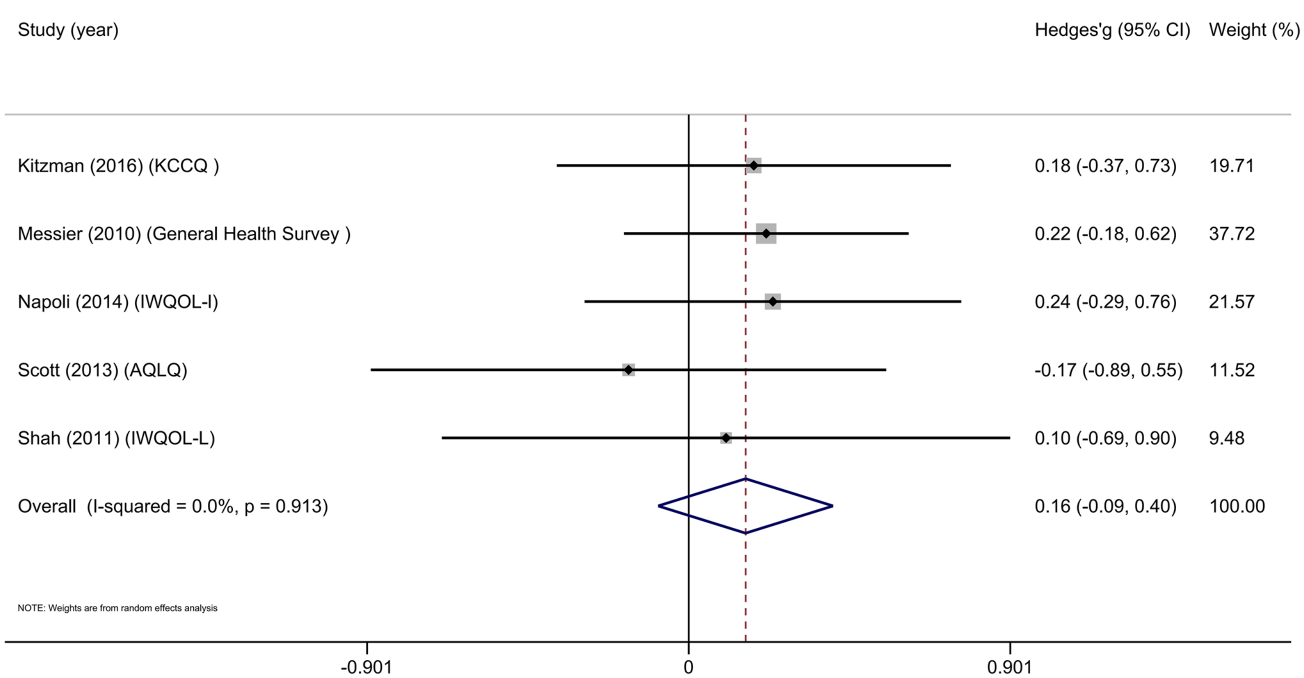


**Fig. 5** Forest plot depicting the effect of exercise plus a weight-loss diet compared with a weight-loss diet alone on disease-specific questionnaire scores using a random-effects model

HRQOL when added to energy-restricted diets, a definitive conclusion was not feasible because of the limited number of included studies. In addition, five more trials [26, 27, 29, 32, 54] which were discounted in Van den Hoek et al. systematic review [25], were included in the current study. It seems that two [26, 54] out of them did not match the inclusion criteria (not proper mean BMI of their participants) of their review [25].

In the present meta-analysis, the random effect and IVhet models were used to account for between-study heterogeneities and floor effects. However, it is essential to acknowledge that there were limitations with the design of the individual studies which might have biased the results in the direction of the non-significant effects on depression and HRQOL of exercise as an adjuvant to diet. These results, found in the present review, were also found in most previous clinical trials [27, 34–37, 54].

