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Effect of exercise on anthropometric measures and serum lipids in older individuals: a systematic review and meta-analysis

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ABSTRACT

Objectives: Overweight and obesity are increasing in individuals over age 60 years. This systematic review quantifies the effect of exercise on body mass index (BMI), waist circumference (WC) and lipids in overweight and obese individuals over the age of 60 years.

Settings: Nine randomised controlled trials conducted in Brazil, Great Britain, Iceland, Japan and the USA compared aerobic and/or resistance exercise with a control group.

Participants: Final analysis reviewed 1166 participants over the age of 60 years for 3–9 months.

Primary outcome measures: This study reviewed the effects of exercise on BMI, WC and low-density lipoprotein (LDL).

Results: Exercise produced a significant reduction in BMI (−1.01 kg/m^2, 95% CI −2.00 to −0.01) and WC (−3.09 cm, 95% CI −4.14 to −2.04) but not LDL cholesterol (−0.31 mg/dL, 95% CI −0.81 to 0.19). Analyses revealed substantial heterogeneity likely due to the type and intensity of exercise. Data on adverse effects were minimal. The overall level of evidence is moderate due to imprecision and heterogeneity.

Conclusions: Exercise in overweight and obese older individuals improves anthropometric measures such as BMI and WC. The effect of exercise on serum lipids is unclear.

Strengths and limitations of this study

- Demonstrates the effectiveness of programmes designed to promote physical activity in older persons.
- Synthesises a large body of heterogeneous evidence about how exercise programmes may benefit obese and overweight individuals over 60 years old.
- Power may be limited by small numbers of participants relative to other large studies of health behaviours in older persons.
- Applicability and implementation may be limited due to varying characteristics of exercise programmes and regimens tested in the trials.

BACKGROUND

Overweight (body mass index (BMI) 25–29.9 kg/m^2) and obesity (BMI >30 kg/m^2) are associated with an increased risk of all-cause mortality, cardiovascular disease, diabetes and cognitive disability.[1] While BMI is a calculation based on height and weight, obesity can also be defined based on waist circumference (WC) or waist–hip ratio (WHR). Men with a WC ≥102 cm (40″) and women ≥88 cm or a WHR >1 in men or >0.9 in women defines abdominal or central obesity. Central obesity is an indicator of excess visceral fat and is regarded as a more accurate measure of associated health risk.[2 3]

The prevalence of overweight and obesity has been increasing in people over the age of 60 years (from 60.1% and 22.2% in 1988–1994 to 68.6% and 30.5% in 2005–2006).[4] Because ageing reduces daily energy requirements, the decreased physical activity also associated with normal ageing exacerbates the onset of central obesity and loss of lean muscle mass.[5–7] The Behavioral Risk Factor Surveillance Survey (BRFSS) reported 28–34% of adults aged 65–74 and 35–44% over age 75 engage in no leisure time physical activity.[8] Conversely, only 13% of individuals between ages 64 and 75 and only 6% over age 75 report vigorous physical activity.[1]

Several systematic reviews have assessed a variety of health issues related to obesity and ageing. Beydoun *et al*[9] reported an increased risk of cognitive disability associated with being overweight and obese elders. Latham *et al*[10] found improvements in muscle strength and gait speed with progressive resistance strength training, but the effect on physical disability in older adults was unclear. Another review of observational and interventional studies found that intensive

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counselling promoted modest sustained weight loss with possible functional improvement.[11] A clinical review by Gostic outlined the critical role of exercise and its impact on the loss of independence in later years of life.[12]

Uncertainty remains about the effect of progressive resistance strength training and/or aerobic exercise on weight reduction, changes in body composition and modulation of metabolic risk factors for cardiovascular disease. Inference from many of these observational studies is limited due to inherent methodological limitations such as selection bias and confounding. Therefore, we conducted this systematic review and meta-analysis to appraise and summarise the randomised controlled trial (RCT) evidence regarding the impact of exercise on body composition and serum lipids.

METHODS

Inclusion criteria

We included RCTs of older obese participants (mean age of 60 years or above with a BMI >25 kg/m^2 or WC >102 cm in men, 88 cm in women). We excluded studies enrolling individuals with diabetes mellitus, cognitive impairment, known cardiovascular disease or participants who were deficient in one or more activities of daily living. We also excluded studies with follow-up less than 3 months and those that involved pharmacological therapy.

