BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-091743
Article Type:	Original research
Date Submitted by the Author:	27-Jul-2024
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Keywords:	Meta-Analysis, Obesity, Overweight

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Effects of water aerobics on body composition in obesity and overweight people: a systematic review and meta-analysis

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Abstract

Background: The problem of obesity and overweight seriously affects people's health. The benefits of water aerobics have been shown in obesity and overweight people, but

the effects of water aerobics on body composition improvement are still unclear.

Methods: A systematic literature search was conducted on October 26, 2023 using the PubMed MEDLINE, Ovid MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library. The studies were independently screened by 2 researchers. All randomized clinical trials on water aerobics that evaluated the anthropometric and body composition parameters of overweight and obesity subjects were included, and a reporting of eligible studies was conducted in accordance with PRISMA statement. Finally, 10 articles out of the 4329 articles searched. Depending on the level of study heterogeneity, the use of a fixed-effects model or a random-effects model was determined. The risk of bias of the selected studies was assessed using the Risk of Bias 2.0 tool, and sensitivity analyses and subgroup analyses were performed on the outcome indicators. The study protocol was registered in PROSPERO (CRD42023466969).

Results: A total of 10 studies with 286 patients were included. Sensitivity analyses are performed for PBF with high heterogeneity, and the results are robust. WAs are able to reduce BW (WMD = -2.69, 95%CI: -4.10 to -1.27, $p < 0.05$, $I^2 = 0.0\%$) and WC (WMD = -2.75, 95%CI: -4.41 to -1.09, $p < 0.05$, $I^2 = 27.0\%$), but the effect on other body indicators is not significant.

Conclusions: For the obesity and overweight people, WAs interventions over 10 weeks (i.e., 12 weeks) reduced BW and WC, with more significant effects in women and better improvements in body composition in middle-aged and older adults (average age ≥ 45 years).

Key words: water aerobics; meta-analysis; body composition; obesity; overweight

Background

The global prevalence of obesity has risen significantly over the past 40 years [1-3]. By 2022, more than 43% of adults worldwide will be overweight, with 504 million female and 374 million male obese [4]. Obesity is a chronic disease that increases the risk of various complications and leads to an estimated 2.8 million deaths each year [5-7]. Although weight management through exercise is highly effective [8-10]. However, due to their weight, obesity and overweight people are prone to serious damage to their bones and joints during exercise [11]. Traditional land-based aerobic exercise methods increase musculoskeletal damage in obese patients [12]. Water aerobics (WAs) interventions are more beneficial and effective as a new approach to treating obesity [13, 14]. WAs can use the buoyant effect of water to reduce joint injuries associated with exercise in obesity and overweight people [15, 16]. Therefore, WAs, as a beneficial exercise method, can be an important way to lose weight for obesity and overweight people [17, 18]. However, fewer studies have been reported on the effects of WAs on physical indicators in obesity and overweight people.

The previous literature review [13, 19, 20]. only provided a wide-ranging overview of the relevant evidence. For example, Haifeng Zhu [21] summarizes the physical effects of aquatic exercise on adults. However, this study only included randomized controlled trials (RCTs) on healthy adults and did not consider studies of obesity and overweight people [21].

Thus, the systematic review and meta-analysis of the present study can, to some extent, fill the research gap on the effects of WAs interventions on obesity and overweight people. The main discussion is whether WAs has a significant improvement in physical indicators in obesity and overweight people.

Methods

Registration

This meta-analysis study is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [22, 23]. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (registration number: CRD42023466969). Minor changes were made to the initial PROSPERO protocol submitted in October 2023 (**Table S1** in Supplementary information 2).

Search strategy

Six databases were searched: PubMed MEDLINE, Ovid MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library. The time span of the search was from the construction of the database to 26 October 2023. Retrieval strategy based on PICOS

tool [24]: (P) Population: adults with overweight and obesity; (I) Intervention: WAs; (C) Comparator: other exercise modalities or no exercise control; (O) Outcome: body composition; (S) Study type: RCTs. The core terms for the searches were identified in the MeSH Database in the PubMed database, respectively, to ensure the scientific validity and accuracy of the search vocabulary, and the comprehensiveness of the search scope (details of the search strategy are in **Table S2** in Supplementary information 2). In addition to the database, reference lists of included articles were screened for articles that satisfied the inclusion criteria.

Eligibility criteria

Inclusion criteria: (1) RCTs; (2) Participants were obesity (BMI ≥30 kg/m^2) and overweight (BMI ≥25kg/m^2) [25] adults (≥18 years, including older adults); (3) The intervention group participated in WAs for at least 4 weeks, and the control group did not participate in exercise or chose other ways of exercising; (4) Results on changes in body composition were obtained in the original article; (5) Full text available in English (i.e., not a review, letter, case series or conference proceedings).

Exclusion criteria: (1) Trials that did not satisfy all inclusion criteria; (2) Participants diagnosed with other diseases were included; (3) Exercise interventions combined with dietary control, medication or other lifestyle changes; (4) There was no exercise of any form, just a trial of being immersed in water or receiving a massage.

Study selection

The study used EndNote (version 21) to manage the articles. First, duplicate articles were removed. Second, the titles and abstracts of the articles were read and qualified

articles were selected. Finally, full-text review was performed. The process was independently screened by 2 researchers (D.Z.Y., Z.H.X.). Disagreements were adjudicated by a third researcher (G.Z.X.).

Data extraction

Data from included studies were recorded using an adapted Cochrane Collaboration [26] standardized data extraction form. The study characteristics are extracted as follows: year of publication, authors, region, study period, study design, sample size, participants, and mean age. Outcome measures: body weight (BW), body mass index (BMI), percent body fat (PBF), lean mass (LM), fat mass (FM), waist–hip ratio (WHR), waist circumference (WC), hip circumference (HC). Two researchers (D.Z.Y., Z.H.X.) independently extracted this information from each study and resolved any disagreements through discussion.

Risk of bias

Two researchers (D.Z.Y. and Z.H.X.) subjected the included RCTs to an independent risk of bias assessment. The Cochrane risk-of-bias tool (RoB 2) was used for the review according to the evaluation criteria of the Cochrane Handbook for Systematic Reviews of Interventions (Version 6.4) [27]. Disagreements arising from the review were discussed and resolved with the participation of the third researcher (G.Z.X.) on the review team.

Data analysis

Meta-analysis was conducted using Stata 18.0 software. Heterogeneity of studies was assessed using Cochrane's Q and I^2 tests [28]. when $P > 0.1$, $I^2 \leq 50\%$, there was

homogeneity, and a fixed-effects model was used for the meta-analysis; when $P \leq 0.1$, $I^2 > 50\%$, there was heterogeneity, and a random-effects model was used [29, 30]. Differences were considered significant at $P < 0.05$ [31]. The standard error of the mean (SEM) of the extracted data were converted to standard deviation (SD) [32]. Using the formula in the Cochrane Handbook [33] (N represents the number of trial participants):

$$SD = SEM \times \sqrt{N}$$

Results

Study search results

A total of 4329 studies were searched. 1136 studies were deleted due to duplication and 3193 studies were further screened. After reading the titles and abstracts 3130 studies were deleted. 63 articles were eligible for full-text screening, of which 53 were deleted. Finally, 10 studies were included in the meta-analysis (**Fig. 1**).

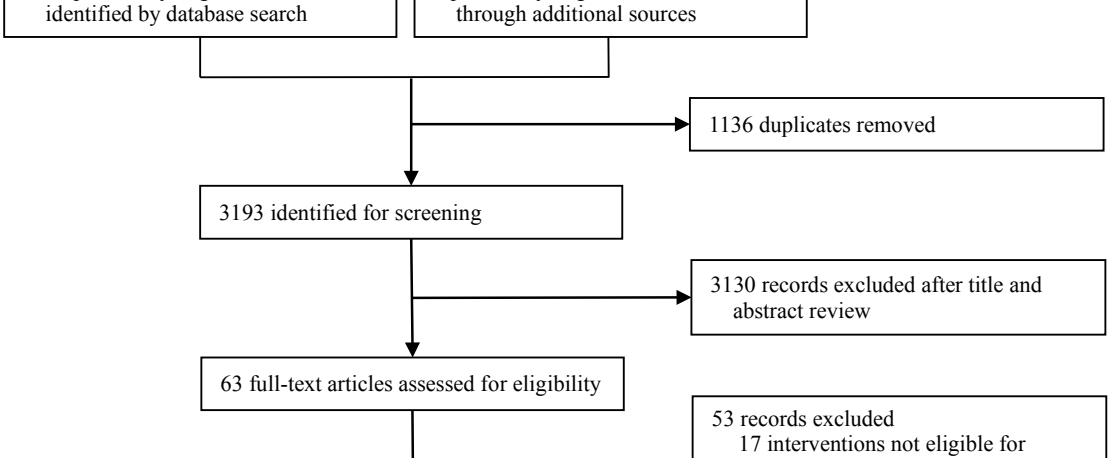

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram

Study characteristics

The RCTs included in the study had 286 participants [34-43]. Publication dates range from 2009 to 2021. A small number of subjects from 5 trials [34, 36, 38, 41, 42] dropped out of the experiment for various reasons, and trial data from those who dropped out was not used. A study [34] had more than 2 groups of trial participants, so the included studies were numbered separately (Yusof-1 and Yusof-2). The basic characteristics of each study are shown in **Table 1**.

Table 1 Experimental details.

Study	Country	Duration (weeks)	Sample	Mean age/ range (SD)	Exercise Category	Study design (Frequency、time)	Outcome
Yusof-1 et al., 2018	Malaysia	12	40 (F)	45.13(5.17)	Aqua Zumba	3 days/week, 60 minutes per session	BW, PBF, WC
Yusof-2 et al., 2018	Malaysia	12	40 (F)	45.28(5.09)	Aqua jog	3 days/week, 60 minutes per session	BW, PBF, WC
Penaforte et al., 2015	Brazil	8	16 (F)	42.8(7.4)	Water aerobics	3 days/week, 60minutes per session	BW, BMI, LM, FM, WC, HC
Palekar et al., 2018	India	6	14 (M)	20.71	Underwater treadmill training	3 days/week, 25minutes per session	BMI, PBF, WC
Rezaeipour, 2020	Iran	12	24 (F)	69.5(4.3)	Aquatic exercises (dancing and walking)	3 days/week, 60minutes per session	BW, BMI, LM, FM,
Greene et al., 2009	American	12	57 (Mix)	42(18.67)	Underwater treadmill	Three times per week	BW, BMI, LM, FM, WC, HC, WHR
Rica et al., 2012	Brazil	12	38 (F)	68.5(5)	Water-based exercise with aerobic	Three times per week, 60-min sessions	BW, BMI, PBF, LM, FM, WC, HC, WHR
Wouters et al., 2009	Netherlands	6	14 (Mix)	44	Aquajogging	2 per week, one hour	BW, BMI, PBF, WC
Rezaeipour, 2021	Iran	12	27 (M)	68.7(3.2)	Water-based exercise with aerobic	3 days/week, 60minutes per session	BW, BMI
Soori et al., 2017	Iran	10	16 (F)	45-60	Swimming or walking in the water	3 per week, 45 min per day	BW, BMI, PBF, WC
Colato et al., 2016	Brazil	12	20 (F)	49.36(11.69)	Water running training	3 per week, 70 minutes/session	BW, BMI, FM, WC, HC

Note: body weight (BW); body mass index BMI)；percent body fat (PBF)；lean mass (LM); fat mass (FM); Waist–hip ratio (WHR); Waist circumference (WC); Hip circumference (HC); mixed sex (Mix); male (M); female(F).

Results of ROB assessment

After a bias risk assessment, the 10 included studies were rated as follows: 6 had low risk, 3 had some concerns, and 1 had high risk (**Fig. 2**).

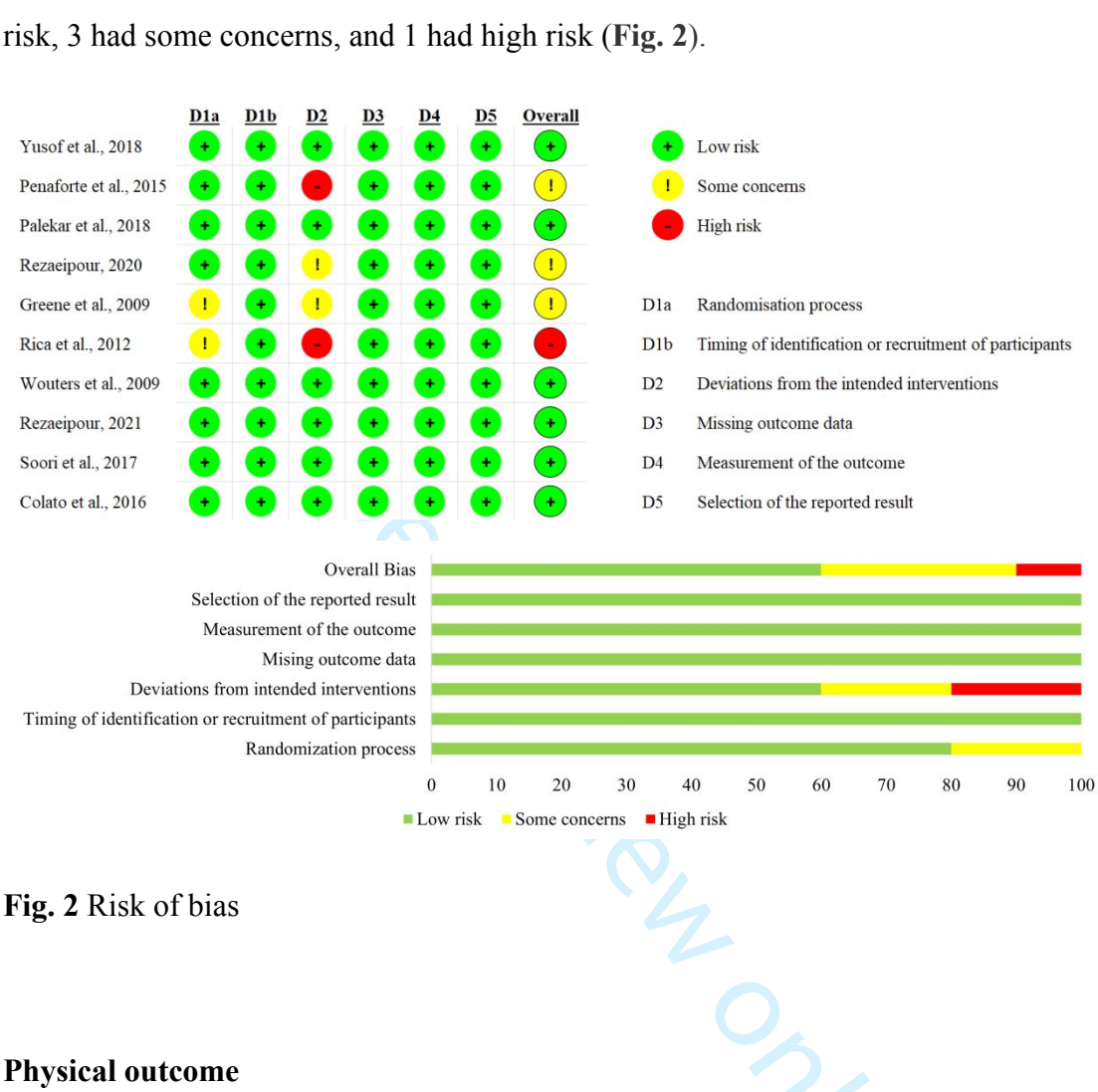

Fig. 2 Risk of bias

Physical outcome

WAs are effective interventions for BW (WMD = -2.69, 95%CI: -4.10 to -1.27, $p < 0.05$, $I^2 = 0.0\%$) and WC (WMD = -2.75, 95%CI: -4.41 to -1.09, $p < 0.05$, $I^2 = 27.0\%$) in obesity and overweight people (**Fig. S1** and **Fig. S2** in Supplementary information 1). Other physical indicators, such as BMI (WMD = -0.55, 95%CI: -1.29 to 0.19, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S3** in Supplementary information 1), PBF (WMD = -4.83, 95%CI: -10.32 to 0.66, $p > 0.05$, $I^2 = 93.6\%$) (**Fig. S4** in Supplementary information 1), LM

(WMD = -0.19, 95%CI: -2.75 to 2.37, p > 0.05, I^2 = 0.0%) (**Fig. S5** in Supplementary information 1), FM (WMD = -0.92, 95%CI: -3.20 to 1.36, p > 0.05, I^2 = 0.0%) (**Fig. S6** in Supplementary information 1), WHR (WMD = -0.02, 95%CI: -0.05 to 0.01, p > 0.05, I^2 = 0.0%) (**Fig. S7** in Supplementary information 1) and HC (WMD = -1.05, 95%CI: -3.64 to 1.55, p > 0.05, I^2 = 0.0%) (**Fig. S8** in Supplementary information 1), did not show significant improvement (**Table 2**).

Subgroup analysis of outcomes

Subgroup analyses of WAs were performed on the included studies to identify appropriate WAs regularity and to explore sources of heterogeneity. Due to the number of subgroups, the results of the subgroup analyses of WAs are summarized in the table (**Table 2**).

Table 2 Subgroup analysis of water aerobics on anthropometric measures

	N	WMD (95% CI)	P within group	P heterogeneity	I^2
Subgroup analyses of WA on BW					
Overall effect	10	-2.69(-4.10, -1.27)	0.000*	0.670	0.0%
Trial duration (week)					
>10	7	-3.31(-5.23, -1.40)	0.001*	0.455	0.0%
≤10	3	-1.93(-4.03, 0.16)	0.071	0.971	0.0%
Sex					
Male	1	-0.60(-8.58, 7.38)	0.883	-	-
Female	7	-2.90(-4.37, -1.43)	0.000*	0.486	0.0%
Mix (male & female)	2	0.24(-6.54, 7.02)	0.944	0.678	0.0%
Average age					
≥45	7	-2.85(-4.31, -1.40)	0.000*	0.465	0.0%
<45	3	0.05(-5.89, 5.98)	0.988	0.911	0.0%
Subgroup analyses of WA on BMI					
Overall effect	9	-0.55(-1.29, 0.13)	0.146	0.984	0.0%
Trial duration (week)					
>10	5	-0.14(-1.25, 0.97)	0.806	0.943	0.0%
≤10	4	-0.88(-1.88, 0.12)	0.083	0.979	0.0%

Sex					
Male	2	-0.47(-2.52, 1.57)	0.649	0.932	0.0%
Female	5	-0.55(-1.41, 0.31)	0.208	0.757	0.0%
Mix (male & female)	2	-0.63(-2.79, 1.52)	0.565	0.932	0.0%
Average age					
≥45	5	-0.55(-1.38, 0.29)	0.199	0.757	0.0%
<45	4	-0.57(-2.21, 1.07)	0.498	0.999	0.0%
Subgroup analyses of WA on PBF					
Overall effect	6	-4.83(-10.32, 0.66)	0.085	0.000	93.6%
Trial duration (week)					
>10	3	-9.01(-18.05, 0.02)	0.051	0.000	94.8%
≤10	3	-0.26(-1.87, 1.36)	0.755	0.938	0.0%
Sex					
Male	1	-0.83(-6.28, 4.61)	0.765	-	-
Female	4	-6.71(-14.24, 0.82)	0.081	0.000	96.0%
Mix (male & female)	1	-0.80(-5.25, 3.65)	0.724	-	-
Average age					
≥45	4	-6.71(-14.24, 0.82)	0.081	0.000	96.0%
<45	2	-0.81(-4.26, 2.63)	0.644	0.993	0.0%
Subgroup analyses of WA on WC					
Overall effect	8	-2.75(-4.41, -1.09)	0.001*	0.213	27.0%
Trial duration (week)					
>10	5	-2.88(-4.63, -1.12)	0.001*	0.057	56.3%
≤10	3	-1.67(-6.76, 3.42)	0.520	0.889	0.0%
Sex					
Male	1	-0.89(-17.54, 15.76)	0.917	-	-
Female	5	-2.89(-4.65, -1.13)	0.001*	0.058	56.1%
Mix (male & female)	2	-1.69(-6.90, 3.52)	0.525	0.626	0.0%
Average age					
≥45	4	-3.03(-4.85, -1.22)	0.001*	0.034	65.5%
<45	4	-1.27(-5.40, 2.86)	0.546	0.959	0.0%
Subgroup analyses of WA on LM					
Overall effect	4	-0.19(-2.75, 2.37)	0.883	0.889	0.0%
Subgroup analyses of WA on FM					
Overall effect	5	-0.92(-3.20, 1.36)	0.429	0.991	0.0%
Subgroup analyses of WA on WHR					
Overall effect	3	-0.02(-0.05, 0.01)	0.256	0.830	0.0%
Subgroup analyses of WA on HC					
Overall effect	4	-1.05(-3.64, 1.55)	0.429	0.610	0.0%

Note: confidence interval (CI); numbers (N); weighted mean differences (WMD); *P < 0.05.