These findings may be due to the following reasons: The first and the most important reason may be limiting the inclusion criteria to trials with an isocaloric weight-loss diet in their arms. This may have attenuated the between-group differences in weight loss which is a key mediator in lifestyle modification-mood status relationship [55]. The second reason is that the generic HRQOL tools (such as SF36) are not specific enough to explore the subtle changes [56] and are susceptible to ceiling and floor effects [57]. Given that a methodological challenge in studies comparing the effect of diet plus exercise and diet alone is the masking of exercise effects by the magnitude of weight-loss effects [35], the questionnaires which are applied in such studies should be sensitive enough to detect the slight differences. Thus, SF36 might not be an ideal questionnaire in this regard. To address these limitations, some studies have proposed the use of the IWQOL questionnaire as a disease-specific tool in addition to the SF36 in trials since the disease-specific tools do not have such limitations [57–60].

The summary effect of adding exercise to an energy-restricted diet on disease-specific HRQOL scores was insignificant in the present meta-analysis. Two [30, 34] out of five [30, 32, 34, 53, 54] included studies used the IWQOL as an obesity-specific tool. However, these two studies [30, 34] did not indicate any significant between-group differences in weight-loss (as a key linkage between lifestyle interventions and HRQOL [55]); as such, they failed to address the effects of exercise plus diet or diet-related weight loss on the HRQOL. Nevertheless, Napoli et al. [34] reported an improvement in HRQOL in the diet plus exercise group compared with the exercise group in the 6-month follow-up period during which all participants were required to maintain their weight loss.

The studies included in the present systematic review used different tools for assessing depression; among these, BDI may be a more practical tool for weight-loss interventions. BDI has two primary factors including cognitive/affective and somatic items. Somatic items (such as body image) might help to explore the effect of weight-loss interventions on depression [61]. However, Geliebter et al. [46] utilized the BDI questionnaire to assess depression status, but failed to show any significant effect. This finding may be related to relatively short duration (8 weeks) and low sample size. Although the depression tools used in these studies were different, we used bias-corrected standardized mean difference (Hedges' g) to reduce the effect of the between-scale heterogeneity.

To the best of our knowledge, this is the first systematic review and meta-analysis investigating the effects of adding exercise to energy-restricted diets on quality of life and depression in overweight/obese adults. The strengths of the current meta-analysis are as follow: (1) it was conducted on clinical trials which are the gold standard methods for evaluating the effectiveness of interventions; (2) a comprehensive search method was applied to identify all potential studies; (3) the exercise protocol details (such as intensity and type of exercise) were considered in the analyses; (4) in the present study, trials with isocaloric weight-loss diets as part of their research arms were included to prevent the confounding effects of the amount of calorie restriction of the diet; (5) the quality of the overall provided evidence was assessed for each outcome using the GRADE system (6) we have used two different approaches to utilize any information available to provide an estimate of the sought overall effect, and appropriate sensitivity analysis adds strength to the evidence to achieve a proper estimation.

The present meta-analysis also has some limitations which should be considered when interpreting its results: (1) most of our included studies had low or unclear risk of bias according to the Cochrane Collaboration tool, and high-quality studies are still needed; (2) most of the trials included in the present study have assessed HRQOL or depression as secondary outcomes; therefore, these studies did not have enough statistical power to address the effects of energy-restricted diets plus exercise in comparison to energy-restricted diets alone on HRQOL or depression; (3) the limited number of trials included in our review may cause a relatively low internal and therefore external validity; (4) given that this study was conducted on overweight or obese adults (age $\geq$ 18 years and BMI $\geq$ 25 kg/m2), the results of the current study might not be generalized to non-obese individuals and other age groups; (5) The outcome variables were assessed by questionnaire and their assessment are prone to a degree of measurement error; (6) As the majority of the included studies did not report the change values in the intervention and control groups, the SDs for change values were calculated by using a hypothetical correlation coefficient of 0.5. However, to check the sensitivity of the meta-analysis to selected correlation coefficients, we repeated the meta-analyses using the lower and upper limits of the confidence interval. It should be mentioned that the results were not sensitive to different values of "correlation coefficient"; (7) as blinding of participants and personnel was not possible for the interventions assessing the effect of diet or exercise, the observed effects in the included studies might have been affected.