Primary interventions included resistance and/or aerobic exercise programmes. Diet interventions were included if they were either the same for the intervention and control groups, or one of the comparison interventions. Resistance exercise was defined as strength training where participants exercised their muscles against an external force. Aerobic exercise was defined as a system of physical conditioning designed to improve circulatory or pulmonary function through exercise. The overall intensity of exercise could be measured by heart rate, heart rate reserve, oxygen consumption, rating of perceived exertion or metabolic equivalents. The outcomes of interest were anthropometric measures including BMI and WC, serum lipids as a surrogate for cardiovascular risk and adverse effects of exercise.

Search strategy

Controlled vocabulary and text words were used to search for the concepts of age, overweight and obese, elderly, exercise therapy, metabolic risk factors, sedentary, cardiovascular risk factors and health status indicators, with limits of human participants and RCTs. Databases searched included PubMed/MEDLINE, EMBASE, SCIRUS, Cochrane Database of Systematic Reviews, Cochrane Controlled Trials Register and clinicaltrials.gov. Two independent reviewers made decisions on the included articles. A third reviewer was available for any differences of opinion. The initial literature search was conducted on 11 January 2011 with query of articles from 1990 to 2010. An additional literature search was conducted on 15 January 2014 with a query of articles from 2011 to 2013. The detailed search strategy is in the online supplementary appendix. Data from the published reports were sufficient for analysis; hence, we did not contact the authors of the included studies.

Study quality

The methodological quality (risk of bias) was evaluated using the Cochrane Risk of Bias Tool that addresses the domains of randomisation adequacy, blinding, allocation concealment, whether the intention-to-treat analysis was utilised, and attrition rate.[13]

Statistical analysis

We estimated the weighted mean difference and 95% CIs from each study and pooled across studies using a random effects model. We chose this outcome measure because the outcomes of interest (BMI, WC, serum lipids) had natural units that were consistent across trials. The weighted mean difference preserves the natural units when estimates are pooled across studies. We chose the random effects model because we expected heterogeneity across study participants and settings. This model incorporates within-study and between-study heterogeneity in the CIs.[14] We used the I-squared statistic (I^2) to assess heterogeneity of the treatment effect across studies.[15] We evaluated publication bias by visual inspection of funnel plots and assessment of their symmetry. We did not conduct statistical testing for funnel asymmetry because of the small number of studies, making analysis unreliable.[16] We planned to conduct subgroup analysis evaluating aerobic versus resistance exercise and comparing different levels of exercise intensity. We planned to test any assumptions in sensitivity analysis. Analysis was conducted using Comprehensive Meta-analysis V.2, Biostat, Englewood, New Jersey, USA (2005).

RESULTS

Study characteristics

The results of the literature search and study selection process are described in figure 1. We included nine RCTs that enrolled 1166 individuals. The length of the trials varied from 3 to 9 months in duration. The participants studied were all healthy, mostly white individuals living independently in the community. One trial exclusively enrolled women[17] whereas the remaining trials enrolled both sexes. The mean ages ranged from 60±1.6 to 80.8±4.7 years. Exercise (EX) interventions included aerobic, resistance training (RT) or a combination of both compared with a sedentary control or a control that was sedentary with some calorie restriction (CR). One study compared EX with RT and one compared EX with EX combined with CR. Aerobic exercise was of moderate intensity based on 50–55% of maximum heart rate or high intensity (HI) based on 75–80% of heart

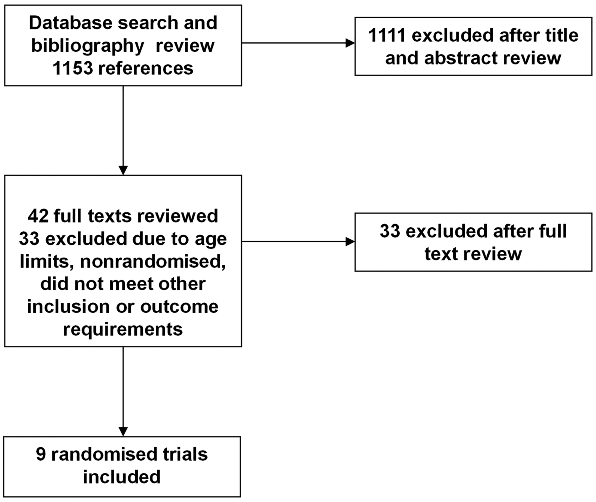

Figure 1 The process of study selection.

rate obtained from VO_2 max at baseline. Resistance exercise was performed with a progressive increase of weight load against muscular resistance. CR was measured in kcal/day or by the goal of per cent reduction of body weight. Study characteristics are described in table 1.