As seen by subgroup analyses of BW, WAs with a trial duration > 10 weeks (i.e.

12 weeks) significantly reduced BW (WMD = -3.31, 95%CI: -5.23 to -1.40, $p < 0.05$, $I^2 = 0.0\%$). In addition, WAs significantly reduced BW in the female population (WMD = -2.90, 95%CI: -4.37 to -1.43, $p < 0.05$, $I^2 = 0.0\%$) and in the population with a mean age of ≥ 45 years (WMD = -2.85, 95%CI: -4.31 to -1.40, $p < 0.05$, $I^2 = 0.0\%$).

From the subgroup analysis of WC, it is shown that WAs with a trial duration >10 weeks significantly reduced WC (WMD = -2.88, 95%CI: -4.63 to -1.12, $p < 0.05$, $I^2 = 56.3\%$). Among them, WAs were mainly able to significantly reduce WC in the female population (WMD = -2.89, 95%CI: -4.65 to -1.13, $p < 0.05$, $I^2 = 56.1\%$) and in the population (WMD = -3.03, 95%CI: -4.85 to -1.22, $p < 0.05$, $I^2 = 65.5\%$) with a mean age ≥45 years.

Other subgroup analyses found that BMI ($P = 0.146$, $I^2 = 0.0\%$), LM ($P = 0.883$, $I^2 = 0.0\%$), FM ($P = 0.429$, $I^2 = 0.0\%$), WHR ($P = 0.256$, $I^2 = 0.0\%$) and HC ($P = 0.429$, $I^2 = 0.0\%$) were neither heterogeneous nor significant. In contrast, PBF ($I^2 = 93.6\%$) and WC ($I^2 = 27.0\%$) were heterogeneous. However, separate subgroup analyses revealed multiple sources of heterogeneity, which could not be adequately explained by only one pair of subgroup analyses.

Sensitivity analysis of PBF

PBF has high heterogeneity. Thus, the robustness of the results was assessed through sensitivity analyses to identify sources of heterogeneity. The results show that the 95%CI excludes 0 (**Fig. 3**). This means that the results are robust, the sensitivity is small, and the original meta-analysis results are statistically significant.

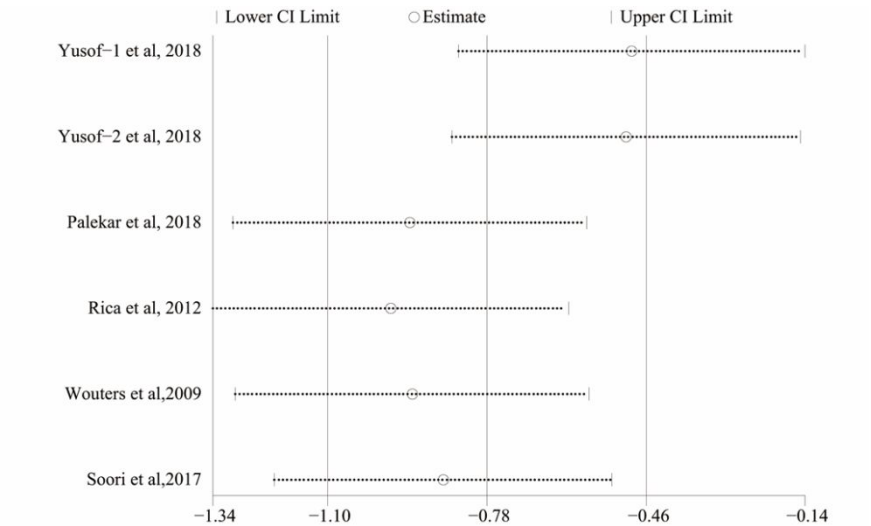

Fig. 3 Sensitivity analysis of percentage body fat

Publication bias

Evaluation of publication bias for the inclusion of more than 10 studies [44]. The study will assess the risk of bias in the BW outcome measures through funnel plots and Egger's regression test [26]. Based on Egger's regression test (P = 0.841 > 0.05) indicates that there is no publication bias, and the visual weight funnel plot (**Fig. 4**) supports this argument.

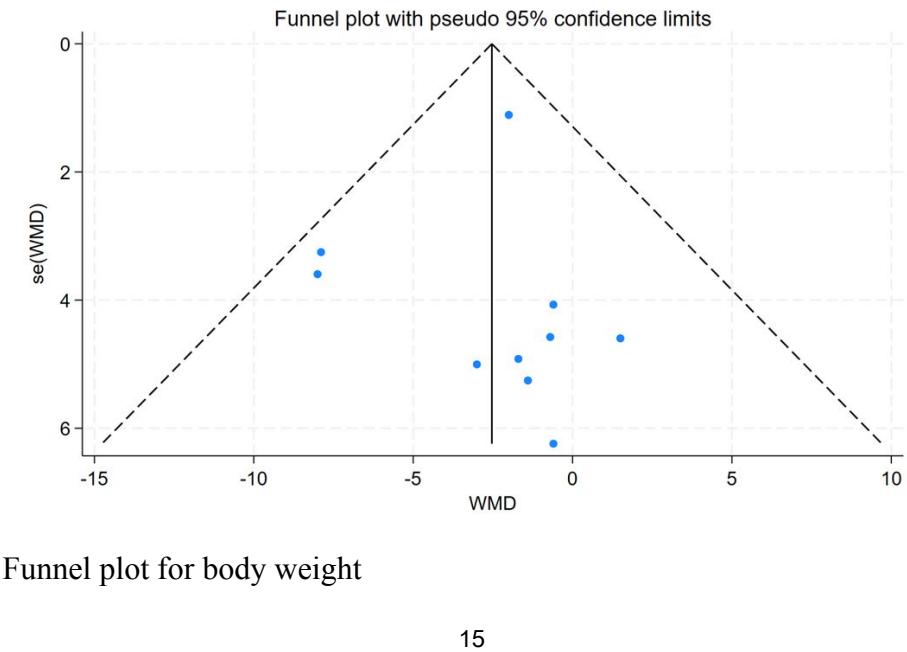

Fig. 4 Funnel plot for body weight

Discussion

This study systematically reviewed the effects of WAs on body composition in obesity and overweight people. The results showed that WAs had an ameliorative effect on body composition [45], with significant effects on reducing BW and WC [46, 47] , mainly: (1) WAs had a reducing effect on BW and WC in female; (2) WAs with a trial duration of 10 weeks or more (i.e., 12 weeks) showed significant reduction in BW and WC; (3) Continuous WAs performed in the middle-aged and older people [48, 49] (average age ≥ 45 years) reduced BW and WC better.

The results of the subgroup analyses show in more detail the factors that influence the impact of WAs on the obesity and overweight people. According to the subgroup analysis of BW, WAs with trial duration >10 weeks (i.e., 12 weeks) showed a more significant reduction in BW, and those with 10 weeks and less showed no significant effect. It is possible that due to the short trial duration, short-term (e.g., six weeks) WAs had little effect on BW and body composition [35, 50] , and that WAs of 12 weeks and longer had a better effect [19, 51]. It has been suggested that WAs have an ameliorative effect on BW in overweight older male [52]. However, the present study found that WAs reduced BW significantly in female and not in male, probably due to the small number of males included in the study, resulting in non-significant differences. WAs were more effective in reducing BW in middle-aged and older adults (average age ≥ 45 years). Aerobic exercise in water is beneficial for middle-aged and elderly people, improving body composition while easing the joint loads associated with land-based exercise [53].

In addition, subgroup analyses based on WC showed that the WAs intervention significantly reduced WC in obesity and overweight people. WC is an important measure of abdominal obesity [54, 55]. 12-week WAs have a significant effect on reducing WC in obesity and overweight female [47]. Detailed subgroup analyses showed that WAs with trial duration >10 weeks (i.e., 12 weeks) had a greater effect on WC, and that trial periods of 10 weeks and less did not have a significant effect on WC. Due to the small number of male participants in the included studies, the reducing effect of WAs on male WC needs to be further confirmed. WAs reduced WC better in middle-aged and older people (average age ≥ 45 years) and not significantly in other (average age < 45 years) people.

Obesity and overweight people can receive many health benefits through exercise. However, subgroup analyses showed that the effect of WAs on improving BMI and PBF in obesity and overweight people was not significant. It has been suggested that 8 weeks of continuous training is not long enough to show beneficial effects, and that the benefits of anthropometric parameters are only gradually revealed when the training period is between 12 and 32 weeks [56]. If subgroups were divided according to trial period, sex, and age for several other body components (LM, FM, WHR, HC), the number of studies in each subgroup would be small, producing results with less confidence. Therefore, several other body components were not analysed in this study.

Limitations

Studies of registered or ongoing RCTs were not included in the search for articles, and

study inclusion was limited to English. Judgements made by persons are more subjective when using ROB tools for literature quality assessment. There were certain limitations to the articles included in the study: (1) Some of the studies had short (6-week) duration of trials, small sample sizes, and less research data; (2) A small number of participants in the study dropped out of the trial halfway through; (3) Differences in the age, sex ratio, and location of the trial participants in three aspects.

Conclusions

For obesity and overweight people, WAs over 10 weeks reduced BW and WC, with more significant effect in female. Middle-aged and elderly people are also better able to improve their body composition after WAs intervention. In conclusion, WAs is an important form of exercise for overweight and obesity people to improve their body composition and overall health.

Abbreviations

PROSPERO: International Prospective Register of Systematic Reviews
WAs: Water aerobics
RCTs: randomized controlled trials
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PICOS： Population, Intervention, Comparison, Outcome, Study type
MeSH: Medical Subject Headings
BW: body weight
BMI: body mass index
PBF: percent body fat
LM: lean mass
FM: fat mass
WHR: waist–hip ratio
WC: waist circumference
HC: hip circumference

SEM: standard error of the mean
SD: standard deviation
Risk of Bias 2.0: RoB 2
Mix: mixed sex
M: male
F: female
CI: confidence interval
N: numbers
WMD: weighted mean differences

Supplementary information

Additional file 1. Supplementary information 1.
Additional file 2. Supplementary information 2.

Acknowledgements

Thanks to all those who helped with this paper.

Author contributions

JP and ZD concept and design. ZD, ZG, and HZ acquisition, analysis, or interpretation of data. ZD, HZ, and ZG drafting of the manuscript. JP critical revision of the manuscript for important intellectual content. ZD, ZG, and HZ statistical analysis. JP, ZG, and HZ administrative, technical, or material support. All authors have read and agreed to the published version of the manuscript.

Funding

This study had no funding.

Availability of data and materials

Not applicable.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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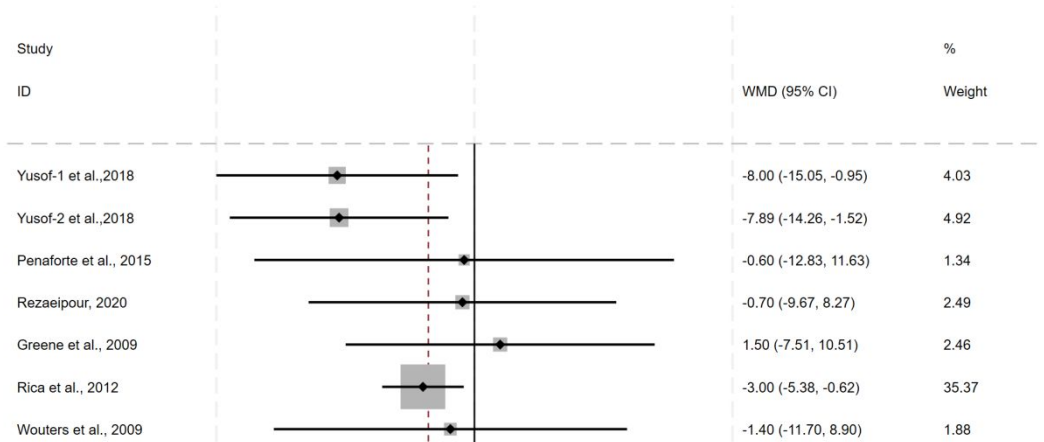
Supplementary information 1



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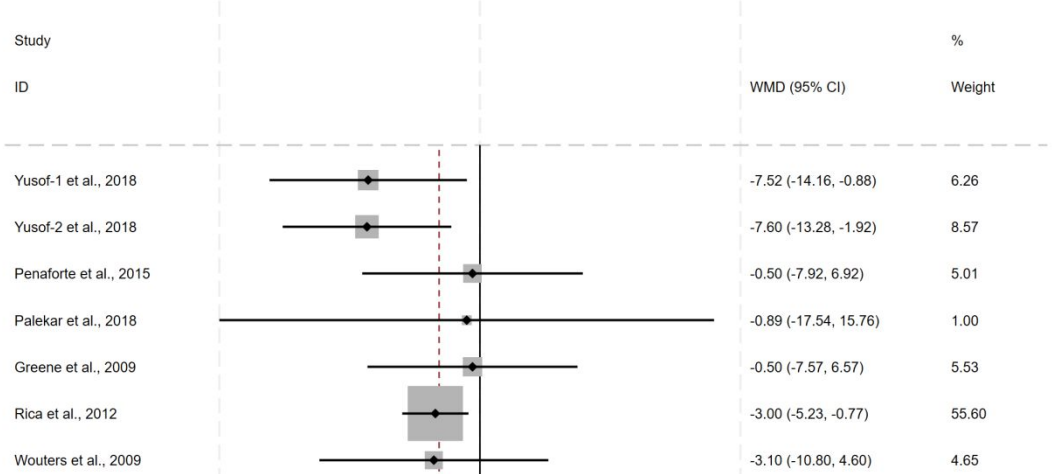

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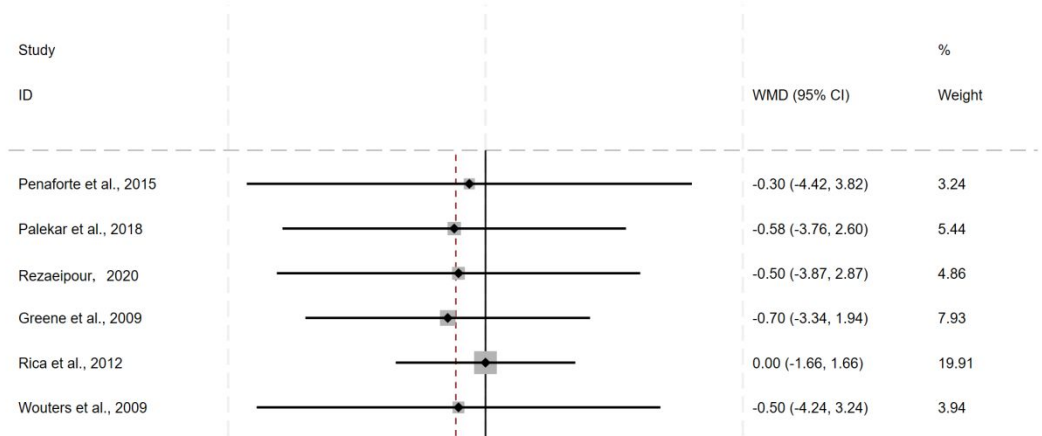

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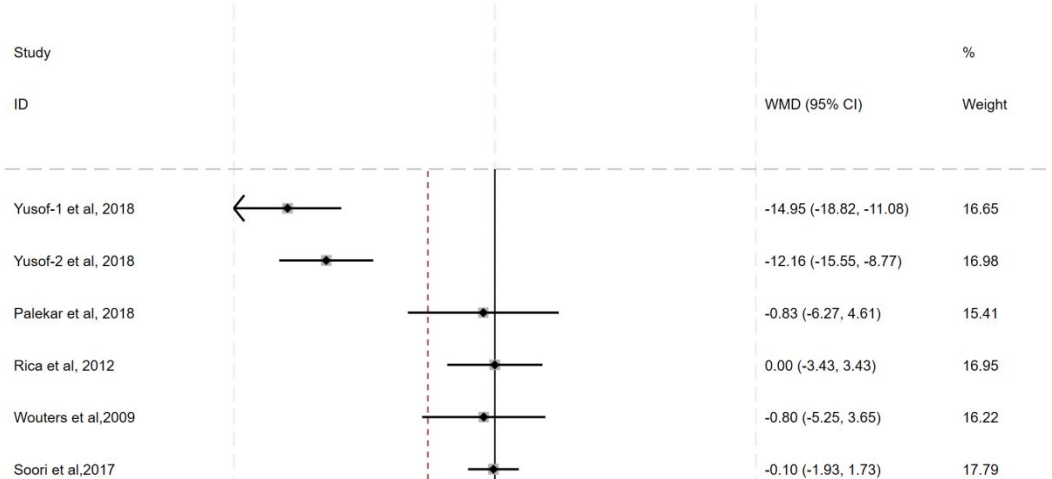