In conclusion, our meta-analysis did not support the improving or reducing effect of adding exercise to an energy-restricted diet for improving depression and HRQOL compared to an energy-restricted diet alone in overweight or obese adults. However, the effect of adding exercise to energy-restricted diets on SF36-PCS was marginally significant. It should be noted that well-designed RCTs are still needed to investigate further the uncertainty of the benefits of exercise plus diet intervention on mood status. Until then, given the well-known benefits of exercise on different aspects of health, exercise should be recommended as an essential component of lifestyle interventions for obesity management.

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**Author contributions** The authors' responsibilities were as follow: designing the study: ASA; managing the study: ASA and ZY; conducting the research: ZY; conducting the statistical analyses: SS; screening, data extraction, and assessment of the risk of bias within studies: ZY, SS, SHR, SB, SMT, and TZ; writing the manuscript: SHR, JSB, and S.S. All authors contributed to the study design and drafting of the manuscript.

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**Data availability** The studies included in the review will be available upon request.

**Code availability** Not applicable.

## Declarations

**Conflict of interest** There is no conflict of interest to report.

**Ethical approval** We will follow the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) for reporting the present systematic review and meta-analysis. The protocol is undergoing registration in the International Prospective Register of Systematic Reviews (PROSPERO) database.

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

## References

1. Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., et al. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the global burden of disease study 2013. *The Lancet, 384*(9945), 766–781. https://doi.org/10.1016/S0140-6736(14)60460-8Get
2. NCD Risk Factor Collaboration, Az, L., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., et al. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128· 9 million children, adolescents, and adults. *The Lancet, 390*, 2627–42. https://doi.org/10.1016/S0140-6736(17)32129-3
3. Blüher, M. (2019). Obesity: Global epidemiology and pathogenesis. *Nature Reviews Endocrinology, 15*(5), 288–298. https://doi.org/10.1038/s41574-019-0176-8
4. Elsenbruch, S., Hahn, S., Kowalsky, D., Öffner, A. H., Schedlowski, M., Mann, K., et al. (2003). Quality of life, psychosocial well-being, and sexual satisfaction in women with polycystic ovary syndrome. *The Journal of Clinical Endocrinology Metabolism, 88*(12), 5801–5807. https://doi.org/10.1210/jc.2003-030562
5. Thomson, R. L., Buckley, J. D., & Brinkworth, G. D. (2016). Perceived exercise barriers are reduced and benefits are improved with lifestyle modification in overweight and obese women with polycystic ovary syndrome: A randomised controlled trial. *BMC women's health, 16*(1), 14. https://doi.org/10.1186/s12905-016-0292-8
6. Bloom, D. E., Cafiero, E., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, LR., Fathima, S., et al.(2012). The global economic burden of noncommunicable diseases. Program on the Global Demography of Aging.
7. Greenberg, P. E., Fournier, A.-A., Sisitsky, T., Pike, C. T., & Kessler, R. C. (2015). The economic burden of adults with major depressive disorder in the United States (2005 and 2010). *The Journal of Clinical Psychiatry, 76*(2), 155–162. https://doi.org/10.4088/JCP.14m09298
8. Cloutier, M., Greene, M., Guerin, A., Touya, M., & Wu, E. (2018). The economic burden of bipolar I disorder in the United States in 2015. *Journal of Affective Disorders, 226*, 45–51. https://doi.org/10.1016/j.jad.2017.09.011
9. Hakulinen, C., Elovainio, M., Arffman, M., Lumme, S., Pirkola, S., Keskimäki, I., et al. (2019). Mental disorders and long-term labour market outcomes: Nationwide cohort study of 2 055 720 individuals. *Acta Psychiatrica Scandinavica, 140*(4), 371–381. https://doi.org/10.1111/acps.13067
10. Segura-Garcia, C., Caroleo, M., Rania, M., Barbuto, E., Sinopoli, F., Aloi, M., et al. (2017). Binge eating disorder and bipolar spectrum disorders in obesity: Psychopathological and eating behaviors differences according to comorbidities. *Journal of Affective Disorders, 208*, 424–430. https://doi.org/10.1016/j.jad.2016.11.005
11. Yumuk, V., Tsigos, C., Fried, M., Schindler, K., Busetto, L., Micic, D., et al. (2015). European guidelines for obesity management in adults. *Obesity Facts, 8*(6), 402–424. https://doi.org/10.1159/000442721