Risk of bias

All the included trials reported adequate random allocation. Only two studies described how the allocation was made, and none of the studies discussed allocation concealment.[18 19] Only three of nine studies clearly performed intention-to-treat analysis,[18–20] while two studies used the original number randomised without specifying it as an intention-to-treat analysis.[17 21] Only five studies explained reasons for withdrawal or dropout.[8–20 22 23] The number of participants in each group was balanced in all trials except one.[18] None of the studies were blinded which would be difficult given the nature of the interventions. Adherence to the exercise protocols was reported in five studies.[17–20 23] Risk of bias indicators is summarised in table 2. The overall risk of bias for the outcomes of interest was moderate.

Meta-analysis

Exercise produced a significant reduction in BMI (-1.01 kg/m^2, 95% CI -2.00 to -0.01) and WC (-3.09 cm, 95% CI -4.14 to -2.04; see figures 2 and 3). Measures of heterogeneity (the I^2 statistic) were high, exceeding 50%. This can likely be explained by the type and intensity of exercise across trials as well as the differences in physical activity of the control groups. Results are depicted in figures 2 and 3.

Serum lipids

The effect of exercise on serum low-density lipoprotein (LDL) cholesterol in older persons was not statistically significant (-0.31 mg/dL, 95% CI -0.81 to 0.19). Meta-analysis was associated with substantial heterogeneity (I^2 >50%). Results are depicted in figure 4. Data on triglycerides and high-density lipoprotein (HDL) cholesterol were insufficient for meta-analysis. In the studies that compared HI exercise with a control group[19 20 22 23] only one study reported a significant increase in HDL in the intervention group (3±3 compared with −0.3±0.7; analysis of variance p=0.01).[23] One study reported a significant decrease in triglycerides in the intervention group (−0.45 (−0.069 to −0.020) compared with 0.003 (−0.020 to 0.025) mg/dL; analysis of covariance p=0.006).[19] When EX plus CR was compared with control in a study by Villareal *et al*,[18] there was a significant decrease in triglycerides (−45±63 compared with 0±36; analysis of variance p=<0.05) but a non-significant decrease in HDL. According to Boardley *et al*, comparisons of EX, RT and a combination of EX and RT with control showed a decrease in triglycerides in all three interventions with the greatest decrease in the EX group compared with control (−37.9±72 compared with −8.2±89). There was also a small, but insignificant, decrease in HDL in all four groups.[22]

Adverse events

All studies reviewed had pre-enrolment screening and some level of physical examination and laboratory tests to exclude individuals at risk for adverse cardiovascular or orthopaedic outcomes during the trial. An exercise stress test was performed prior to enrolment in five trials.[17 18 20 21 23] In four trials, all the exercise interventions were supervised.[12 17 18 21 23] One study that compared aerobic exercise with control reported a participant with an exacerbation of osteoarthritis of the knees and another participant with exercise-induced palpitations.[20] Otherwise, there were no adverse effects reported.

Sensitivity and subgroup analyses

Two RCTs had a three-arm design (HI exercise vs medium intensity exercise vs a control group).[17 21] In order to not count the common control group twice and inflate the weight of these two studies, we only used one intervention group at a time. In sensitivity analysis, there was no change to study conclusions regardless of which intervention group is analysed. One RCT had a cross-over design.[24] We repeated the analysis three times using the first phase; the second phase or both phases combined using various correlation coefficients. The conclusions of the main analysis (ie, statistically significant reduction in BMI and WC) did not change. Data were insufficient to conduct subgroup analysis comparing aerobic versus strength training or based on exercise intensity.