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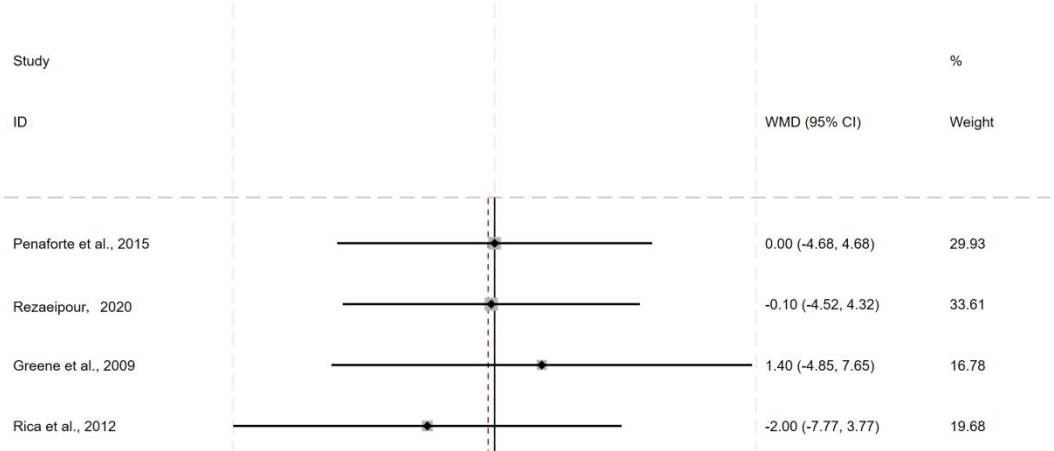
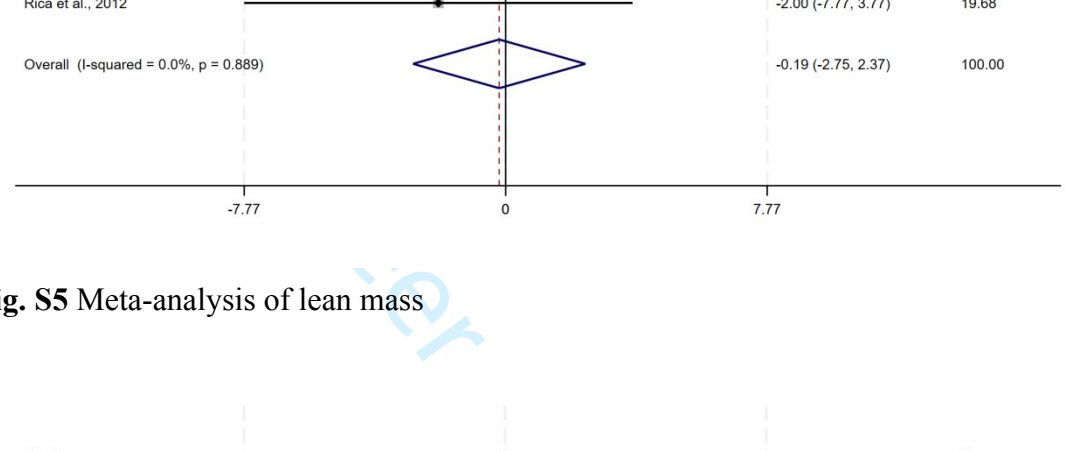


Fig. S5 Meta-analysis of lean mass



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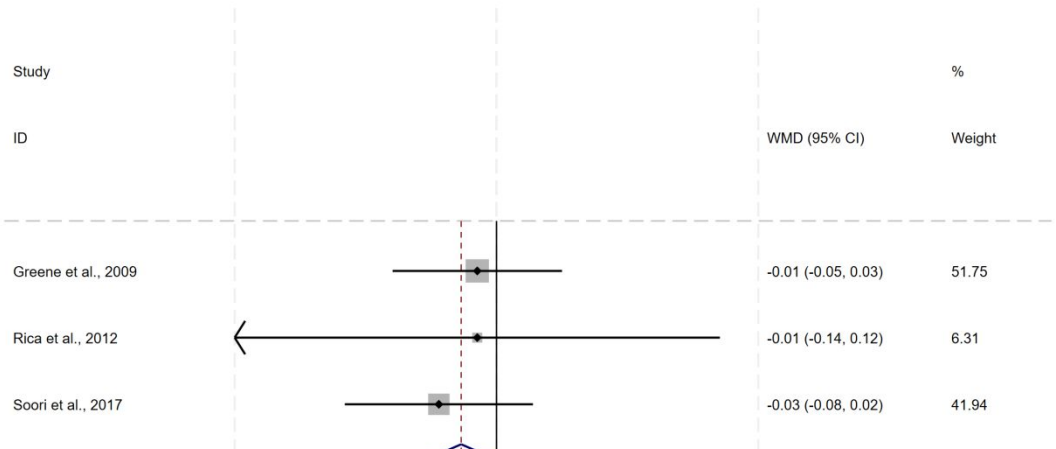

Fig. S7 Meta-analysis of waist–hip ratio

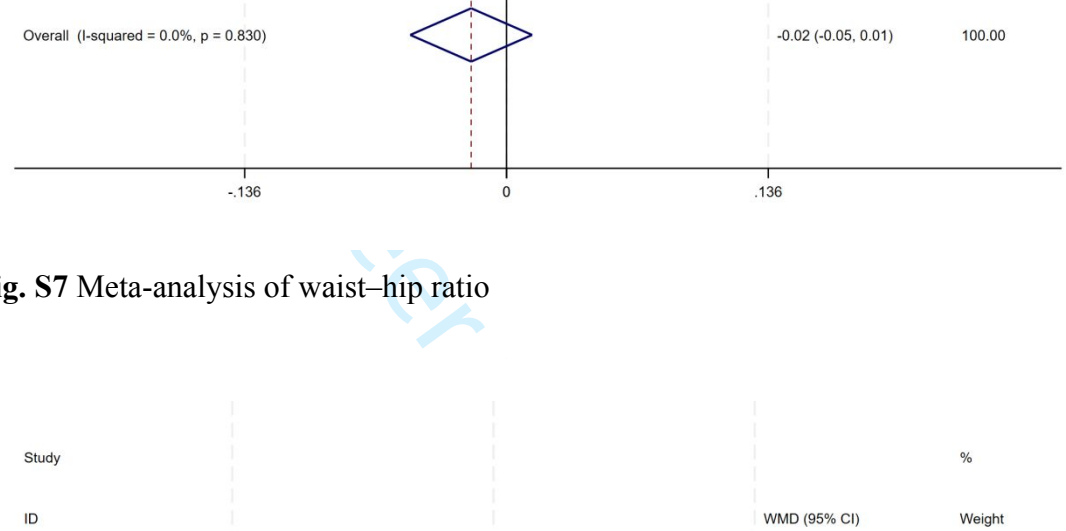

Fig. S8 Meta-analysis of hip circumference

Supplementary information 2

Table S1 Minor changes

Numbers	Changes
1	Delete “body fat mass” and add “waist-to-hip ratio, waist circumference, and hip circumference”.
2	Delete “mean baseline, follow-up” from the data extraction content.
3	Statistical software Change the “Review Manager” to “Stata”.
4	Add water aerobics subgroup analysis.

Table S2 Database search terms

Database	Search terms	Results
PubMed Medline	((((((((((((((((((((((((((((((aerobics) OR (Exercises)) OR (cycling)) OR (Physical Activity)) OR (Activities, Physical)) OR (Activity, Physical)) OR (Physical Activities)) OR (Exercise, Physical)) OR (Exercises, Physical)) OR (Physical Exercise)) OR (Physical Exercises)) OR (Acute Exercise)) OR (Acute Exercises)) OR (Exercise, Acute)) OR (Exercises, Acute)) OR (Exercise, Isometric)) OR (Exercises, Isometric)) OR (Isometric Exercises)) OR (Isometric Exercise)) OR (Exercise, Aerobic)) OR (Aerobic Exercise)) OR (Aerobic Exercises)) OR (Exercises, Aerobic)) OR (Exercise Training)) OR (Exercise Trainings)) OR (Training, Exercise)) OR (Trainings, Exercise)) AND ("Water"[Mesh])) OR ((((((((((water aerobics) OR (waterobics)) OR (aquarobics)) OR (aquatic fitness)) OR (aquafitness)) OR (aquafit)) OR (aqua zumba)) OR (water yoga)) OR (aqua aerobics)) OR (aqua jog))) AND ((("Obesity"[Mesh]) OR ((fat) OR (obese))) OR ("Overweight"[Mesh]))) AND (("Randomized Controlled Trials as Topic"[Mesh]) OR ((((((Randomised controlled trial) OR (controlled trial)) OR (randomized controlled study)) OR (Clinical Trials, Randomized)) OR (Trials, Randomized Clinical)) OR (Controlled Clinical Trials, Randomized)))	357
Embase	('randomised controlled trial'/exp OR 'randomised controlled trial' OR 'randomized controlled trials as topic'/exp OR 'randomized controlled trials as topic' OR 'controlled trial'/exp OR 'controlled trial' OR 'randomized controlled study'/exp OR 'randomized controlled study' OR 'clinical trials, randomized' OR 'trials, randomized clinical' OR 'controlled clinical trials, randomized') AND ('obesity'/exp OR 'obesity' OR 'fat'/exp	2099

	OR 'fat' OR 'obese' OR 'overweight'/exp OR 'overweight') AND ('water aerobics'/exp OR 'water aerobics' OR 'waterobics' OR 'aquarobics' OR 'aquatic fitness' OR 'aquafitness' OR 'aquafit' OR 'aqua zumba' OR 'water yoga' OR 'aqua aerobics' OR 'aqua jog' OR (('water'/exp OR 'water') AND ('exercise'/exp OR 'exercise' OR 'aerobics'/exp OR 'aerobics' OR 'exercises' OR 'cycling'/exp OR 'cycling' OR 'physical activity'/exp OR 'physical activity' OR 'activities, physical' OR 'activity, physical'/exp OR 'activity, physical' OR 'physical activities' OR 'exercise, physical' OR 'exercises, physical' OR 'physical exercise'/exp OR 'physical exercise' OR 'physical exercises' OR 'acute exercise'/exp OR 'acute exercise' OR 'acute exercises' OR 'exercise, acute' OR 'exercises, acute' OR 'exercise, isometric'/exp OR 'exercise, isometric' OR 'exercises, isometric' OR 'isometric exercises' OR 'isometric exercise'/exp OR 'isometric exercise' OR 'exercise, aerobic'/exp OR 'exercise, aerobic' OR 'aerobic exercise'/exp OR 'aerobic exercise' OR 'aerobic exercises' OR 'exercises, aerobic' OR 'exercise training'/exp OR 'exercise training' OR 'exercise trainings' OR 'training, exercise' OR 'trainings, exercise')))	
Ovid MEDLINE	1 "Randomised controlled trial ".mp. 2 exp Randomized Controlled Trials as Topic/ 3 " controlled trial".mp. 4 " randomized controlled study ".mp. 5 "Clinical Trials, Randomized".mp. 6 "Trials, Randomized Clinical".mp. 7 "Controlled Clinical Trials, Randomized".mp. 8 1 or 2 or 3 or 4 or 5 or 6 or 7 9 exp Obesity/ 10 exp Fats/ 11 "obese".mp. 12 exp Overweight/ 13 9 or 10 or 11 or 12 14 "water aerobics ".mp. 15 "aquarobics ".mp. 16 "aquatic fitness ".mp. 17 "aquafitness ".mp. 18 "aquafit".mp. 19 " water yoga".mp. 20 "aqua aerobics".mp. 21 14 or 15 or 16 or 17 or 18 or 19 or 20 22 exp Water/ 23 exp Exercise/ 24 "aerobics ".mp. 25 "Exercises".mp. 26 "cycling".mp.	19

	27 "Physical Activity".mp. 28 "Activities, Physical".mp. 29 "Activity, Physical".mp. 30 "Physical Activities".mp. 31 "Exercise, Physical".mp. 32 "Exercises, Physical".mp. 33 "Physical Exercise".mp. 34 "Physical Exercises".mp. 35 "Acute Exercise".mp. 36 "Acute Exercises".mp. 37 "Exercise, Acute".mp. 38 "Exercises, Acute".mp. 39 "Exercise, Isometric".mp. 40 "Exercises, Isometric".mp. 41 "Isometric Exercises".mp. 42 "Isometric Exercise".mp. 43 "Exercise, Aerobic".mp. 44 "Aerobic Exercise".mp. 45 "Aerobic Exercises".mp. 46 "Exercises, Aerobic".mp. 47 "Exercise Training".mp. 48 "Exercise Trainings".mp. 49 "Training, Exercise".mp. 50 "Trainings, Exercise".mp. 51 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 52 22 and 51 53 21 or 52 54 8 and 13 and 53	
Scopus	((TITLE-ABS-KEY ("randomised controlled trial ") OR TITLE-ABS-KEY ("randomized controlled trials as topic ") OR TITLE-ABS-KEY (" controlled trial") OR TITLE-ABS-KEY (" randomized controlled study ") OR TITLE-ABS-KEY ("clinical trials, randomized") OR TITLE-ABS-KEY ("trials, randomized clinical") OR TITLE-ABS-KEY ("controlled clinical trials, randomized"))) AND ((TITLE-ABS-KEY (obesity) OR TITLE-ABS-KEY (fat) OR TITLE-ABS-KEY (obese) OR TITLE-ABS-KEY (overweight))) AND (((TITLE-ABS-KEY (water)) AND ((TITLE-ABS-KEY (exercise) OR TITLE-ABS-KEY (exercises) OR TITLE-ABS-KEY (cycling) OR TITLE-ABS-KEY ("physical activity") OR TITLE-ABS-KEY ("activities, physical") OR TITLE-ABS-KEY ("activity, physical") OR TITLE-ABS-KEY ("physical activities") OR TITLE-ABS-KEY ("exercise, physical") OR	433

	TITLE-ABS-KEY ("exercises, physical") OR TITLE-ABS-KEY ("physical exercise") OR TITLE-ABS-KEY ("physical exercises") OR TITLE-ABS-KEY ("acute exercise") OR TITLE-ABS-KEY ("acute exercises") OR TITLE-ABS-KEY ("exercise, acute") OR TITLE-ABS-KEY ("exercises, acute") OR TITLE-ABS-KEY ("exercise, isometric") OR TITLE-ABS-KEY ("exercises, isometric") OR TITLE-ABS-KEY ("isometric exercises") OR TITLE-ABS-KEY ("isometric exercise") OR TITLE-ABS-KEY ("exercise, aerobic") OR TITLE-ABS-KEY ("aerobic exercise") OR TITLE-ABS-KEY ("aerobic exercises") OR TITLE-ABS-KEY ("exercises, aerobic") OR TITLE-ABS-KEY ("exercise training") OR TITLE-ABS-KEY ("exercise trainings") OR TITLE-ABS-KEY ("training, exercise") OR TITLE-ABS-KEY ("trainings, exercise")))) OR ((TITLE-ABS-KEY ("water aerobics ") OR TITLE-ABS-KEY ("waterobics ") OR TITLE-ABS-KEY ("aquarobics ") OR TITLE-ABS-KEY ("aquatic fitness ") OR TITLE-ABS-KEY ("aquafitness ") OR TITLE-ABS-KEY ("aquafit") OR TITLE-ABS-KEY (" aqua zumba") OR TITLE-ABS-KEY (" water yoga") OR TITLE-ABS-KEY ("aqua aerobics") OR TITLE-ABS-KEY (" aqua jog")))))	
The Cochrane Library	#1 MeSH descriptor: [Randomized Controlled Trials as Topic] explode all trees #2 MeSH descriptor: [Randomized Controlled Trial] explode all trees #3 " controlled trial" #4 " randomized controlled study " #5 "Clinical Trials, Randomized" #6 "Trials, Randomized Clinical" #7 "Controlled Clinical Trials, Randomized" #8 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 #9 MeSH descriptor: [Obesity] explode all trees #10 MeSH descriptor: [Fats] explode all trees #11 obese #12 MeSH descriptor: [Overweight] explode all trees #13 #9 OR #10 OR #11 OR #12 #14 "water aerobics " #15 waterobics #16 aquarobics #17 "aquatic fitness " #18 aquafitness #19 aquafit #20 " aqua zumba" #21 " water yoga" #22 "aqua aerobics"	1223

	#23 " aqua jog" #24 #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 #25 MeSH descriptor: [Water] explode all trees #26 MeSH descriptor: [Exercise] explode all trees #27 Exercises #28 cycling #29 "Physical Activity" #30 "Activity, Physical" #31 "Exercise, Physical" #32 "Exercises, Physical" #33 "Physical Exercise" #34 "Physical Exercises" #35 "Acute Exercise" #36 "Acute Exercises" #37 "Exercise, Acute" #38 "Exercises, Acute" #39 "Exercise, Isometric" #40 "Exercises, Isometric" #41 "Isometric Exercises" #42 "Isometric Exercise" #43 "Exercise, Aerobic" #44 "Aerobic Exercise" #45 "Aerobic Exercises" #46 "Exercises, Aerobic" #47 "Exercise Training" #48 "Exercise Trainings" #49 "Training, Exercise" #50 "Trainings, Exercise" #51 #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50 #52 #25 AND #51 #53 #24 OR #52 #54 #8 AND #13 AND #53	
Web of science	((((((((((((((((((((((((((TS=(Exercise)) OR TS=(Exercises)) OR TS=(cycling)) OR TS=("Physical Activity")) OR TS=("Activities, Physical")) OR TS=("Activity, Physical")) OR TS=("Physical Activities")) OR TS=("Exercise, Physical")) OR TS=("Exercises, Physical")) OR TS=("Physical Exercise")) OR TS=("Physical Exercises")) OR TS=("Acute Exercise")) OR TS=("Acute Exercises")) OR TS=("Exercise, Acute")) OR TS=("Exercises, Acute")) OR TS=("Exercise, Isometric")) OR TS=("Exercises, Isometric")) OR	192

	TS=("Isometric Exercises")) OR TS=("Isometric Exercise")) OR TS=("Exercise, Aerobic")) OR TS=("Aerobic Exercise")) OR TS=("Aerobic Exercises")) OR TS=("Exercises, Aerobic")) OR TS=("Exercise Training")) OR TS=("Exercise Trainings")) OR TS=("Training, Exercise")) OR TS=("Trainings, Exercise")) AND TS=(water) OR (((((((((TS=("water aerobics ")) OR TS=("waterobics ")) OR TS=("aquarobics ")) OR TS=("aquatic fitness ")) OR TS=("aquafitness ")) OR TS=("aquafit")) OR TS=(" aqua zumba")) OR TS=(" water yoga")) OR TS=("aqua aerobics")) OR TS=(" aqua jog") AND ((((((TS=("Randomised controlled trial ")) OR TS=("Randomized Controlled Trials as Topic")) OR TS=(" controlled trial")) OR TS=(" randomized controlled study ")) OR TS=("Clinical Trials, Randomized")) OR TS=("Trials, Randomized Clinical")) OR TS=("Controlled Clinical Trials, Randomized")AND (((TS=(obesity)) OR TS=(fat)) OR TS=(obese)) OR TS=(Overweight)	