12. Fruh, S. M. (2017). Obesity: Risk factors, complications, and strategies for sustainable long-term weight management. *Journal of the American Association of Nurse Practitioners, 29*(S1), S3–S14. https://doi.org/10.1002/2327-6924.12510
13. Ein, N., Armstrong, B., & Vickers, K. (2019). The effect of a very low calorie diet on subjective depressive symptoms and anxiety: meta-analysis and systematic review. *International Journal of Obesity, 43*(7), 1444–55. https://doi.org/10.1038/s41366-018-0245-4
14. Fabricatore, A. N., Wadden, T. A., Higginbotham, A. J., Faulconbridge, L. F., Nguyen, A. M., Heymsfield, S. B., et al. (2011). Intentional weight loss and changes in symptoms of depression: A systematic review and meta-analysis. *International Journal of Obesity, 35*(11), 1363–76. https://doi.org/10.1038/ijo.2011.2
15. Carson, T. L., Hidalgo, B., Ard, J. D., & Affuso, O. (2014). Dietary interventions and quality of life: A systematic review of the literature. *Journal of Nutrition Education and Behavior, 46*(2), 90–101. https://doi.org/10.1016/j.jneb.2013.09.005
16. Dauwan, M., Begemann, M. J., Heringa, S. M., & Sommer, I. E. (2015). Exercise improves clinical symptoms, quality of life, global functioning, and depression in schizophrenia: A systematic review and meta-analysis. *Schizophrenia Bulletin, 42*(3), 588–599. https://doi.org/10.1093/schbul/sbv164
17. Schuch, F. B., Vancampfort, D., Rosenbaum, S., Richards, J., Ward, P. B., & Stubbs, B. (2016). Exercise improves physical and psychological quality of life in people with depression: A meta-analysis including the evaluation of control group response. *Psychiatry Research, 241*, 47–54. https://doi.org/10.1016/j.psychres.2016.04.054
18. Catalan-Matamoros, D., Gomez-Conesa, A., Stubbs, B., & Vancampfort, D. (2016). Exercise improves depressive symptoms in older adults: An umbrella review of systematic reviews and meta-analyses. *Psychiatry Research, 244*, 202–209. https://doi.org/10.1016/j.psychres.2016.07.028
19. Schuch, F. B., Vancampfort, D., Richards, J., Rosenbaum, S., Ward, P. B., & Stubbs, B. (2016). Exercise as a treatment for depression: A meta-analysis adjusting for publication bias. *Journal of Psychiatric Research, 77*, 42–51. https://doi.org/10.1016/j.jpsychires.2016.02.023Get
20. Curioni, C., & Lourenco, P. (2005). Long-term weight loss after diet and exercise: A systematic review. *International Journal of Obesity, 29*(10), 1168–1174. https://doi.org/10.1038/sj.ijo.0803015
21. Edwards, B. A., Bristow, C., O'Driscoll, D. M., Wong, A. M., Ghazi, L., Davidson, Z. E., et al. (2019). Assessing the impact of diet, exercise and the combination of the two as a treatment for OSA: A systematic review and meta-analysis. *Respirology, 24*(8), 740–751. https://doi.org/10.1111/resp.13580
22. Fagard, R. (2005). Effects of exercise, diet and their combination on blood pressure. *Journal of Human Hypertension, 19*(3), S20–S24. https://doi.org/10.1038/sj.jhh.1001956
23. Fock, K. M., & Khoo, J. (2013). Diet and exercise in management of obesity and overweight. *Journal of Gastroenterology Hepatology, 28*, 59–63. https://doi.org/10.1111/jgh.12407
24. Garrow, J., & Summerbell, C. (1995). Meta-analysis: Effect of exercise, with or without dieting, on the body composition of overweight subjects. *European Journal of Clinical Nutrition, 49*(1), 1–10.
25. van den Hoek, D. J., Miller, C. T., Fraser, S. F., Selig, S. E., & Dixon, J. B. (2017). Does exercise training augment improvements in quality of life induced by energy restriction for obese populations? A systematic review. *Quality of Life Research, 26*(10), 2593–2605. https://doi.org/10.1007/s11136-017-1602-9
26. Lalonde, L., Gray-Donald, K., Lowensteyn, I., Marchand, S., Dorais, M., Michaels, G., et al. (2002). Comparing the benefits of diet and exercise in the treatment of dyslipidemia. *Preventive Medicine, 35*(1), 16–24. https://doi.org/10.1006/pmed.2002.1052