DISCUSSION

This systematic review summarised the available evidence focused on how exercise influences BMI, WC and LDL in older overweight and obese individuals. Exercise

Table 1 Study characteristics

Study year/origin	Length (months)	Sample size	Sex	Age	BMI (kg/m^2)	Interventions
Stewart *et al*[23] 2005/USA	6	EX 57	F 31 M 26	63±1.5	29.4±1.1	3 days/week: RT, 7 EX 2 sets of 10–15 reps 45 min; aerobic at 60–90% VO_2 max
		Ctrl 58	F 31 M 27	64±1.7	29.7±1.4	NIA guidelines for EX and AHA Step I Diet given to both groups
Coker *et al*[21] 2006/USA	3	MI 7	NR	73±2	29±1	Cycle ergometer 4–5 days/week 50% VO_2 max
		HI 7		73±2	31±1	Cycle ergometer 4–5 days/week 75% VO_2 max
		Ctrl 7		70±3	31±1	Usual sedentary activity
DiPietro *et al*[17] 2006/USA	9	MI 9	All F	73±3	28±4.5	Expend 300 kcal/day at 80% VO_2 max
		HI 9		72±3	26.3±3	Expend 300 kcal/day at 65% peak VO_2 max
		Ctrl 7		75±5	27±4.7	Stretching and strengthening Thera-Bands and Thera-Balls
Villareal *et al*[6] 2006/USA	6	INT 17	F 12 M 4	69±5	39±5	Energy deficit of 750 kcal/day, EX 30 min endurance (70% VO_2 peak), 30 min of strength training, 15 min balance, EX 3 non-consecutive day/week in group
		Ctrl 10	F 6 M 4	71±4	39±5	Usual sedentary PA
Boardley *et al*[22] 2007/USA	4	EX 33	F 96	73.2±6.6	29.8±4.2	Walking intensity Borg 11–16
		RT 31	M 35	74.1±6.2	31.1±6.8	Thera-Bands, 13 exercises 2 sets of 12 reps
		Comb 32		75.3±6.0	29.0±5.3	Total time same as individual times
		Ctrl 35		75.9±7.7	29.4±4.6	Usual sedentary PA
Nishijima *et al*[19] 2007/Japan	6	INT 281	F 359 M 171	67±6.7	26.5±2.5	Bicycle exercise 2–4 times/week, light RT 60–90 min/session at fitness club
		Ctrl 280		66.9±6.9	26.5±2.0	Usual care
Finucane *et al*[20] 2010/UK	3	INT 50	F 44 M 56	71.4±4.2	27.4±4.9	3,1-h sessions/week @ 70% W_{max}
		Ctrl 50		71.4±4.2	26.9±3.6	Usual sedentary PA
Bocalini *et al*[45] 2012/Brazil	3	AWC 9	All F	67±9	23±5	Circuit-based weight training
		AWT 18		66±4	22±1	50 min 3 days/week
		OWC 10		63±2	26±1	
		OWT 14		64±4	27±1	
		OC 9		62±1	33±1	
		OT 9		62±2	34±1	
Gudlaugsson *et al*[24] 2013/Iceland	6	Grp 1, 56	M 25	80.8±4.7	27.6±5.3	20–45 min walking, with 12-exercise circuit 2 day/week
		Grp 2, 61	F 31 M 29 F 32	78.3±4.1	27.4±3.4	

AHA, American Heart Association; AWC, appropriate weight control; AWT appropriate weight trained; BMI, body mass index; Comb, combination; Ctrl, control; EX, exercise; Grp, Group; HI, high intensity; INT, intervention; MI, moderate intensity; NIA, National Institute on Aging; OC, obese control; OT, obese trained; OWC, overweight control; OWT, overweight trained; PA, physical activity; RT, resistance training.

Table 2 Quality measures of randomised controlled trials

Study	Generation of allocation Number of randomised	Allocation concealment	Analysis basis	Attrition
Stewart *et al*[23]	No information 115	Not reported	Number completed	EX 6 Ctrl 5 All explained 9.5%
Coker *et al*[21]	No information 21	Not reported	Original 21 Did not specify ITT	EX training 1 MI (2), HI (1) did not FU for VO_2max 19%
DiPietro *et al*[17]	No information 25	Not reported	Original 25 Did not specify ITT	Reported 90% retention overall
Villareal *et al*[18]	Computer generated block permutation, stratified for sex 27	Not reported	Intention to treat	INT 2 non-compliant Ctrl 1 no FU 11%
Boardley *et al*[22]	No information (published elsewhere) 151	Not reported	Number who completed 70% of exercise sessions	13%
Nishijima *et al*[19]	Lottery with block stratification for fitness club, age and gender 561	Not reported	Intention to treat	EX 32 Ctrl 28 All explained 10.6%
Finucane *et al*[20]	No information 100	Not reported	Intention to treat	EX 2 lost to FU Ctrl 2 lost to FU 4%
Bocalini *et al*[45]	No information 78	Not reported	Number who completed 90% of exercise sessions	2 from AWT and 7 from OT completed <90% of training All explained 11%
Gudlaugsson *et al*[24]	No information 117	Not reported	Cross-over design, no loss to FU	0%