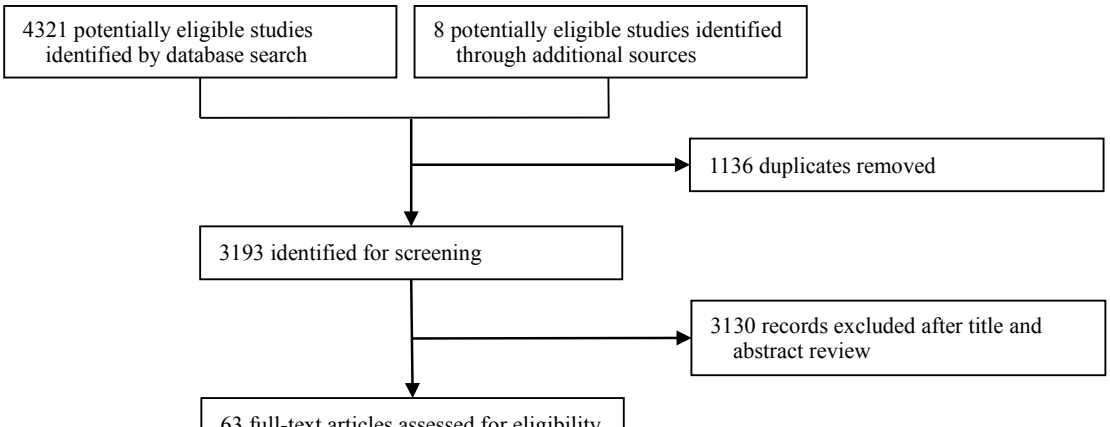

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow

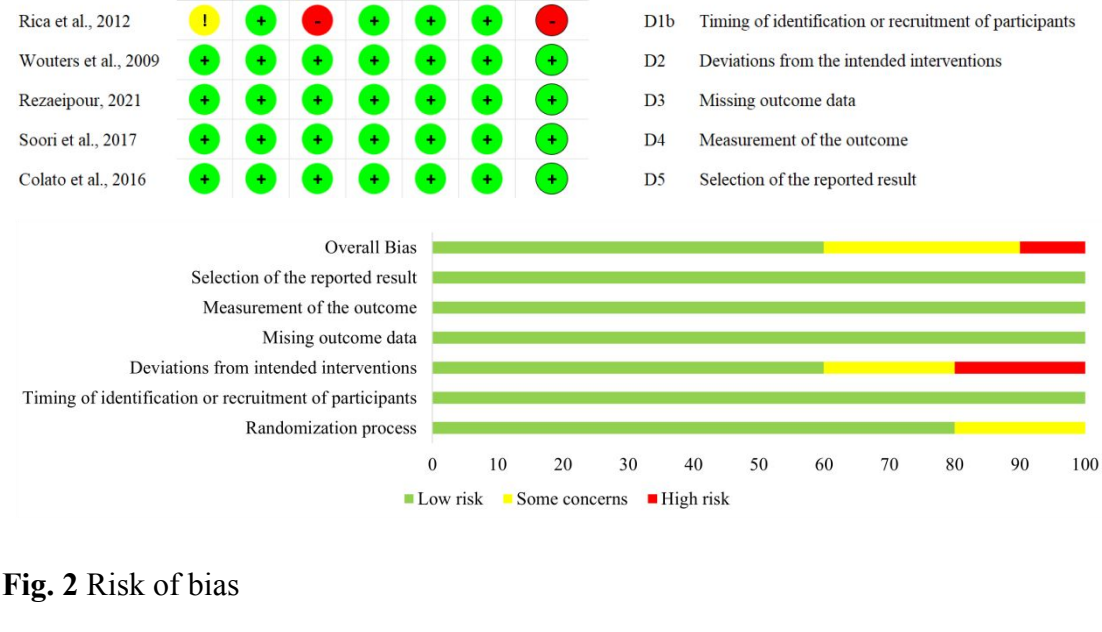

Fig. 2 Risk of bias

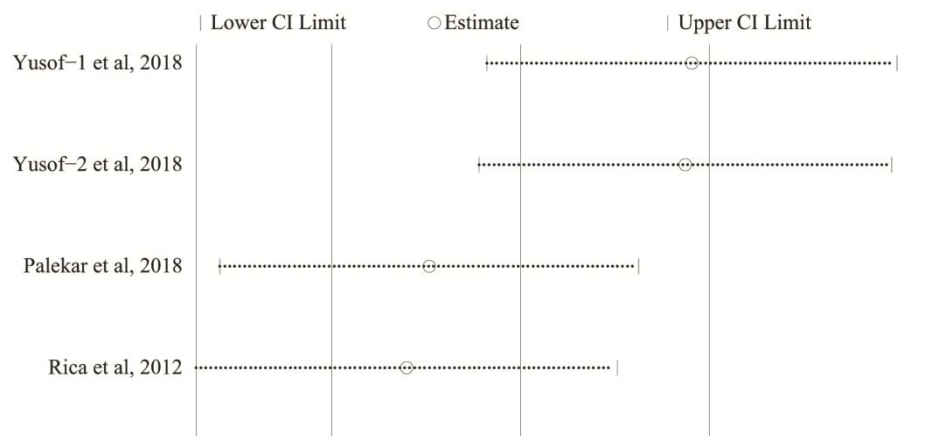

Fig. 3 Sensitivity analysis of percentage body fat

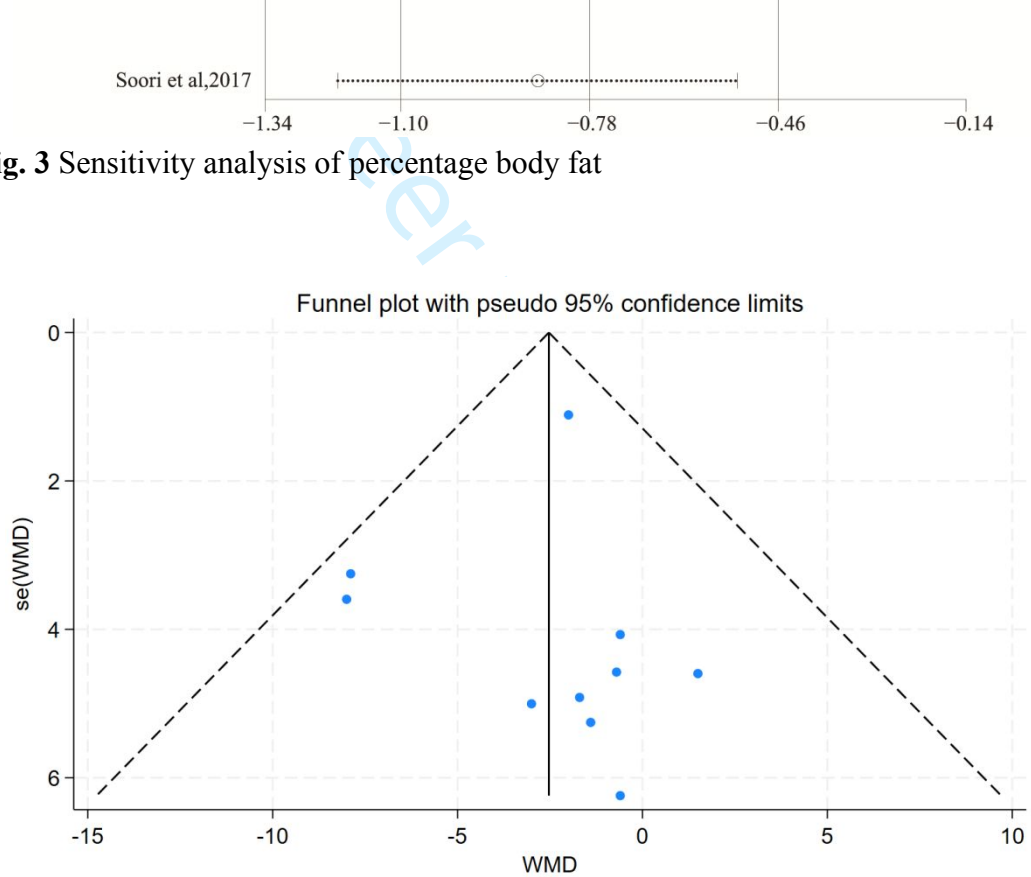

Fig. 4 Funnel plot for body weight

BMJ Open

Effects of water aerobics on body composition in obesity and overweight people: a systematic review and meta-analysis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-091743.R1
Article Type:	Original research
Date Submitted by the Author:	13-Dec-2024
Complete List of Authors:	DING, ZIYAN; Pukyong National University - Daeyeon Campus, Gao, Zixuan; Chaoyang Normal University Zhou, Haixu; Jilin Sport University Park, Jongchul; Pukyong National University, Department of Smart Healthcare
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Rehabilitation medicine, Research methods, Sports and exercise medicine
Keywords:	Meta-Analysis, Obesity, Overweight, SPORTS MEDICINE

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Effects of water aerobics on body composition in obesity and overweight people: a systematic review and meta-analysis

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Effects of water aerobics on body composition in obesity and overweight people: a systematic review and meta-analysis

Abstract

Objectives The problem of obesity and overweight seriously affects people's health. The benefits of WAs have been shown in obesity and overweight people, but the effects of WAs on body composition improvement are still unclear.

Design Systematic review and meta-analysis.

Data sources A systematic literature search was conducted on November 16, 2024, using the PubMed MEDLINE, Ovid MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library.

Eligibility criteria for selecting studies These studies were RCTs and were screened independently by 2 researchers. All RCTs on WAs that evaluated the anthropometric and body composition parameters of overweight and obesity subjects were included, and a reporting of eligible studies was conducted in accordance with PRISMA statement.

Data extraction and synthesis All process were independently screened by 2 researchers (D.Z.Y., Z.H.X.). Depending on the level of study heterogeneity, the use of a fixed-effects model or a random-effects model was determined. The risk of bias of the selected studies was assessed using the Risk of Bias 2.0 tool, and sensitivity analyses and subgroup analyses were performed on the outcome indicators. The quality of evidence for each outcome was evaluated using the GRADE system.

Results A total of 10 studies with 286 patients were included. Sensitivity analyses were performed for PBF with high heterogeneity, and the results were robust. WAs were able to reduce BW (WMD = -2.69, 95%CI: -4.10 to -1.27, $p < 0.05$, $I^2 = 0.0\%$) and WC (WMD = -2.75, 95%CI: -4.41 to -1.09, $p < 0.05$, $I^2 = 27.0\%$), but the effect on other body indicators was not significant. The GRADE assessment revealed that the certainty of evidence was low for BMI, LM, FM, WHR, and HC, and very low for PBF. However, the moderate certainty of evidence for BW and WC.

Conclusion For the obesity and overweight people, WAs interventions over 10 weeks (i.e., 12 weeks) reduced BW and WC, with more significant effects in women and better improvements in body composition in middle-aged and older adults (average age ≥ 45 years). The certainty of evidence, as assessed using the GRADE framework, was moderate for both BW and WC, indicating that these findings were robust.

PROSPERO registration number CRD42023466969.

Strengths and limitations of this study

- This study systematically reviewed and meta-analyzed RCTs, the gold standard in clinical research, ensuring a high level of methodological rigor.
- Studies of registered or ongoing RCTs were not included in the search for articles, and study inclusion was limited to English.
- Judgements made by persons were more subjective when using ROB tools and the GRADE system for literature and outcome quality assessment.
- There were certain limitations to the articles included in the study: (1) Some of the studies had a short (6-week) duration of trials, small sample sizes, and less research

data; (2) A small number of participants in the study dropped out of the trial halfway through; (3) Differences in the age, sex ratio, and location of the trial participants in three aspects.

Introduction

The global prevalence of obesity has risen significantly over the past 40 years [1-3]. By 2022, more than 43% of adults worldwide will be overweight, with 504 million female and 374 million male obese [4]. Obesity is a chronic disease that increases the risk of various complications and leads to an estimated 2.8 million deaths each year [5-7]. Although weight management through exercise is highly effective [8-10]. However, due to their weight, obesity and overweight people are prone to serious damage to their bones and joints during exercise [11]. Traditional land-based aerobic exercise methods increase musculoskeletal damage in obese patients [12]. American College Sports Medicine recommends water aerobics (WAs) for obesity people to reduce injury risk and increase adherence to exercise [13]. WAs interventions are more beneficial and effective as a new approach to treating obesity [14, 15]. WAs can use the buoyant effect of water to reduce joint injuries associated with exercise in obesity and overweight people [16, 17]. Studies have shown that WAs have a better effect on improving body composition in obesity and overweight people. Young obese adults (mean age 18-25

years) lost weight and improved their body mass index (BMI) after 12 weeks of WAs [18]. Middle-aged adults (mean age 47-70 years) also showed greater improvements in body weight (BW) and percent body fat (PBF) after participating in the 6-week WAs [19]. WAs had significant improvements in body composition (e.g., PBF, BW, BMI, and waist-hip ratio (WHR)) in a population of overweight older men (mean age 62-70 years) [20]. Overweight older adults (mean age 72 years) who participated in a 28-week WAs had reduced body fat mass (FM), leg and waist circumference (WC) [21]. Therefore, WAs, as a beneficial exercise method, can be an important way to lose weight for obesity and overweight people [19, 21].

However, fewer studies have been reported on the effects of WAs on physical indicators in obesity and overweight people. The previous literature review [14, 22, 23], only provided a wide-ranging overview of the relevant evidence. For example, Haifeng Zhu [24] summarizes the physical effects of aquatic exercise on adults. However, this study only included randomized controlled trials (RCTs) on healthy adults and did not consider studies of obesity and overweight people [24].

Thus, the systematic review and meta-analysis of the present study can, to some extent, fill the research gap on the effects of WAs interventions on obesity and overweight people. The main discussion is whether WAs has a significant improvement in physical indicators in obesity and overweight people.

Methods

Registration

This meta-analysis study is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [25, 26]. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (registration number: CRD42023466969). Minor changes were made to the initial PROSPERO protocol submitted in October 2023 (**Table S1** in Supplementary information 2).

Search strategy

Six databases were searched: PubMed MEDLINE, Ovid MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library. The time span of the search was from the construction of the database to 26 October 2023. We have updated the search records (as of November 16, 2024) to make the search more comprehensive. Retrieval strategy based on PICOS tool [27]: (P) Population: adults with overweight and obesity; (I) Intervention: WAs; (C) Comparator: other exercise modalities or no exercise control; (O) Outcome: body composition; (S) Study type: RCTs. Search using core terms: water aerobics (e.g., aquatic fitness, aqua aerobics), obesity or overweight (e.g., fat, obese), and RCTs (e.g., randomized controlled study, controlled clinical trials). The core terms for the searches were identified in the MeSH Database in the PubMed database, respectively, to ensure the scientific validity and accuracy of the search vocabulary, and the comprehensiveness of the search scope (details of the search strategy are in **Table S2** in Supplementary information 2). In addition to the database, reference lists of included articles were screened for articles that satisfied the inclusion criteria.

Eligibility criteria

Inclusion criteria: (1) RCTs; (2) Participants were obesity (BMI ≥ 30 kg/m^2) and overweight (BMI ≥ 25kg/m^2) [28] adults (≥ 18 years, including older adults); (3) The intervention group participated in WAs for at least 4 weeks, and the control group did not participate in exercise or chose other ways of exercising; (4) Results on changes in body composition were obtained in the original article; (5) Full text available in English (i.e., not a review, letter, case series or conference proceedings). Grey literature (i.e., dissertations, conference abstracts) was not included, as it has been shown that these represent only a small percentage of the studies included in the systematic review and rarely affect the statistical or clinical significance of the results [29].

Exclusion criteria: (1) Trials that did not satisfy all inclusion criteria; (2) Participants diagnosed with other diseases were included; (3) Exercise interventions combined with dietary control, medication or other lifestyle changes; (4) There was no exercise of any form, just a trial of being immersed in water or receiving a massage.

Study selection

The study used EndNote (Version 21) to manage the articles. First, duplicate articles were removed. Second, the titles and abstracts of the articles were read and qualified articles were selected. Finally, full-text review was performed. The process was independently screened by 2 researchers (D.Z.Y., Z.H.X.). Disagreements were adjudicated by a third researcher (G.Z.X.).

Data extraction

Data from included studies were recorded using an adapted Cochrane Collaboration [30] standardized data extraction form. The study characteristics are extracted as follows:

year of publication, authors, region, study period, study design, sample size, participants, and mean age.

BW, measured in kilograms (kg), serves as a direct indicator of overall weight loss and is a key measure of intervention effectiveness in obesity management [31]. BMI, a widely used but indirect measure of body fatness, is calculated as weight in kilograms divided by height in meters squared (kg/m^2) [32]. PBF is an important metric for distinguishing between lean mass (LM) and FM [33]. FM and LM were assessed using bioelectrical impedance analysis or dual-energy X-ray absorptiometry, with PBF calculated using the formula: PBF = (FM (kg)/BW (kg)) × 100 [34]. WC reflects abdominal fat distribution and is a validated marker of central obesity and metabolic risk [35]. Risk thresholds for WC are ≥ 102 cm for male and ≥ 88 cm for female [36]. Both WC and hip circumference (HC) were measured in centimeters (cm) using an inelastic tape. WC was defined as the minimum circumference between the rib margins and iliac crests, while HC was defined as the maximum circumference between the waist and thighs. The WHR was calculated as WC/HC [34]. WHR is a measure of upper and lower body fat distribution, with higher values indicating a greater risk of obesity-related health problems. Risk thresholds for WHR are male ≥ 1.0 and female ≥ 0.85 [36]. Therefore, the primary outcomes were BW, BMI, PBF, WHR, WC, and HC, while the secondary outcomes were FM and LM.

Two researchers (D.Z.Y., Z.H.X.) independently extracted this information from each study and resolved any disagreements through discussion.

Risk of bias

Two researchers (D.Z.Y. and Z.H.X.) subjected the included RCTs to an independent risk of bias assessment. The Cochrane risk-of-bias tool (RoB 2) was used for the review according to the evaluation criteria of the Cochrane Handbook for Systematic Reviews of Interventions (Version 6.4) [37]. Disagreements arising from the review were discussed and resolved with the participation of the third researcher (G.Z.X.) on the review team.

Data analysis

Meta-analysis was conducted using Stata 18.0 software. Heterogeneity of studies was assessed using Cochrane's Q and I^2 tests [38]. When $P > 0.1$, $I^2 \leq 50\%$, there was homogeneity, and a fixed-effects model was used for the meta-analysis; when $P \leq 0.1$, $I^2 > 50\%$, there was heterogeneity, and a random-effects model was used [39, 40]. Therefore, this study uses a fixed-effects model for the meta-analysis, which will be changed when $I^2 > 50\%$.

To further test the stability of the results, we conducted a sensitivity analysis using the leave-one-out method [41]. The leave-one-out method involves excluding 1 study, combining the remaining studies in a meta-analysis, and evaluating whether the results of the original meta-analysis were significantly altered by the influence of certain studies by observing the changes in the combined results [42]. Publication bias of studies was assessed using funnel plots in which the asymmetric distribution of studies suggested bias [43]. Quantitative analysis of funnel plot asymmetry using the Egger regression test [44].

Differences were considered significant at $P < 0.05$ [45].

The standard error of the mean (SEM) of the extracted data were converted to standard deviation (SD) [46]. Using the formula in the Cochrane Handbook [47] (N represents the number of trial participants):

$$SD = SEM \times \sqrt{N}$$

Quality of GRADE evidence

The quality of evidence for each outcome was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology [48]. Two researchers (D.Z.Y. and Z.H.X.) independently conducted the assessments. Any disagreements were resolved through discussion and, when necessary, consultation with a third researcher (G.Z.X.) to reach a consensus. As all included studies were RCTs, the initial evidence quality was rated as high. However, the confidence in the evidence could be downgraded based on specific limitations in the original studies, including risk of bias, inconsistency, indirectness, imprecision, and publication bias [49]. Following GRADE guidelines, the final quality of evidence was categorized into one of four levels: high, moderate, low, and very low [50].