27. Leehey, D. J., Collins, E., Kramer, H. J., Cooper, C., Butler, J., McBurney, C., et al. (2016). Structured exercise in obese diabetic patients with chronic kidney disease: A randomized controlled trial. *American Journal of Nephrology, 44*(1), 54–62. https://doi.org/10.1159/000447703
28. Messier, S. P., Mihalko, S. L., Legault, C., Miller, G. D., Nicklas, B. J., DeVita, P., et al. (2013). Effects of intensive diet and exercise on knee joint loads, inflammation, and clinical outcomes among overweight and obese adults with knee osteoarthritis: The IDEA randomized clinical trial. *JAMA, 310*(12), 1263–1273. https://doi.org/10.1001/jama.2013.277669
29. Nikroo, H., Mohammadian, M., Nematy, M., Sima, H., & Attarzadeh Hosseini, S. R. (2015). The effect of diet and exercise on improvement of quality of life in patients with nonalcoholic steatohepatitis. *Journal of Kerman University of Medical Sciences, 22*, 61–72.
30. Shah, M., Snell, P. G., Rao, S., Adams-Huet, B., Quittner, C., Livingston, E. H., et al. (2011). High-volume exercise program in obese bariatric surgery patients: A randomized, controlled trial. *Obesity Reviews, 19*(9), 1826–1834. https://doi.org/10.1038/oby.2011.172
31. Villareal, D. T., Chode, S., Parimi, N., Sinacore, D. R., Hilton, T., Armamento-Villareal, R., et al. (2011). Weight loss, exercise, or both and physical function in obese older adults. *New England Journal of Medicine, 364*(13), 1218–1229. https://doi.org/10.1056/NEJMoa1008234
32. Kitzman, D. W., Brubaker, P., Morgan, T., Haykowsky, M., Hundley, G., Kraus, W. E., et al. (2016). Effect of caloric restriction or aerobic exercise training on peak oxygen consumption and quality of life in obese older patients with heart failure with preserved ejection fraction: A randomized clinical trial. *JAMA, 315*(1), 36–46. https://doi.org/10.1001/jama.2015.17346
33. Imayama, I., Alfano, C. M., Kong, A., Foster-Schubert, K. E., Bain, C. E., Xiao, L., et al. (2011). Dietary weight loss and exercise interventions effects on quality of life in overweight/obese postmenopausal women: A randomized controlled trial. *International Journal of Behavioral Nutrition Physical Activity, 8*(1), 118. https://doi.org/10.1186/1479-5868-8-118
34. Napoli, N., Shah, K., Waters, D. L., Sinacore, D. R., Qualls, C., & Villareal, D. T. (2014). Effect of weight loss, exercise, or both on cognition and quality of life in obese older adults. *The American Journal of Clinical Nutrition, 100*(1), 189–198. https://doi.org/10.3945/ajcn.113.082883
35. Snel, M., Sleddering, M. A., vd Peijl, I. D., Romijn, J. A., Pijl, H., Meinders, A. E., et al. (2012). Quality of life in type 2 diabetes mellitus after a very low calorie diet and exercise. *European Journal of Internal Medicine, 23*(2), 143–9. https://doi.org/10.1016/j.ejim.2011.07.004
36. Thomson, R. L., Buckley, J. D., Lim, S. S., Noakes, M., Clifton, P. M., Norman, R. J., et al. (2010). Lifestyle management improves quality of life and depression in overweight and obese women with polycystic ovary syndrome. *BMC Women's Health, 94*(5), 1812–1816. https://doi.org/10.1186/s12905-016-0292-8
37. Wadden, T. A., Vogt, R. A., Andersen, R. E., Bartlett, S. J., Foster, G. D., Kuehnel, R. H., et al. (1997). Exercise in the treatment of obesity: Effects of four interventions on body composition, resting energy expenditure, appetite, and mood. *Journal of Consulting Clinical Psychology, 65*(2), 269–277. https://doi.org/10.1037/0022-006X.65.2.269
38. Bowen, D. J., Fesinmeyer, M. D., Yasui, Y., Tworoger, S., Ulrich, C. M., Irwin, M. L., et al. (2006). Randomized trial of exercise in sedentary middle aged women: Effects on quality of life. *International Journal of Behavioral Nutrition Physical Activity, 3*(1), 34–42. https://doi.org/10.1186/1479-5868-3-34

39. Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews, 4*(1), 1–9. https://doi.org/10.1186/2046-4053-4-1
40. Beigrezaei, S., Yazdanpanah, Z., Soltani, S., Rajaie, S. H., Mohseni-Takalloo, S., Zohrabi, T., et al. (2021). The effects of exercise and low-calorie diets compared with low-calorie diets alone on health: A protocol for systematic reviews and meta-analyses of controlled clinical trials. *Systematic Reviews, 10*(1), 1–6. https://doi.org/10.1186/2046-4053-4-1
41. Higgins, J. P., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., et al. (2019). *Cochrane handbook for systematic reviews of interventions*. Wiley.
42. Higgins JP, Green S. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1. 0 [updated March 2011]. The Cochrane Collaboration, 2011 (p. 29). Retrieved from https://www.cochrane-handbook.org
43. Guyatt, G. H., Oxman, A. D., Kunz, R., Falck-Ytter, Y., Vist, G. E., Liberati, A., et al. (2008). Going from evidence to recommendations. *BMJ, 336*(7652), 1049–1051. https://doi.org/10.1136/bmj.39493.646875.AE
44. Guyatt, G., Oxman, A. D., Akl, E. A., Kunz, R., Vist, G., Brozek, J., et al. (2011). GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. *Journal of Clinical Epidemiology, 64*(4), 383–94. https://doi.org/10.1016/j.jclinepi.2010.04.026
45. Guyatt, G. H., Oxman, A. D., Schünemann, H. J., Tugwell, P., & Knottnerus, A. (2011). GRADE guidelines: A new series of articles in the Journal of Clinical Epidemiology. *Journal of Clinical Epidemiology, 64*(4), 380–382. https://doi.org/10.1016/j.jclinepi.2010.09.011
46. Geliebter, A., Maher, M. M., Gerace, L., Gutin, B., Heymsfield, S. B., & Hashim, S. A. (1997). Effects of strength or aerobic training on body composition, resting metabolic rate, and peak oxygen consumption in obese dieting subjects. *The American Journal of Clinical Nutrition, 66*(3), 557–563. https://doi.org/10.1093/ajcn/66.3.557
47. DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials, 7*(3), 177–188. https://doi.org/10.1016/0197-2456(86)90046-2
48. Doi, S. A., Barendregt, J. J., Khan, S., Thalib, L., & Williams, G. M. (2015). Advances in the meta-analysis of heterogeneous clinical trials I: The inverse variance heterogeneity model. *Contemporary Clinical Trials, 45*, 130–8.
49. Higgins, J. P., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine, 21*(11), 1539–1558. https://doi.org/10.1002/sim.1186
50. Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ, 315*(7109), 629–634. https://doi.org/10.1136/bmj.315.7109.629
51. Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. *Biometrics, 50*(4), 1088–101. https://doi.org/10.2307/2533446
52. Egger, M., Davey-Smith, G., & Altman, D. (2008). *Systematic reviews in health care: meta-analysis in context*. Wiley.