AWT, appropriate weight trained; OT, obese trained; Ctrl, control; EX, exercise; FU, follow-up; HI, high intensity; INT, intervention; ITT, Intention To Treat; MI, moderate intensity.

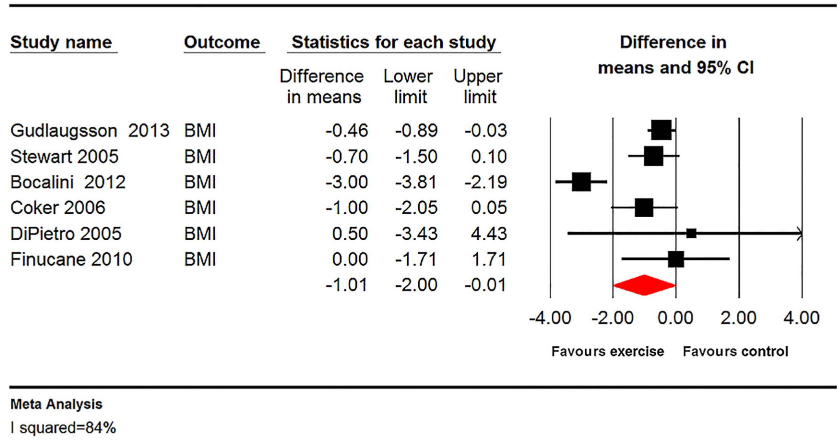

Figure 2 The effect of exercise on body mass index (BMI).

interventions reviewed for this age category do seem to show a small but statistically significant reduction in BMI and WC, but not in LDL cholesterol.

Obesity in older people is a complex topic. BMIs of ≤24 and ≥30 kg/m^2 are associated with increased mortality in older individuals. The Australian Longitudinal Study on Women's Health studied the optimal range for BMI in older women and found after a 5-year follow-up that the optimal weight associated with decreased mortality for women in their 70s was a BMI of 25–27 kg/m^2.[25] Thus, being an overweight individual may be protective, while being obese may contribute to morbidity associated with overweight such as osteoarthritis, diabetes and impaired function. Older adults who are obese have been found to have poorer health than younger obese patients and non-obese older patients.[26] Furthermore, the timing of weight gain may play a role. Several large epidemiological studies in participants over the age of 65 years have found that midlife weight gain is more strongly associated with decreased survival than weight gain in later life.[27 28] Exercise effects may also be more pronounced in the middle-aged adult. A systematic review of the literature of women and men (mean age 47±6) found aerobic exercise combined with a prudent diet to be highly effective for improving total cholesterol (−15.5, 95% CI −20.3 to −10.7), LDL cholesterol (−9.2, 95% CI −12.7 to −5.8) and body weight (−5.7, 95% CI −7.4 to −4.1).[29]

While this systematic review demonstrated improvements in BMI and WC, several other health benefits are expected in obese older adults such as the increase in lean muscle mass, prevention of osteoporosis and reductions in fall risk.[30–32] Preventing or postponing disease onset in the older adult population is a crucial public health issue. Obesity can be predictive of a decline in physical function.[5 6 33–35] Combined with ageing, obesity can put the older persons at even greater risk for functional decline.[36 37] One 14-year longitudinal trial found that overweight or obese women (mean age 74.3, SD±4.3) who remained active performed similar activities of daily living and walked at a similar gait speed as active and inactive normal weight women.[38] Consistent with other studies, physical activity is considered an independent predictor of physical function in older individuals, even in the obese.[39–41]

Few older adults are meeting the American Heart Association and American College of Sports Medicine guidelines of 30 min of aerobic exercise five times a week for adults over age 65 years.[1] In order to inform their public health guidelines, the Centers for Medicare and Medicaid performed a systematic review of studies that aimed to improve physical activity in the elderly.