Results

Study search results

A total of 4517 studies were searched. 1185 studies were deleted due to duplication and 3332 studies were further screened. After reading the titles and abstracts 3267 studies were deleted. 65 articles were eligible for full-text screening, of which 55 were deleted. Finally, 10 studies were included in the meta-analysis (**Fig. 1**).

Study characteristics

The RCTs included in the study had 286 participants [51-60]. Publication dates range from 2009 to 2021. Inclusion of research trials in Malaysia, Brazil, India, American, and the Netherlands. From 20 to 70 years old was the average age of the participants.

A small number of subjects from 5 trials [51, 53, 55, 58, 59] dropped out of the experiment for various reasons, and trial data from those who dropped out was not used.

One study [51] included two distinct intervention groups: Aqua Zumba (Yusof-1) and Aqua Jogging (Yusof-2). Due to the differing exercise programs, these groups were treated as separate studies (Yusof-1 and Yusof-2) in the analysis.

The types of WAs included in this review were diverse and encompassed activities such as water aerobics, aqua Zumba, water yoga, and aqua jogging. Across all included trials, the intervention period ranged from 6 to 12 weeks. One of the trials [55] had an exercise frequency of 2 times a week; others were 3 times a week. The exercise time varied according to the needs of the trials, with most being 60 minutes each.

The units for BW, LM, and FM are kilograms (kg); for BMI, kilograms per square meter (kg/m^2); and for WC and HC, centimeters (cm). The basic characteristics of each study are shown in **Table 1**.

Table 1 Experimental details.

Study	Country	Duration (weeks)	Sample	Mean age/ range (SD)	Exercise Category	Study design (Frequency、time)	Outcome
Yusof-1 et al., 2018	Malaysia	12	40 (F)	45.13(5.17)	Aqua zumba	3 days/week, 60 minutes per session	BW, PBF, WC
Yusof-2 et al., 2018	Malaysia	12	40 (F)	45.28(5.09)	Aqua jog	3 days/week, 60 minutes per session	BW, PBF, WC
Penaforte et al., 2015	Brazil	8	16 (F)	42.8(7.4)	Water aerobics	3 days/week, 60minutes per session	BW, BMI, LM, FM, WC, HC
Palekar et al., 2018	India	6	14 (M)	20.71	Underwater treadmill training	3 days/week, 25minutes per session	BMI, PBF, WC
Rezaeipour, 2020	Iran	12	24 (F)	69.5(4.3)	Aquatic exercises (dancing and walking)	3 days/week, 60minutes per session	BW, BMI, LM, FM,
Greene et al., 2009	American	12	57 (Mix)	42(18.67)	Underwater treadmill	Three times per week	BW, BMI, LM, FM, WC, HC, WHR
Rica et al., 2012	Brazil	12	38 (F)	68.5(5)	Water-based exercise with aerobic	Three times per week, 60-min sessions	BW, BMI, PBF, LM, FM, WC, HC, WHR
Wouters et al., 2009	Netherlands	6	14 (Mix)	44	Aquajogging	2 per week, one hour	BW, BMI, PBF, WC
Rezaeipour, 2021	Iran	12	27 (M)	68.7(3.2)	Water-based exercise with aerobic	3 days/week, 60minutes per session	BW, BMI
Soori et al., 2017	Iran	10	16 (F)	45-60	Swimming or walking in the water	3 per week, 45 min per day	BW, BMI, PBF, WC
Colato et al., 2016	Brazil	12	20 (F)	49.36(11.69)	Water running training	3 per week, 70 minutes/session	BW, BMI, FM, WC, HC

Note: body weight (BW); body mass index BMI)；percent body fat (PBF)；lean mass (LM); fat mass (FM); Waist–hip ratio (WHR); Waist circumference (WC); Hip circumference (HC); mixed sex (Mix); male (M); female(F).

Results of ROB assessment

After a bias risk assessment, the 10 included studies were rated as follows: 6 had low risk, 3 had some concerns, and 1 had high risk (**Fig. 2**).

Physical outcome

WAs are effective interventions for BW (WMD = -2.69, 95%CI: -4.10 to -1.27, $p < 0.05$, $I^2 = 0.0\%$) and WC (WMD = -2.75, 95%CI: -4.41 to -1.09, $p < 0.05$, $I^2 = 27.0\%$) in obesity and overweight people (**Fig. S1** and **Fig. S2** in Supplementary information 1). Other physical indicators, such as BMI (WMD = -0.55, 95%CI: -1.29 to 0.19, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S3** in Supplementary information 1), PBF (WMD = -4.83, 95%CI: -10.32 to 0.66, $p > 0.05$, $I^2 = 93.6\%$) (**Fig. S4** in Supplementary information 1), LM (WMD = -0.19, 95%CI: -2.75 to 2.37, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S5** in Supplementary information 1), FM (WMD = -0.92, 95%CI: -3.20 to 1.36, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S6** in Supplementary information 1), WHR (WMD = -0.02, 95%CI: -0.05 to 0.01, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S7** in Supplementary information 1) and HC (WMD = -1.05, 95%CI: -3.64 to 1.55, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S8** in Supplementary information 1), did not show significant improvement (**Table 2**).

Subgroup analysis of outcomes

Subgroup analyses of WAs were performed on the included studies to identify appropriate WAs regularity and to explore sources of heterogeneity. Due to the number of subgroups, the results of the subgroup analyses of WAs are summarized in the table (**Table 2**).

Table 2 Subgroup analysis of water aerobics on anthropometric measures

	N	WMD (95% CI)	P within group	P heterogeneity	I^2
Subgroup analyses of WA on BW					
Overall effect	10	-2.69(-4.10, -1.27)	0.000*	0.670	0.0%
Trial duration (week)					
>10	7	-3.31(-5.23, -1.40)	0.001*	0.455	0.0%
≤10	3	-1.93(-4.03, 0.16)	0.071	0.971	0.0%
Sex					
Male	1	-0.60(-8.58, 7.38)	0.883	-	-
Female	7	-2.90(-4.37, -1.43)	0.000*	0.486	0.0%
Mix (male & female)	2	0.24(-6.54, 7.02)	0.944	0.678	0.0%
Average age					
≥45	7	-2.85(-4.31, -1.40)	0.000*	0.465	0.0%
<45	3	0.05(-5.89, 5.98)	0.988	0.911	0.0%
Subgroup analyses of WA on BMI					
Overall effect	9	-0.55(-1.29, 0.13)	0.146	0.984	0.0%
Trial duration (week)					
>10	5	-0.14(-1.25, 0.97)	0.806	0.943	0.0%
≤10	4	-0.88(-1.88, 0.12)	0.083	0.979	0.0%
Sex					
Male	2	-0.47(-2.52, 1.57)	0.649	0.932	0.0%
Female	5	-0.55(-1.41, 0.31)	0.208	0.757	0.0%
Mix (male & female)	2	-0.63(-2.79, 1.52)	0.565	0.932	0.0%
Average age					
≥45	5	-0.55(-1.38, 0.29)	0.199	0.757	0.0%
<45	4	-0.57(-2.21, 1.07)	0.498	0.999	0.0%
Subgroup analyses of WA on PBF					
Overall effect	6	-4.83(-10.32, 0.66)	0.085	0.000	93.6%
Trial duration (week)					
>10	3	-9.01(-18.05, 0.02)	0.051	0.000	94.8%
≤10	3	-0.26(-1.87, 1.36)	0.755	0.938	0.0%
Sex					
Male	1	-0.83(-6.28, 4.61)	0.765	-	-
Female	4	-6.71(-14.24, 0.82)	0.081	0.000	96.0%
Mix (male & female)	1	-0.80(-5.25, 3.65)	0.724	-	-
Average age					
≥45	4	-6.71(-14.24, 0.82)	0.081	0.000	96.0%
<45	2	-0.81(-4.26, 2.63)	0.644	0.993	0.0%
Subgroup analyses of WA on WC					
Overall effect	8	-2.75(-4.41, -1.09)	0.001*	0.213	27.0%
Trial duration (week)					
>10	5	-2.88(-4.63, -1.12)	0.001*	0.057	56.3%
≤10	3	-1.67(-6.76, 3.42)	0.520	0.889	0.0%

Sex					
Male	1	-0.89(-17.54, 15.76)	0.917	-	-
Female	5	-2.89(-4.65, -1.13)	0.001*	0.058	56.1%
Mix (male & female)	2	-1.69(-6.90, 3.52)	0.525	0.626	0.0%
Average age					
≥45	4	-3.03(-4.85, -1.22)	0.001*	0.034	65.5%
<45	4	-1.27(-5.40, 2.86)	0.546	0.959	0.0%
Subgroup analyses of WA on LM					
Overall effect	4	-0.19(-2.75, 2.37)	0.883	0.889	0.0%
Subgroup analyses of WA on FM					
Overall effect	5	-0.92(-3.20, 1.36)	0.429	0.991	0.0%
Subgroup analyses of WA on WHR					
Overall effect	3	-0.02(-0.05, 0.01)	0.256	0.830	0.0%
Subgroup analyses of WA on HC					
Overall effect	4	-1.05(-3.64, 1.55)	0.429	0.610	0.0%

Note: confidence interval (CI); numbers (N); weighted mean differences (WMD); *P < 0.05.

As seen by subgroup analyses of BW, WAs with a trial duration > 10 weeks (i.e., 12 weeks) significantly reduced BW (WMD = -3.31, 95%CI: -5.23 to -1.40, p < 0.05, I^2 = 0.0%). In addition, WAs significantly reduced BW in the female population (WMD = -2.90, 95%CI: -4.37 to -1.43, p < 0.05, I^2 = 0.0%) and in the population with a mean age of ≥ 45 years (WMD = -2.85, 95%CI: -4.31 to -1.40, p < 0.05, I^2 = 0.0%).

From the subgroup analysis of WC, it is shown that WAs with a trial duration >10 weeks significantly reduced WC (WMD = -2.88, 95%CI: -4.63 to -1.12, p < 0.05, I^2 = 56.3%). Among them, WAs were mainly able to significantly reduce WC in the female population (WMD = -2.89, 95%CI: -4.65 to -1.13, p < 0.05, I^2 = 56.1%) and in the population (WMD = -3.03, 95%CI: -4.85 to -1.22, p < 0.05, I^2 = 65.5%) with a mean age ≥45 years.

Other subgroup analyses found that BMI (P = 0.146, I^2 = 0.0%), LM (P = 0.883, I^2 = 0.0%), FM (P = 0.429, I^2 = 0.0%), WHR (P = 0.256, I^2 = 0.0%), and HC (P = 0.429,

I^2 = 0.0%) were neither heterogeneous nor significant. In contrast, PBF (I^2 = 93.6%) and WC (I^2 = 27.0%) were heterogeneous. However, separate subgroup analyses revealed multiple sources of heterogeneity, which could not be adequately explained by only one pair of subgroup analyses.

Sensitivity analysis of PBF

PBF has high heterogeneity. Thus, the robustness of the results was assessed through sensitivity analyses to identify sources of heterogeneity. A leave-one-out sensitivity analysis was performed, revealing that the direction of the combined estimates did not change significantly with the removal of any individual study. This finding suggests that the meta-analysis was robust and not unduly influenced by any single study [61]. The results show that the 95%CI excludes 0 (**Fig. 3**). This means that the results are robust, the sensitivity is small, and the original meta-analysis results are statistically significant.

Publication bias

Evaluation of publication bias for the inclusion of more than 10 studies [62]. The study will assess the risk of bias in the BW outcome measures through funnel plots and Egger's regression test [30]. Based on Egger's regression test (P = 0.841 > 0.05) indicates that there is no publication bias, and the visual weight funnel plot (**Fig. 4**) supports this argument.

GRADE Assessment

The quality of evidence for each outcome was evaluated using the GRADE system. The results indicated that the quality of evidence was moderate for BW and WC, low for

BMI, LM, FM, WHR, and HC, and very low for PBF (Table 3). Primary reasons for downgrading included small sample sizes in the included studies, 95%CI crossing equivalence thresholds, and high heterogeneity.

Table 3 GRADE quality of evidence

Outcomes	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Quality of evidence
BW	not serious	not serious	not serious	serious [a]	none	⊕⊕⊕◯ Moderate
BMI	not serious	not serious	not serious	very serious [a,b]	none	⊕⊕◯◯ Low
PBF	not serious	very serious [c]	not serious	very serious [a,b]	none	⊕◯◯◯ Very low
LM	not serious	not serious	not serious	very serious [a,b]	none	⊕⊕◯◯ Low
FM	not serious	not serious	not serious	very serious [a,b]	none	⊕⊕◯◯ Low
WHR	not serious	not serious	not serious	very serious [a,b]	none	⊕⊕◯◯ Low
WC	not serious	not serious	not serious	serious [a]	none	⊕⊕⊕◯ Moderate
HC	not serious	not serious	not serious	very serious [a,b]	none	⊕⊕◯◯ Low

Note: a. small sample sizes in the included studies; b. 95% CI crossing equivalence thresholds; c. high heterogeneity.

Discussion

This study systematically reviewed the effects of WAs on body composition in obesity and overweight people. The results showed that WAs had an ameliorative effect on body composition [63], with significant effects on reducing BW and WC [18, 64] , mainly: (1) WAs had a reducing effect on BW and WC in female; (2) WAs with a trial duration of 10 weeks or more (i.e., 12 weeks) showed significant reduction in BW and WC; (3) Continuous WAs performed in the middle-aged and older people [65, 66]

(average age ≥ 45 years) reduced BW and WC better.

The results of the subgroup analyses show in more detail the factors that influence the impact of WAs on the obesity and overweight people. According to the subgroup analysis of BW, WAs with trial duration >10 weeks (i.e., 12 weeks) showed a more significant reduction in BW, and those with 10 weeks and less showed no significant effect. It is possible that due to the short trial duration, short-term (e.g., six weeks) WAs had little effect on BW and body composition [52, 67] , and that WAs of 12 weeks and longer had a better effect [22, 68]. It has been suggested that WAs have an ameliorative effect on BW in overweight older male [20]. However, the present study found that WAs reduced BW significantly in female and not in male, probably due to the small number of males included in the study, resulting in non-significant differences. WAs were more effective in reducing BW in middle-aged and older adults (average age ≥ 45 years). Aerobic exercise in water is beneficial for middle-aged and elderly people, improving body composition while easing the joint loads associated with land-based exercise [69].

In addition, subgroup analyses based on WC showed that the WAs intervention significantly reduced WC in obesity and overweight people. WC is an important measure of abdominal obesity [70, 71]. 12-week WAs have a significant effect on reducing WC in obesity and overweight female [64]. Detailed subgroup analyses showed that WAs with trial duration >10 weeks (i.e., 12 weeks) had a greater effect on WC, and that trial periods of 10 weeks and less did not have a significant effect on WC. Due to the small number of male participants in the included studies, the reducing effect

of WAs on male WC needs to be further confirmed. WAs reduced WC better in middle-aged and older people (average age ≥ 45 years) and not significantly in other (average age < 45 years) people.

Obesity and overweight people can receive many health benefits through exercise. However, subgroup analyses showed that the effect of WAs on improving BMI and PBF in obesity and overweight people was not significant. It has been suggested that 8 weeks of continuous training is not long enough to show beneficial effects, and that the benefits of anthropometric parameters are only gradually revealed when the training period is between 12 and 32 weeks [72]. If subgroups were divided according to trial period, sex, and age for several other body components (LM, FM, WHR, HC), the number of studies in each subgroup would be small, producing results with less confidence. Therefore, several other body components were not analyzed in this study.

The GRADE assessment revealed that the certainty of evidence was low for BMI, LM, FM, WHR, and HC, and very low for PBF. The downgrading was primarily due to small sample sizes, which reduce statistical power and the precision of effect estimates. In addition, high heterogeneity among studies, particularly in PBF outcomes, indicated variability in study populations, methodologies, and intervention effects. Imprecision, as evidenced by wide confidence intervals crossing equivalence thresholds, further contributed to the reduced quality of evidence.

These findings have significant implications for clinical practice. The low certainty of evidence for BMI, WHR, HC, and other secondary outcomes and very low for PBF suggests that current evidence was insufficient to reliably inform clinical

guidelines for using WAs to improve these parameters. Health professionals should approach these results with caution and prioritize interventions with stronger evidence when aiming to target these specific outcomes. However, the moderate certainty of evidence for BW and WC supports the use of WAs as effective interventions for reducing overall body weight and central obesity, which were critical factors in managing obesity-related health risks [73, 74].

Conclusions

The results of this systematic review and meta-analysis suggest that WAs is an effective intervention for reducing BW and WC in overweight and obesity adults. For obesity and overweight people, WAs over 10 weeks reduced BW and WC, with more significant effect in female. Middle-aged and elderly people are also better able to improve their body composition after WAs intervention. The certainty of evidence, as assessed using the GRADE framework, was moderate for both BW and WC, indicating that these findings are robust but would benefit from further research to enhance confidence. In contrast, the certainty of evidence for other outcomes was rated as low or very low, primarily due to small sample sizes, high heterogeneity, and imprecision in the included studies. Future research should aim to address these limitations by conducting larger, well-designed RCTs with standardized methodologies and diverse populations. Additionally, exploring the long-term effects of WAs and comparing its efficacy with other exercise modalities will provide valuable insights. In conclusion, WAs is an important form of exercise for overweight and obesity people to improve

their body composition and overall health.

Abbreviations

PROSPERO: International Prospective Register of Systematic Reviews
WAs: Water aerobics
RCTs: randomized controlled trials
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PICOS： Population, Intervention, Comparison, Outcome, Study type
MeSH: Medical Subject Headings
GRADE: Grading of Recommendations Assessment, Development, and Evaluation
BW: body weight
BMI: body mass index
PBF: percent body fat
LM: lean mass
FM: fat mass
WHR: waist–hip ratio
WC: waist circumference
HC: hip circumference
SEM: standard error of the mean
SD: standard deviation
Risk of Bias 2.0: RoB 2
Mix: mixed sex
M: male
F: female
CI: confidence interval
N: numbers
WMD: weighted mean differences

Supplementary information

Additional file 1. Supplementary information 1.
Additional file 2. Supplementary information 2.

Acknowledgements

Thanks to all those who helped with this paper.

Author contributions

Study conception and design: ZD, JP. Acquisition, analysis or interpretation of data: ZD, ZG, HZ. Drafting the manuscript: ZD, HZ, ZG. Critical revision of the manuscript

for important intellectual content: JP. Statistical analysis: ZD, ZG, HZ. Supervision: JP. Guarantor: JP. All authors have read and agreed to the published version of the manuscript.

Funding

This study had no funding.

Competing interests

The authors declare that they have no competing interests.

Patient and Public Involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication

Not applicable.

Ethics approval

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

All data relevant to the study are included in thearticle or uploaded as supplementary information.