53. Messier, V., Rabasa-Lhoret, R., Doucet, E., Brochu, M., Lavoie, J.-M., Karelis, A., et al. (2010). Effects of the addition of a resistance training programme to a caloric restriction weight loss intervention on psychosocial factors in overweight and obese post-menopausal women: A montreal Ottawa new emerging team study. *Journal of Sports Sciences, 28*(1), 83–92. https://doi.org/10.1080/02640410903390105
54. Scott, H., Gibson, P., Garg, M., Pretto, J., Morgan, P., Callister, R., et al. (2013). Dietary restriction and exercise improve airway inflammation and clinical outcomes in overweight and obese asthma: A randomized trial. *Clinical Experimental Allergy, 43*(1), 36–49. https://doi.org/10.1111/cea.12004
55. Fontaine, K., & Barofsky, I. (2001). Obesity and health-related quality of life. *Obesity reviews, 2*(3), 173–182. https://doi.org/10.1046/j.1467-789x.2001.00032.x
56. Kolotkin, R. L., & Crosby, R. D. (2002). Psychometric evaluation of the impact of weight on quality of life-lite questionnaire (IWQOL-lite) in a community sample. *Quality of Life Research, 11*(2), 157–171. https://doi.org/10.1023/A:1015081805439
57. Maciejewski, M. L., Patrick, D. L., & Williamson, D. F. (2005). A structured review of randomized controlled trials of weight loss showed little improvement in health-related quality of life. *Journal of Clinical Epidemiology, 58*(6), 568–578. https://doi.org/10.1016/j.jclinepi.2004.10.015
58. Alkatib, A. A., Cosma, M., Elamin, M. B., Erickson, D., Swiglo, B. A., Erwin, P. J., et al. (2009). A systematic review and meta-analysis of randomized placebo-controlled trials of DHEA treatment effects on quality of life in women with adrenal insufficiency. *The Journal of Clinical Endocrinology Metabolism, 94*(10), 3676–3681. https://doi.org/10.1016/j.jclinepi.2004.10.015
59. Blissmer, B., Riebe, D., Dye, G., Ruggiero, L., Greene, G., & Caldwell, M. (2006). Health-related quality of life following a clinical weight loss intervention among overweight and obese adults: Intervention and 24 month follow-up effects. *Health Quality of Life Outcomes, 4*(1), 1–8. https://doi.org/10.1186/1477-7525-4-43
60. Warkentin, L., Das, D., Majumdar, S., Johnson, J., & Padwal, R. (2014). The effect of weight loss on health-related quality of life: Systematic review and meta-analysis of randomized trials. *Obesity Reviews, 15*(3), 169–182. https://doi.org/10.1111/obr.12113
61. Munoz, D. J., Chen, E., Fischer, S., Roehrig, M., Sanchez-Johnson, L., Alverdy, J., et al. (2007). Considerations for the use of the beck depression inventory in the assessment of weight-loss surgery seeking patients. *Obesity Surgery, 17*(8), 1097–1101. https://doi.org/10.1007/s11695-007-9185-0