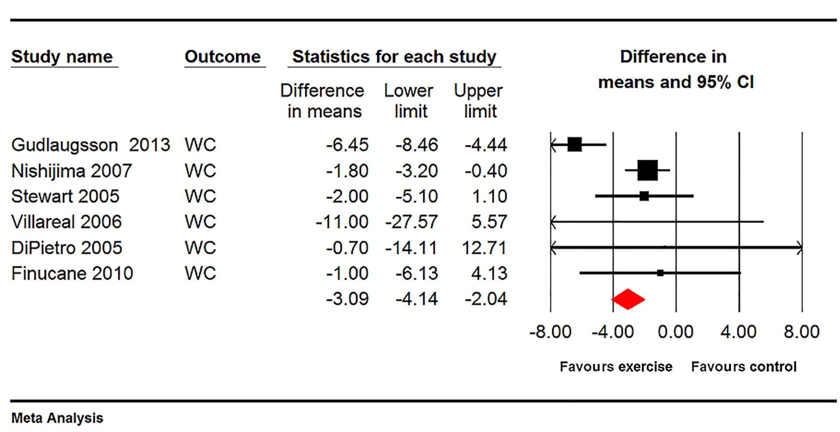

Figure 3 The effect of exercise on waist circumference (WC).

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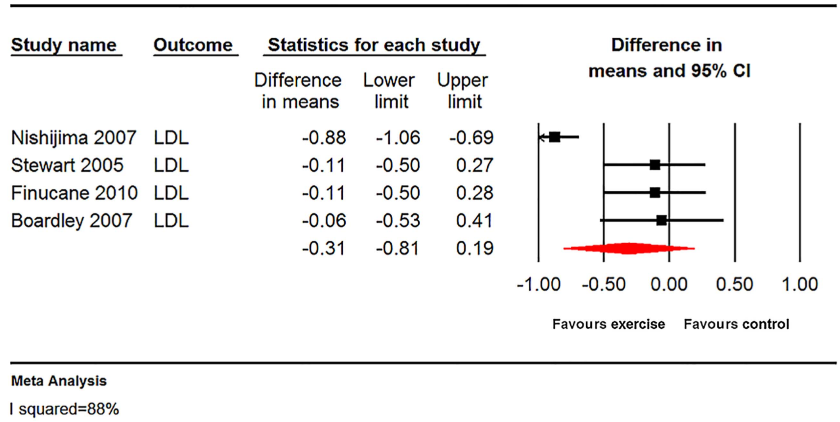

Figure 4 The effect of exercise on low-density lipoprotein (LDL) cholesterol.

The report concluded that motivating older adults to remain active was the most important public health objective.[42] Although the benefit of physical activity counselling in the primary care setting is inconclusive, a review carried out for the Guide to Community Preventive Services has identified effective programmes with behavioural, social and environmental components tailored to the individual's readiness for change.[43] A cost-effectiveness analysis reported that 'individually adapted behaviour change' and 'social support' programmes are the least cost effective but produce the largest effect, adding 35–43% increases in recommended physical activity.[44]

The main limitations to this review include imprecision (small sample size and wide CIs) and heterogeneity (varying interventions and study settings). Therefore, despite the fact that the overall methodological quality of the trials was fair, the quality of the evidence (ie, confidence in estimates) is limited. The length of follow-up was not sufficiently long, although this is typical of trials of lifestyle modifications in which maintaining long-term adherence is challenging. Furthermore, results may not be fully generalisable since most participants were Caucasian and trials excluded participants at higher risk for exercise adverse effects. Publication bias could not be adequately assessed due to the small number of included studies and due to heterogeneity, but it is possible in a field that mainly consists of small trials. Loss to follow-up could also have biased the observed estimates. Nonetheless, this systematic review has several strengths, including comprehensive search of multiple databases and selecting studies by two independent reviewers. We believe the evidence summarised in this report is important and relevant for the development of lifestyle modification programmes targeting older adults, an increasing proportion of the population.

CONCLUSIONS

Exercise in obese older individuals improves anthropometric measures such as BMI and WC. Despite the limitations in the current evidence, lifestyle modification programmes targeting older adults are justified.

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Contributors CLK created the study design, did the initial literature search and drafted the manuscript including the statistical analysis. MWS was the second reviewer and edited the manuscript. PJA contributed to data collection and critically revised the manuscript. MHM assisted with the study design and critically revised the manuscript. All authors read and approved the final manuscript.

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