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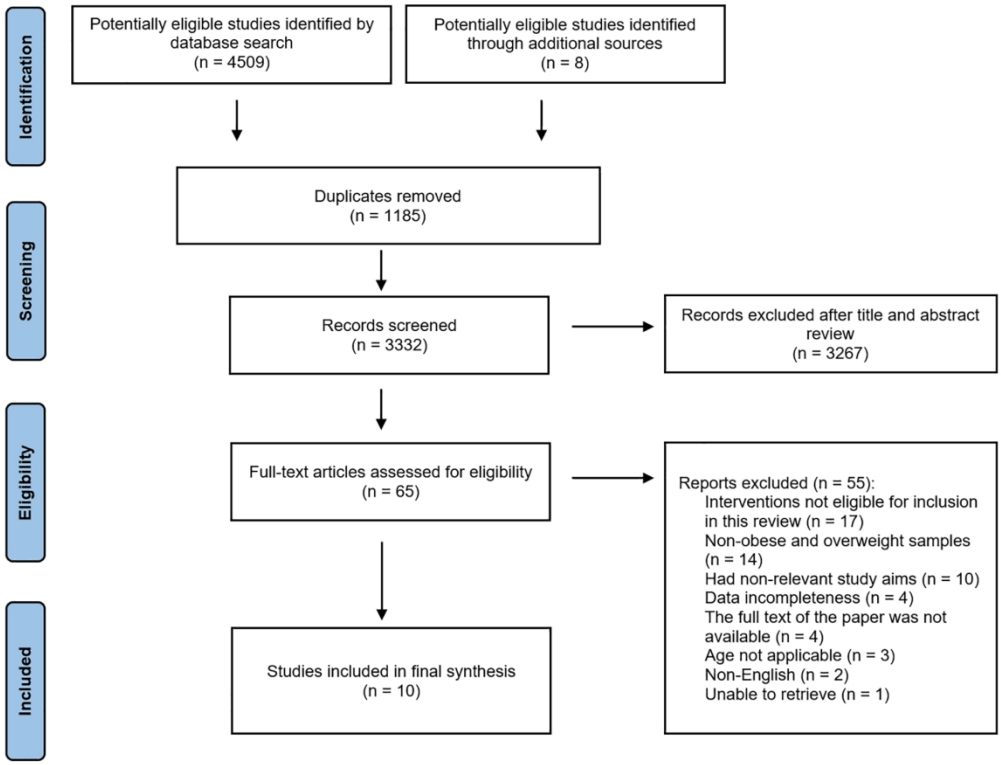
Figure legends:

Fig. 1 Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.

Fig. 2 Risk of bias.

Fig. 3 Sensitivity analysis of percentage body fat.

Fig. 4 Funnel plot for body weight.



Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram

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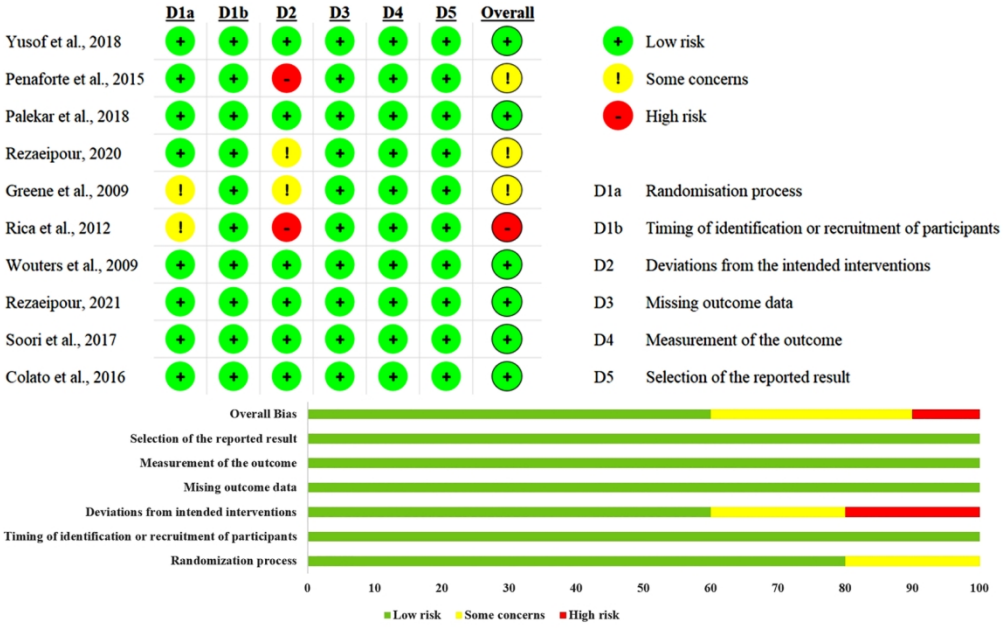

Risk of bias

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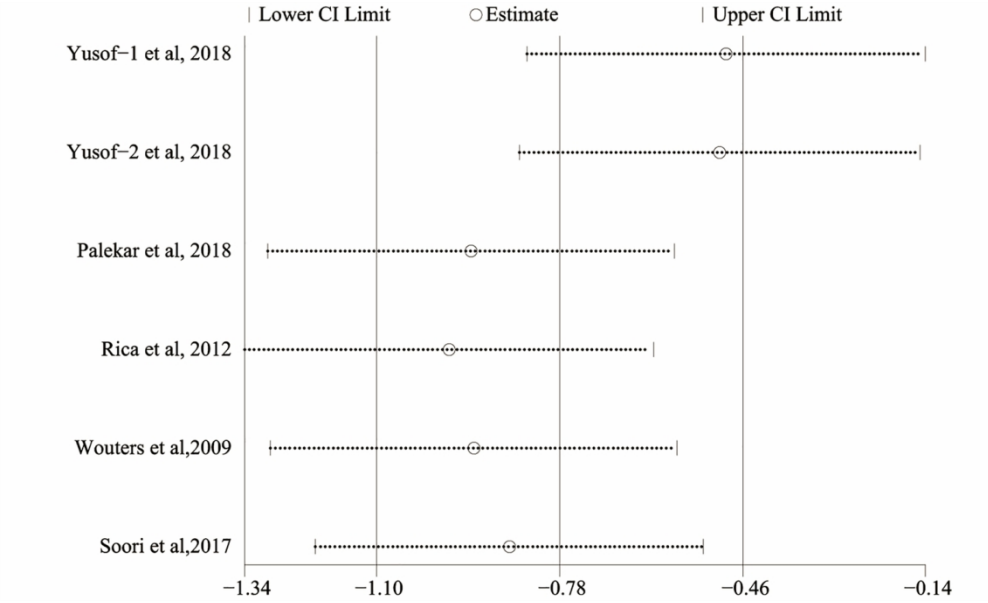

Sensitivity analysis of percentage body fat

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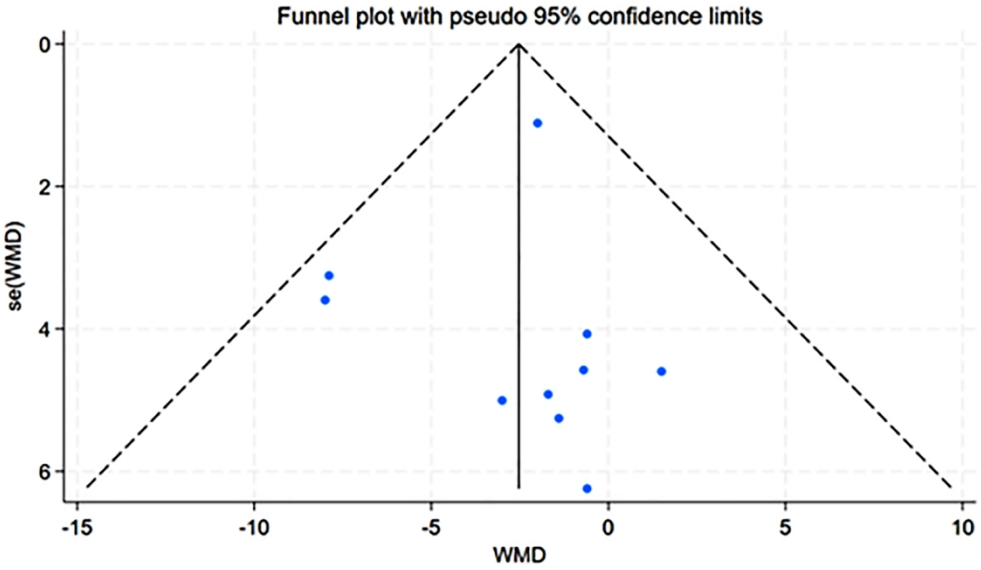

Funnel plot for body weight

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Supplementary information 1

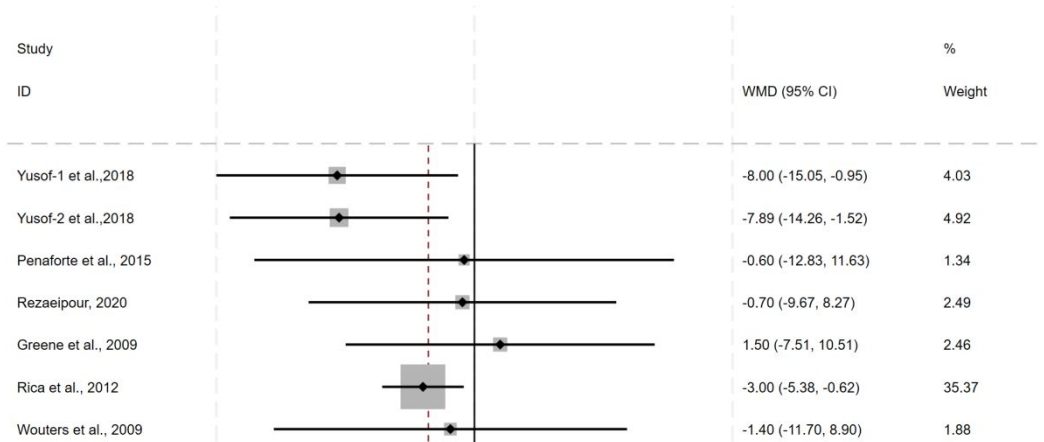

Fig. S1 Meta-analysis of body weight

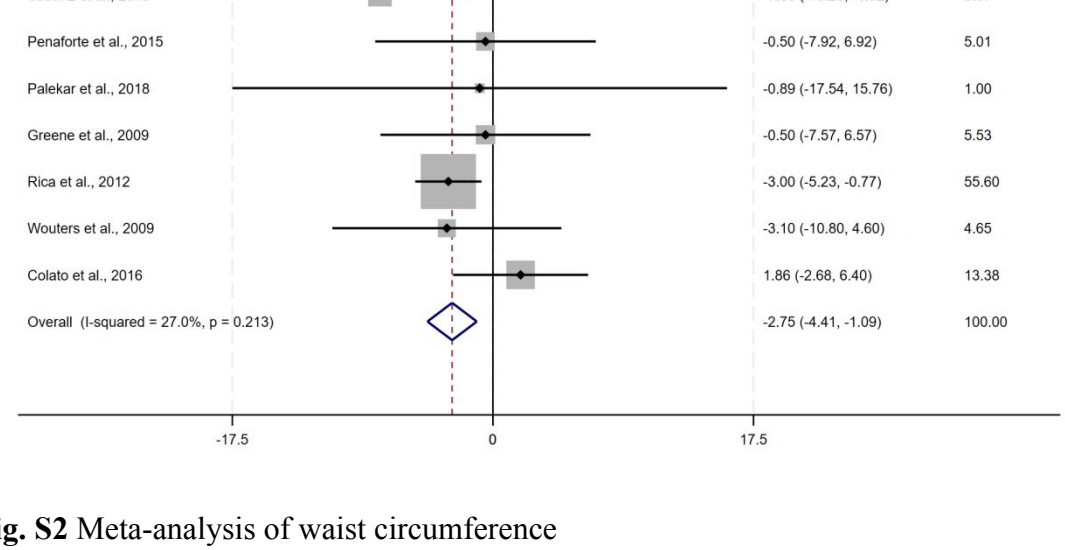

Fig. S2 Meta-analysis of waist circumference

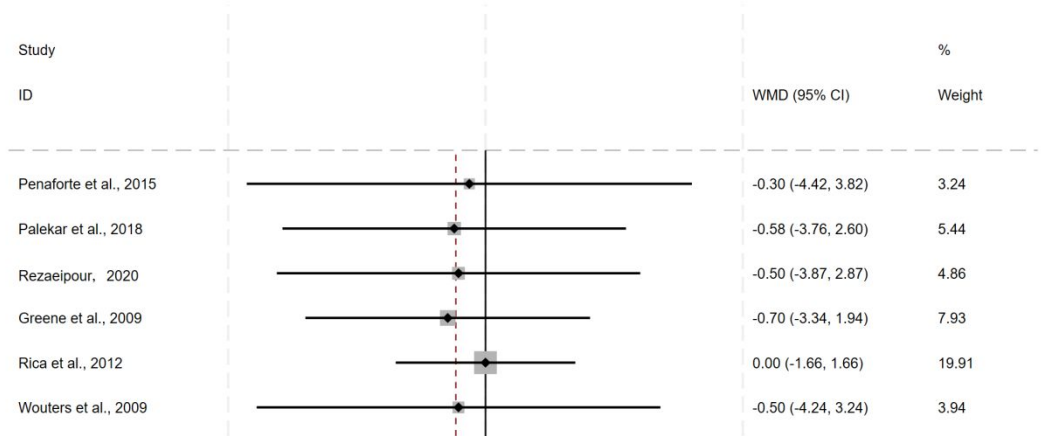

Fig. S3 Meta-analysis of body mass index

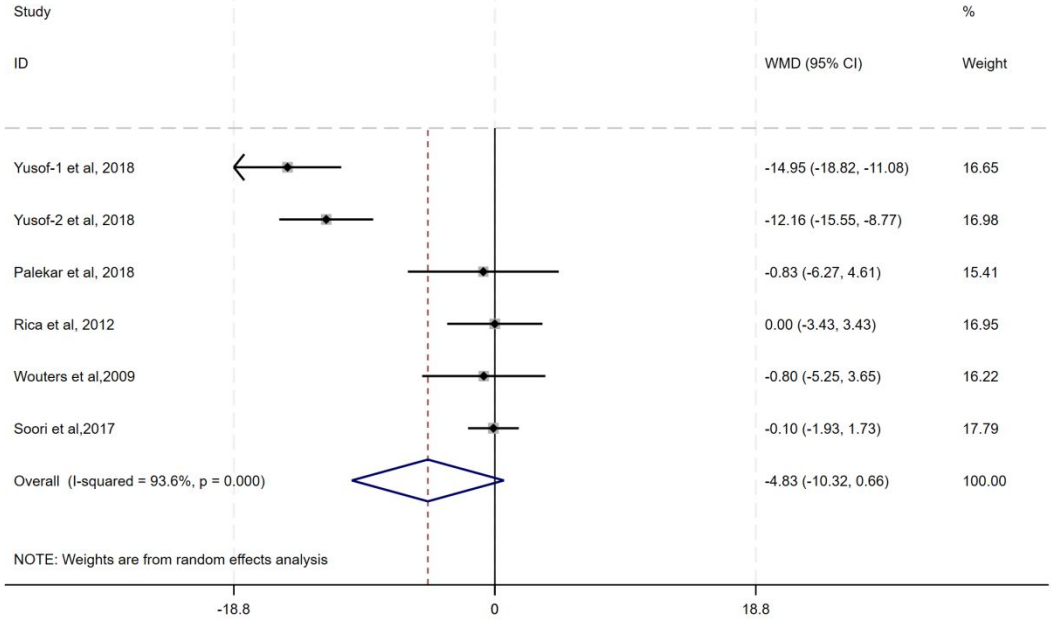

Fig. S4 Meta-analysis of percent body fat

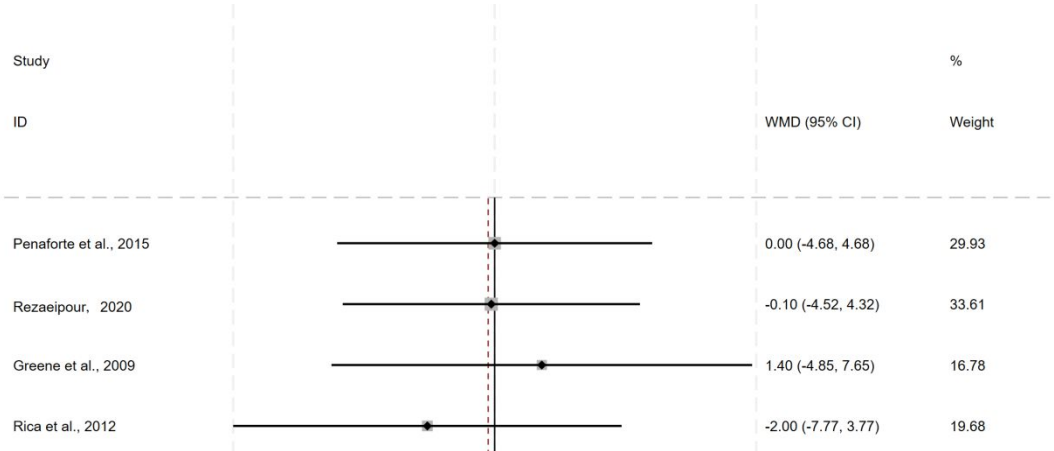

Fig. S5 Meta-analysis of lean mass

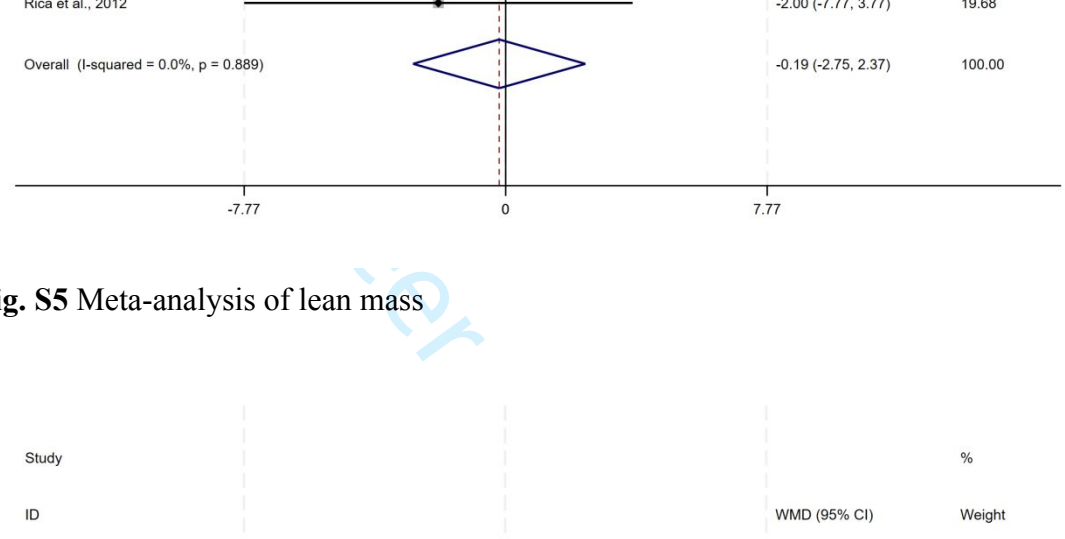

Fig. S6 Meta-analysis of fat mass

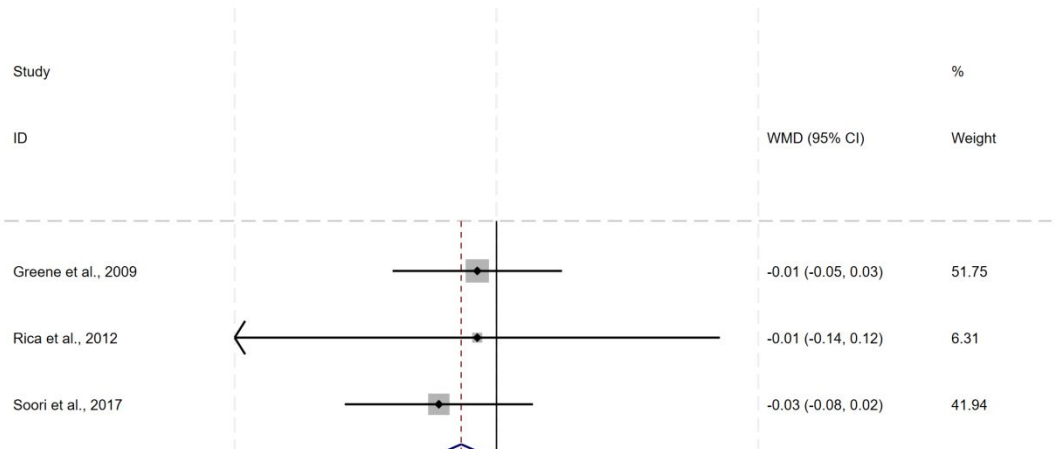

Fig. S7 Meta-analysis of waist–hip ratio

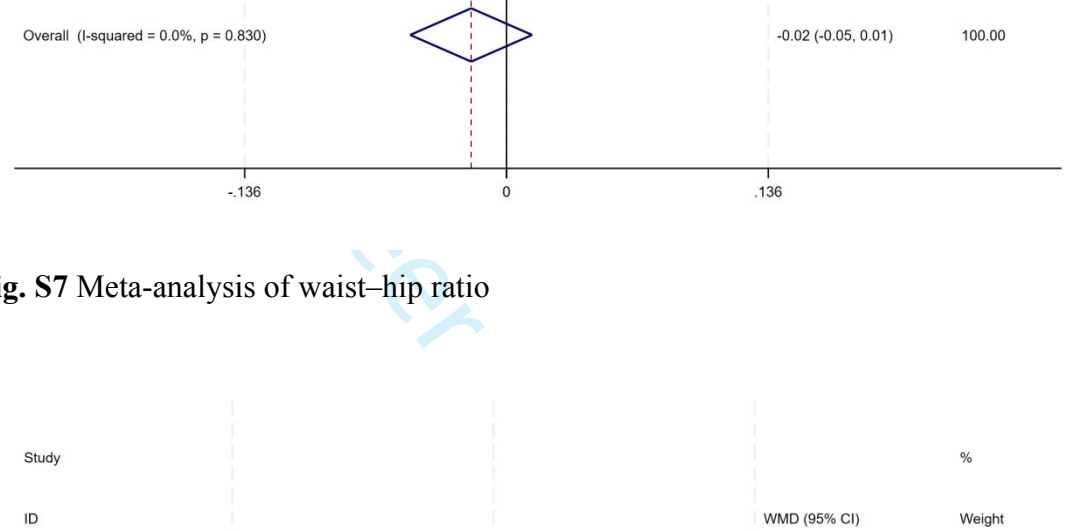

Fig. S8 Meta-analysis of hip circumference

Supplementary information 2

Table S1 Minor changes

Numbers	Changes
1	Delete “body fat mass” and add “waist-to-hip ratio, waist circumference, and hip circumference”.
2	Delete “mean baseline, follow-up” from the data extraction content.
3	Statistical software Change the “Review Manager” to “Stata”.
4	Add water aerobics subgroup analysis.

Table S2 Database search terms

Database	Search terms	Results
PubMed Medline	((((((((((((((((((((((((((((((aerobics) OR (Exercises)) OR (cycling)) OR (Physical Activity)) OR (Activities, Physical)) OR (Activity, Physical)) OR (Physical Activities)) OR (Exercise, Physical)) OR (Exercises, Physical)) OR (Physical Exercise)) OR (Physical Exercises)) OR (Acute Exercise)) OR (Acute Exercises)) OR (Exercise, Acute)) OR (Exercises, Acute)) OR (Exercise, Isometric)) OR (Exercises, Isometric)) OR (Isometric Exercises)) OR (Isometric Exercise)) OR (Exercise, Aerobic)) OR (Aerobic Exercise)) OR (Aerobic Exercises)) OR (Exercises, Aerobic)) OR (Exercise Training)) OR (Exercise Trainings)) OR (Training, Exercise)) OR (Trainings, Exercise)) AND ("Water"[Mesh])) OR ((((((((((water aerobics) OR (waterobics)) OR (aquarobics)) OR (aquatic fitness)) OR (aquafitness)) OR (aquafit)) OR (aqua zumba)) OR (water yoga)) OR (aqua aerobics)) OR (aqua jog))) AND ((("Obesity"[Mesh]) OR ((fat) OR (obese))) OR ("Overweight"[Mesh]))) AND (("Randomized Controlled Trials as Topic"[Mesh]) OR ((((((Randomised controlled trial) OR (controlled trial)) OR (randomized controlled study)) OR (Clinical Trials, Randomized)) OR (Trials, Randomized Clinical)) OR (Controlled Clinical Trials, Randomized)))	375
Embase	('randomised controlled trial'/exp OR 'randomised controlled trial' OR 'randomized controlled trials as topic'/exp OR 'randomized controlled trials as topic' OR 'controlled trial'/exp OR 'controlled trial' OR 'randomized controlled study'/exp OR 'randomized controlled study' OR 'clinical trials, randomized' OR 'trials, randomized clinical' OR 'controlled clinical trials, randomized') AND ('obesity'/exp OR 'obesity' OR 'fat'/exp	2169

	OR 'fat' OR 'obese' OR 'overweight'/exp OR 'overweight') AND ('water aerobics'/exp OR 'water aerobics' OR 'waterobics' OR 'aquarobics' OR 'aquatic fitness' OR 'aquafitness' OR 'aquafit' OR 'aqua zumba' OR 'water yoga' OR 'aqua aerobics' OR 'aqua jog' OR (('water'/exp OR 'water') AND ('exercise'/exp OR 'exercise' OR 'aerobics'/exp OR 'aerobics' OR 'exercises' OR 'cycling'/exp OR 'cycling' OR 'physical activity'/exp OR 'physical activity' OR 'activities, physical' OR 'activity, physical'/exp OR 'activity, physical' OR 'physical activities' OR 'exercise, physical' OR 'exercises, physical' OR 'physical exercise'/exp OR 'physical exercise' OR 'physical exercises' OR 'acute exercise'/exp OR 'acute exercise' OR 'acute exercises' OR 'exercise, acute' OR 'exercises, acute' OR 'exercise, isometric'/exp OR 'exercise, isometric' OR 'exercises, isometric' OR 'isometric exercises' OR 'isometric exercise'/exp OR 'isometric exercise' OR 'exercise, aerobic'/exp OR 'exercise, aerobic' OR 'aerobic exercise'/exp OR 'aerobic exercise' OR 'aerobic exercises' OR 'exercises, aerobic' OR 'exercise training'/exp OR 'exercise training' OR 'exercise trainings' OR 'training, exercise' OR 'trainings, exercise')))	
Ovid MEDLINE	1 "Randomised controlled trial ".mp. 2 exp Randomized Controlled Trials as Topic/ 3 " controlled trial".mp. 4 " randomized controlled study ".mp. 5 "Clinical Trials, Randomized".mp. 6 "Trials, Randomized Clinical".mp. 7 "Controlled Clinical Trials, Randomized".mp. 8 1 or 2 or 3 or 4 or 5 or 6 or 7 9 exp Obesity/ 10 exp Fats/ 11 "obese".mp. 12 exp Overweight/ 13 9 or 10 or 11 or 12 14 "water aerobics ".mp. 15 "aquarobics ".mp. 16 "aquatic fitness ".mp. 17 "aquafitness ".mp. 18 "aquafit".mp. 19 " water yoga".mp. 20 "aqua aerobics".mp. 21 14 or 15 or 16 or 17 or 18 or 19 or 20 22 exp Water/ 23 exp Exercise/ 24 "aerobics ".mp. 25 "Exercises".mp. 26 "cycling".mp.	19

	27 "Physical Activity".mp. 28 "Activities, Physical".mp. 29 "Activity, Physical".mp. 30 "Physical Activities".mp. 31 "Exercise, Physical".mp. 32 "Exercises, Physical".mp. 33 "Physical Exercise".mp. 34 "Physical Exercises".mp. 35 "Acute Exercise".mp. 36 "Acute Exercises".mp. 37 "Exercise, Acute".mp. 38 "Exercises, Acute".mp. 39 "Exercise, Isometric".mp. 40 "Exercises, Isometric".mp. 41 "Isometric Exercises".mp. 42 "Isometric Exercise".mp. 43 "Exercise, Aerobic".mp. 44 "Aerobic Exercise".mp. 45 "Aerobic Exercises".mp. 46 "Exercises, Aerobic".mp. 47 "Exercise Training".mp. 48 "Exercise Trainings".mp. 49 "Training, Exercise".mp. 50 "Trainings, Exercise".mp. 51 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 52 22 and 51 53 21 or 52 54 8 and 13 and 53	
Scopus	((TITLE-ABS-KEY ("randomised controlled trial ") OR TITLE-ABS-KEY ("randomized controlled trials as topic ") OR TITLE-ABS-KEY (" controlled trial") OR TITLE-ABS-KEY (" randomized controlled study ") OR TITLE-ABS-KEY ("clinical trials, randomized") OR TITLE-ABS-KEY ("trials, randomized clinical") OR TITLE-ABS-KEY ("controlled clinical trials, randomized"))) AND ((TITLE-ABS-KEY (obesity) OR TITLE-ABS-KEY (fat) OR TITLE-ABS-KEY (obese) OR TITLE-ABS-KEY (overweight))) AND (((TITLE-ABS-KEY (water)) AND ((TITLE-ABS-KEY (exercise) OR TITLE-ABS-KEY (exercises) OR TITLE-ABS-KEY (cycling) OR TITLE-ABS-KEY ("physical activity") OR TITLE-ABS-KEY ("activities, physical") OR TITLE-ABS-KEY ("activity, physical") OR TITLE-ABS-KEY ("physical activities") OR TITLE-ABS-KEY ("exercise, physical") OR	468

	TITLE-ABS-KEY ("exercises, physical") OR TITLE-ABS-KEY ("physical exercise") OR TITLE-ABS-KEY ("physical exercises") OR TITLE-ABS-KEY ("acute exercise") OR TITLE-ABS-KEY ("acute exercises") OR TITLE-ABS-KEY ("exercise, acute") OR TITLE-ABS-KEY ("exercises, acute") OR TITLE-ABS-KEY ("exercise, isometric") OR TITLE-ABS-KEY ("exercises, isometric") OR TITLE-ABS-KEY ("isometric exercises") OR TITLE-ABS-KEY ("isometric exercise") OR TITLE-ABS-KEY ("exercise, aerobic") OR TITLE-ABS-KEY ("aerobic exercise") OR TITLE-ABS-KEY ("aerobic exercises") OR TITLE-ABS-KEY ("exercises, aerobic") OR TITLE-ABS-KEY ("exercise training") OR TITLE-ABS-KEY ("exercise trainings") OR TITLE-ABS-KEY ("training, exercise") OR TITLE-ABS-KEY ("trainings, exercise")))) OR ((TITLE-ABS-KEY ("water aerobics ") OR TITLE-ABS-KEY ("waterobics ") OR TITLE-ABS-KEY ("aquarobics ") OR TITLE-ABS-KEY ("aquatic fitness ") OR TITLE-ABS-KEY ("aquafitness ") OR TITLE-ABS-KEY ("aquafit") OR TITLE-ABS-KEY (" aqua zumba") OR TITLE-ABS-KEY (" water yoga") OR TITLE-ABS-KEY ("aqua aerobics") OR TITLE-ABS-KEY (" aqua jog")))))	
The Cochrane Library	#1 MeSH descriptor: [Randomized Controlled Trials as Topic] explode all trees #2 MeSH descriptor: [Randomized Controlled Trial] explode all trees #3 " controlled trial" #4 " randomized controlled study " #5 "Clinical Trials, Randomized" #6 "Trials, Randomized Clinical" #7 "Controlled Clinical Trials, Randomized" #8 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 #9 MeSH descriptor: [Obesity] explode all trees #10 MeSH descriptor: [Fats] explode all trees #11 obese #12 MeSH descriptor: [Overweight] explode all trees #13 #9 OR #10 OR #11 OR #12 #14 "water aerobics " #15 waterobics #16 aquarobics #17 "aquatic fitness " #18 aquafitness #19 aquafit #20 " aqua zumba" #21 " water yoga" #22 "aqua aerobics" #23 " aqua jog"	1284

	#24 #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 #25 MeSH descriptor: [Water] explode all trees #26 MeSH descriptor: [Exercise] explode all trees #27 Exercises #28 cycling #29 "Physical Activity" #30 "Activity, Physical" #31 "Exercise, Physical" #32 "Exercises, Physical" #33 "Physical Exercise" #34 "Physical Exercises" #35 "Acute Exercise" #36 "Acute Exercises" #37 "Exercise, Acute" #38 "Exercises, Acute" #39 "Exercise, Isometric" #40 "Exercises, Isometric" #41 "Isometric Exercises" #42 "Isometric Exercise" #43 "Exercise, Aerobic" #44 "Aerobic Exercise" #45 "Aerobic Exercises" #46 "Exercises, Aerobic" #47 "Exercise Training" #48 "Exercise Trainings" #49 "Training, Exercise" #50 "Trainings, Exercise" #51 #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50 #52 #25 AND #51 #53 #24 OR #52 #54 #8 AND #13 AND #53	
Web of science	((((((((((((((((((((((((((TS=(Exercise)) OR TS=(Exercises)) OR TS=(cycling)) OR TS=("Physical Activity")) OR TS=("Activities, Physical")) OR TS=("Activity, Physical")) OR TS=("Physical Activities")) OR TS=("Exercise, Physical")) OR TS=("Exercises, Physical")) OR TS=("Physical Exercise")) OR TS=("Physical Exercises")) OR TS=("Acute Exercise")) OR TS=("Acute Exercises")) OR TS=("Exercise, Acute")) OR TS=("Exercises, Acute")) OR TS=("Exercise, Isometric")) OR TS=("Exercises, Isometric")) OR TS=("Isometric Exercises")) OR TS=("Isometric Exercise")) OR	194

	TS=("Exercise, Aerobic")) OR TS=("Aerobic Exercise")) OR TS=("Aerobic Exercises")) OR TS=("Exercises, Aerobic")) OR TS=("Exercise Training")) OR TS=("Exercise Trainings")) OR TS=("Training, Exercise")) OR TS=("Trainings, Exercise")) AND TS=(water) OR (((((((((TS=("water aerobics ")) OR TS=("waterobics ")) OR TS=("aquarobics ")) OR TS=("aquatic fitness ")) OR TS=("aquafitness ")) OR TS=("aquafit")) OR TS=(" aqua zumba")) OR TS=(" water yoga")) OR TS=("aqua aerobics")) OR TS=(" aqua jog") AND ((((((TS=("Randomised controlled trial ")) OR TS=("Randomized Controlled Trials as Topic")) OR TS=(" controlled trial")) OR TS=(" randomized controlled study ")) OR TS=("Clinical Trials, Randomized")) OR TS=("Trials, Randomized Clinical")) OR TS=("Controlled Clinical Trials, Randomized")AND (((TS=(obesity)) OR TS=(fat)) OR TS=(obese)) OR TS=(Overweight)	

BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-091743.R2
Article Type:	Original research
Date Submitted by the Author:	23-Jan-2025
Complete List of Authors:	DING, ZIYAN; Pukyong National University - Daeyeon Campus, Gao, Zixuan; Chaoyang Normal University Zhou, Haixu; Jilin Sport University Park, Jongchul; Pukyong National University, Department of Smart Healthcare
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Rehabilitation medicine, Research methods, Sports and exercise medicine
Keywords:	Meta-Analysis, Obesity, Overweight, SPORTS MEDICINE

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Effects of water aerobics on body composition in obesity and overweight people: a systematic review and meta-analysis

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Effects of water aerobics on body composition in obesity and overweight people: a systematic review and meta-analysis

Abstract

Objectives Obesity and overweight significantly impact public health. The benefits of water aerobics (WAs) have been shown in obesity and overweight people, but the effects of WAs on body composition improvement are still unclear.

Design Systematic review and meta-analysis.

Data sources A systematic literature search was conducted on November 16, 2024, across the PubMed MEDLINE, Ovid MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library.

Eligibility criteria for selecting studies Only randomized controlled trials (RCTs) were included, which were independently screened by two researchers. All RCTs on WAs that evaluated the anthropometric and body composition parameters of overweight and obesity subjects were included. Eligible studies were reported following the PRISMA statement.

Data extraction and synthesis All process were independently screened by 2 researchers (D.Z.Y., Z.H.X.). A fixed-effects or random-effects model was chosen based on the heterogeneity of the studies. The risk of bias in the included studies was assessed using the Risk of Bias 2.0 tool, and sensitivity and subgroup analyses were conducted for outcome indicators. The quality of evidence for each outcome was assessed using the GRADE system.

Results A total of 10 studies involving 286 participants were included. Sensitivity analyses were performed for PBF with high heterogeneity, and the results were robust. WAs were able to reduce BW (WMD = -2.69, 95% CI: -4.10 to -1.27, $p < 0.05$, $I^2 = 0.0\%$) and WC (WMD = -2.75, 95%CI: -4.41 to -1.09, $p < 0.05$, $I^2 = 27.0\%$), but the effect on other body indicators was not significant. The GRADE assessment revealed that the certainty of evidence was low for BMI, LM, FM, WHR, and HC, and very low for PBF. In contrast, the certainty of evidence for BW and WC was moderate.

Conclusion For the obesity and overweight people, WAs interventions over 10 weeks (i.e., 12 weeks) reduced BW and WC, with more significant effects in women and greater improvements in body composition in middle-aged and older adults (average age ≥ 45 years). The moderate certainty of evidence for BW and WC, as assessed using the GRADE framework, indicates that these findings are robust.

PROSPERO registration number CRD42023466969.

Strengths and limitations of this study

- This study systematically reviewed and meta-analyzed RCTs, the gold standard in clinical research, ensuring a high level of methodological rigor.
- Studies of registered or ongoing RCTs were not included in the search for articles, and only studies published in English were considered.
- Judgements made by persons were more subjective when using ROB tools and the GRADE system for literature and outcome quality assessment.
- There were certain limitations to the articles included in the study: (1) Some studies had short durations (e.g., 6 weeks), small sample sizes, and limited data; (2) A

small number of participants in the study dropped out of the trial halfway through; (3) Differences in the age, sex ratio, and location of the trial participants in three aspects.

Introduction

The global prevalence of obesity has increased significantly over the past 40 years [1-3]. By 2022, more than 43% of adults worldwide will be overweight, with 504 million female and 374 million male obese [4]. Obesity is a chronic disease that raises the risk of various complications and contributes to an estimated 2.8 million deaths annually [5-7]. Exercise is a highly effective method for weight management [8-10], but individuals with obesity and overweight are prone to severe bone and joint injuries during physical activity due to their weight [11]. Traditional land-based aerobic exercise methods increase musculoskeletal damage in obese patients [12]. The American College of Sports Medicine recommends water aerobics (WAs) for people with obesity to reduce the risk of injury and enhance exercise adherence [13]. WAs interventions are increasingly recognized as a beneficial and effective approach to treating obesity [14, 15]. The buoyant effect of water helps reduce joint injuries commonly associated with exercise in overweight and obese individuals [16, 17]. Studies have shown that WAs have a better effect on improving body composition in

obesity and overweight people. For example, young obese adults (mean age 18-25 years) lost weight and improved their body mass index (BMI) after 12 weeks of WAs [18]. Middle-aged adults (mean age 47 – 70 years) also demonstrated significant reductions in body weight (BW) and percent body fat (PBF) after participating in 6 weeks of WAs [19]. Additionally, WAs led to significant improvements in body composition (e.g., PBF, BW, BMI, and waist-to-hip ratio [WHR]) in overweight older men (mean age 62 – 70 years) [20]. Overweight older adults (mean age 72 years) who participated in a 28-week WAs program showed reductions in body fat mass (FM) and both leg and waist circumference (WC) [21]. Therefore, WAs is a valuable exercise method and can be an important strategy for weight loss in individuals with obesity and overweight [19, 21].

However, fewer studies have been reported on the effects of WAs on physical indicators in obesity and overweight people. Previous literature review have provided broad overviews of the relevant evidence, but none have specifically focused on obesity and overweight people [14, 22, 23]. For example, Haifeng Zhu [24] summarizes the physical effects of aquatic exercise on adults. However, this study only included randomized controlled trials (RCTs) on healthy adults and did not consider those with obesity or overweight [24].

Thus, the systematic review and meta-analysis presented in this study aims to fill this research gap by specifically examining the effects of WAs on physical indicators in obesity and overweight people. The primary focus of this study is to determine whether WAs significantly improve physical indicators in obesity and overweight people.

Methods

Registration

This meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [25, 26]. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (registration number: CRD42023466969). Minor changes were made to the initial PROSPERO protocol submitted in October 2023 (**Table S1** in Supplementary information 2).

Search strategy

Six databases were searched: PubMed MEDLINE, Ovid MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library. The search covered the period from the inception of the database up to November 16, 2024. Retrieval strategy based on PICOS tool [27]: (P) Population: adults with overweight and obesity; (I) Intervention: WAs; (C) Comparator: other exercise modalities or no exercise control; (O) Outcome: body composition; (S) Study type: RCTs. Search using core terms: water aerobics (e.g., aquatic fitness, aqua aerobics), obesity or overweight (e.g., fat, obese), and RCTs (e.g., randomized controlled study, controlled clinical trials). The core terms for the searches were identified in the MeSH Database in the PubMed database, respectively, to ensure the scientific validity and accuracy of the search vocabulary, and the comprehensiveness of the search scope (details of the search strategy are in **Table S2** in Supplementary information 2). In addition to the database search, the reference lists

of included articles were screened for studies that met the inclusion criteria.

Eligibility criteria

Inclusion criteria: (1) RCTs; (2) Participants were adults (≥ 18 years) with obesity (BMI ⩾30 kg/m²) or overweight (BMI ≥ 25 kg/m²), including older adults [28]; (3) The intervention group participated in WAs for at least 4 weeks, and the control group did not participate in exercise or chose other ways of exercising; (4) The study reported results on changes in body composition; (5) The full text of the study was available in English (i.e., not a review, letter, case series, or conference proceedings). Grey literature (i.e., dissertations, conference abstracts) was excluded, as it has been shown that these represent only a small percentage of the studies included in the systematic review and rarely affect the statistical or clinical significance of the results [29].

Exclusion criteria: (1) Trials that did not satisfy all inclusion criteria; (2) Studies that included participants diagnosed with other diseases; (3) Exercise interventions combined with dietary control, medication or other lifestyle changes; (4) There was no exercise of any form, just a trial of being immersed in water or receiving a massage.

Study selection

The study used EndNote (Version 21) to manage the articles. First, duplicate articles were removed. Second, the titles and abstracts of the articles were read and qualified articles were selected. Finally, full-text review was performed. The process was independently screened by 2 researchers (D.Z.Y., Z.H.X.). Disagreements were adjudicated by a third researcher (G.Z.X.).

Data extraction

ata from the included studies were recorded using an adapted Cochrane Collaboration standardized data extraction form [30]. The following study characteristics were extracted: year of publication, authors, region, study period, study design, sample size, participants, and mean age.

BW, measured in kilograms (kg), serves as a direct indicator of overall weight loss and is a key measure of intervention effectiveness in obesity management [31]. BMI, a widely used but indirect measure of body fatness, is calculated as weight in kilograms divided by height in meters squared (kg/m^2) [32]. PBF is an important metric for distinguishing between lean mass (LM) and FM [33]. FM and LM were assessed using bioelectrical impedance analysis or dual-energy X-ray absorptiometry, with PBF calculated using the formula: PBF = (FM (kg)/BW (kg)) × 100 [34]. WC reflects abdominal fat distribution and is a validated marker of central obesity and metabolic risk [35]. Risk thresholds for WC are ≥ 102 cm for male and ≥ 88 cm for female [36]. Both WC and hip circumference (HC) were measured in centimeters (cm) using an inelastic tape. WC was defined as the minimum circumference between the rib margins and iliac crests, while HC was defined as the maximum circumference between the waist and thighs. The WHR was calculated as WC/HC [34]. WHR is a measure of upper and lower body fat distribution, with higher values indicating a greater risk of obesity-related health problems. Risk thresholds for WHR are male ≥ 1.0 and female ≥ 0.85 [36]. Therefore, the primary outcomes were BW, BMI, PBF, WHR, WC, and HC, while the secondary outcomes were FM and LM.

Two researchers (D.Z.Y., Z.H.X.) independently extracted this information from each

study, and any disagreements were resolved through discussion.

Risk of bias

Two researchers (D.Z.Y. and Z.H.X.) independently assessed the risk of bias in the included RCTs using the Cochrane risk-of-bias tool (RoB 2), following the evaluation criteria outlined in the Cochrane Handbook for Systematic Reviews of Interventions (Version 6.4) [37]. Any disagreements during the review process were discussed and resolved through consultation with a third researcher (G.Z.X.) from the review team.

Data analysis

Meta-analysis was conducted using Stata 18.0 software. Heterogeneity among studies was assessed using Cochran's Q and I^2 tests [38]. When $P > 0.1$, $I^2 \leq 50\%$, there was homogeneity, and a fixed-effects model was used for the meta-analysis; when $P \leq 0.1$, $I^2 > 50\%$, there was heterogeneity, and a random-effects model was used [39, 40]. Therefore, this study uses a fixed-effects model for the meta-analysis, which was changed to a random-effects model when $I^2 > 50\%$.

To further test the stability of the results, a sensitivity analysis was performed using the leave-one-out method [41]. This method involves excluding one study at a time, combining the remaining studies in a meta-analysis, and assessing whether the results of the original meta-analysis were significantly altered by the influence of certain studies by observing the changes in the combined results [42]. Publication bias was assessed using funnel plots, with asymmetric distribution indicating potential bias [43]. Quantitative analysis of funnel plot asymmetry was conducted using the Egger regression test [44].

Differences were considered significant at $P < 0.05$ [45].

The standard error of the mean (SEM) of the extracted data was converted to standard deviation (SD) [46], using the formula in the Cochrane Handbook [47] (N represents the number of trial participants):

$$SD = SEM \times \sqrt{N}$$

Quality of GRADE evidence

The quality of evidence for each outcome was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology [48]. Two researchers (D.Z.Y. and Z.H.X.) independently conducted the assessments. Any disagreements were resolved through discussion and, when necessary, consultation with a third researcher (G.Z.X.) to reach a consensus. As all included studies were RCTs, the initial evidence quality was rated as high. However, the confidence in the evidence could be downgraded based on specific limitations in the original studies, including risk of bias, inconsistency, indirectness, imprecision, and publication bias [49]. Following GRADE guidelines, the final quality of evidence was categorized into one of four levels: high, moderate, low, and very low [50].

Results

Study search results

A total of 4517 studies were searched. Of these, 1,185 were removed due to duplication, leaving 3,332 studies for further screening. After reviewing the titles and abstracts, 3,267 studies were excluded. 65 articles were eligible for full-text screening, of which

55 were deleted. Ultimately, 10 studies were included in the meta-analysis (**Fig. 1**).

Study characteristics

The 10 RCTs included in this study involved a total of 286 participants [51-60]. Publication dates range from 2009 to 2021 (note: this refers to the publication date of articles analyzed that met the inclusion criteria; the search strategy was from database construction to November 16, 2024). The studies included trials conducted in Malaysia, Brazil, India, the United States, and the Netherlands. The participants' ages ranged from 20 to 70 years.

A small number of subjects from 5 trials [51, 53, 55, 58, 59] dropped out of the experiment for various reasons, and trial data from those who dropped out was not used. One study [51] included two distinct intervention groups: Aqua Zumba (Yusof-1) and Aqua Jogging (Yusof-2). Due to the differing exercise programs, these groups were treated as separate studies (Yusof-1 and Yusof-2) in the analysis.

The types of WAs included in this review were diverse and encompassed activities such as water aerobics, aqua Zumba, water yoga, and aqua jogging. The intervention periods ranged from 6 to 12 weeks across all included trials. One of the trials [55] had an exercise frequency of 2 times a week; others were 3 times a week. The exercise time varied according to the needs of the trials, with most being 60 minutes each.

The units for BW, LM, and FM are kilograms (kg); for BMI, kilograms per square meter (kg/m^2); and for WC and HC, it is centimeters (cm). The basic characteristics of each study are shown in **Table 1**.

Table 1 Experimental details.

Study	Country	Duration (weeks)	Sample	Mean age/ range (SD)	Exercise Category	Study design (Frequency、time)	Outcome
Yusof-1 et al., 2018	Malaysia	12	40 (F)	45.13(5.17)	Aqua zumba	3 days/week, 60 minutes per session	BW, PBF, WC
Yusof-2 et al., 2018	Malaysia	12	40 (F)	45.28(5.09)	Aqua jog	3 days/week, 60 minutes per session	BW, PBF, WC
Penaforte et al., 2015	Brazil	8	16 (F)	42.8(7.4)	Water aerobics	3 days/week, 60minutes per session	BW, BMI, LM, FM, WC, HC
Palekar et al., 2018	India	6	14 (M)	20.71	Underwater treadmill training	3 days/week, 25minutes per session	BMI, PBF, WC
Rezaeipour, 2020	Iran	12	24 (F)	69.5(4.3)	Aquatic exercises (dancing and walking)	3 days/week, 60minutes per session	BW, BMI, LM, FM,
Greene et al., 2009	American	12	57 (Mix)	42(18.67)	Underwater treadmill	Three times per week	BW, BMI, LM, FM, WC, HC, WHR
Rica et al., 2012	Brazil	12	38 (F)	68.5(5)	Water-based exercise with aerobic	Three times per week, 60-min sessions	BW, BMI, PBF, LM, FM, WC, HC, WHR
Wouters et al., 2009	Netherlands	6	14 (Mix)	44	Aquajogging	2 per week, one hour	BW, BMI, PBF, WC
Rezaeipour, 2021	Iran	12	27 (M)	68.7(3.2)	Water-based exercise with aerobic	3 days/week, 60minutes per session	BW, BMI
Soori et al., 2017	Iran	10	16 (F)	45-60	Swimming or walking in the water	3 per week, 45 min per day	BW, BMI, PBF, WC
Colato et al., 2016	Brazil	12	20 (F)	49.36(11.69)	Water running training	3 per week, 70 minutes/session	BW, BMI, FM, WC, HC

Note: body weight (BW); body mass index BMI)；percent body fat (PBF)；lean mass (LM); fat mass (FM); Waist–hip ratio (WHR); Waist circumference (WC); Hip circumference (HC); mixed sex (Mix); male (M); female(F).

Results of ROB assessment

Following the risk of bias assessment, the 10 included studies were rated as follows: 6 studies had a low risk of bias, 3 had some concerns, and 1 study had a high risk (**Fig. 2**).

Physical outcome

WAs proved to be an effective intervention for reducing BW (WMD = -2.69, 95%CI: -4.10 to -1.27, $p < 0.05$, $I^2 = 0.0\%$) and WC (WMD = -2.75, 95%CI: -4.41 to -1.09, $p < 0.05$, $I^2 = 27.0\%$) in obesity and overweight people (**Fig. S1** and **Fig. S2** in Supplementary information 1). However, other physical indicators, such as BMI (WMD = -0.55, 95%CI: -1.29 to 0.19, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S3** in Supplementary information 1), PBF (WMD = -4.83, 95%CI: -10.32 to 0.66, $p > 0.05$, $I^2 = 93.6\%$) (**Fig. S4** in Supplementary information 1), LM (WMD = -0.19, 95%CI: -2.75 to 2.37, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S5** in Supplementary information 1), FM (WMD = -0.92, 95%CI: -3.20 to 1.36, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S6** in Supplementary information 1), WHR (WMD = -0.02, 95%CI: -0.05 to 0.01, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S7** in Supplementary information 1) and HC (WMD = -1.05, 95%CI: -3.64 to 1.55, $p > 0.05$, $I^2 = 0.0\%$) (**Fig. S8** in Supplementary information 1), did not show significant improvements (**Table 2**).

Subgroup analysis of outcomes

Subgroup analyses of WAs were performed on the included studies to identify appropriate WAs regularity and to explore sources of heterogeneity. Due to the number of subgroups, the results of the subgroup analyses of WAs are summarized in table 2 (**Table 2**).

Table 2 Subgroup analysis of water aerobics on anthropometric measures

	N	WMD (95% CI)	P within group	P heterogeneity	I^2
Subgroup analyses of WA on BW					
Overall effect	10	-2.69(-4.10, -1.27)	0.000*	0.670	0.0%
Trial duration (week)					
>10	7	-3.31(-5.23, -1.40)	0.001*	0.455	0.0%
≤10	3	-1.93(-4.03, 0.16)	0.071	0.971	0.0%
Sex					
Male	1	-0.60(-8.58, 7.38)	0.883	-	-
Female	7	-2.90(-4.37, -1.43)	0.000*	0.486	0.0%
Mix (male & female)	2	0.24(-6.54, 7.02)	0.944	0.678	0.0%
Average age					
≥45	7	-2.85(-4.31, -1.40)	0.000*	0.465	0.0%
<45	3	0.05(-5.89, 5.98)	0.988	0.911	0.0%
Subgroup analyses of WA on BMI					
Overall effect	9	-0.55(-1.29, 0.13)	0.146	0.984	0.0%
Trial duration (week)					
>10	5	-0.14(-1.25, 0.97)	0.806	0.943	0.0%
≤10	4	-0.88(-1.88, 0.12)	0.083	0.979	0.0%
Sex					
Male	2	-0.47(-2.52, 1.57)	0.649	0.932	0.0%
Female	5	-0.55(-1.41, 0.31)	0.208	0.757	0.0%
Mix (male & female)	2	-0.63(-2.79, 1.52)	0.565	0.932	0.0%
Average age					
≥45	5	-0.55(-1.38, 0.29)	0.199	0.757	0.0%
<45	4	-0.57(-2.21, 1.07)	0.498	0.999	0.0%
Subgroup analyses of WA on PBF					
Overall effect	6	-4.83(-10.32, 0.66)	0.085	0.000	93.6%
Trial duration (week)					
>10	3	-9.01(-18.05, 0.02)	0.051	0.000	94.8%
≤10	3	-0.26(-1.87, 1.36)	0.755	0.938	0.0%
Sex					
Male	1	-0.83(-6.28, 4.61)	0.765	-	-
Female	4	-6.71(-14.24, 0.82)	0.081	0.000	96.0%
Mix (male & female)	1	-0.80(-5.25, 3.65)	0.724	-	-
Average age					
≥45	4	-6.71(-14.24, 0.82)	0.081	0.000	96.0%
<45	2	-0.81(-4.26, 2.63)	0.644	0.993	0.0%
Subgroup analyses of WA on WC					
Overall effect	8	-2.75(-4.41, -1.09)	0.001*	0.213	27.0%
Trial duration (week)					

>10	5	-2.88(-4.63, -1.12)	0.001*	0.057	56.3%
≤10	3	-1.67(-6.76, 3.42)	0.520	0.889	0.0%
Sex					
Male	1	-0.89(-17.54, 15.76)	0.917	-	-
Female	5	-2.89(-4.65, -1.13)	0.001*	0.058	56.1%
Mix (male & female)	2	-1.69(-6.90, 3.52)	0.525	0.626	0.0%
Average age					
≥45	4	-3.03(-4.85, -1.22)	0.001*	0.034	65.5%
<45	4	-1.27(-5.40, 2.86)	0.546	0.959	0.0%
Subgroup analyses of WA on LM					
Overall effect	4	-0.19(-2.75, 2.37)	0.883	0.889	0.0%
Subgroup analyses of WA on FM					
Overall effect	5	-0.92(-3.20, 1.36)	0.429	0.991	0.0%
Subgroup analyses of WA on WHR					
Overall effect	3	-0.02(-0.05, 0.01)	0.256	0.830	0.0%
Subgroup analyses of WA on HC					
Overall effect	4	-1.05(-3.64, 1.55)	0.429	0.610	0.0%

Note: confidence interval (CI); numbers (N); weighted mean differences (WMD); *P < 0.05.

As shown by the subgroup analyses of BW, WAs with a trial duration greater than 10 weeks (i.e., 12 weeks) significantly reduced BW (WMD = -3.31, 95%CI: -5.23 to -1.40, $p < 0.05$, $I^2 = 0.0\%$). Additionally, WAs significantly reduced BW in the female population (WMD = -2.90, 95%CI: -4.37 to -1.43, $p < 0.05$, $I^2 = 0.0\%$) and in the population with a mean age of ≥ 45 years (WMD = -2.85, 95%CI: -4.31 to -1.40, $p < 0.05$, $I^2 = 0.0\%$).

From the subgroup analysis of WC, it is shown that WAs with a trial duration >10 weeks significantly reduced WC (WMD = -2.88, 95%CI: -4.63 to -1.12, $p < 0.05$, $I^2 = 56.3\%$). Among them, WAs were mainly able to significantly reduce WC in the female population (WMD = -2.89, 95%CI: -4.65 to -1.13, $p < 0.05$, $I^2 = 56.1\%$) and in the population (WMD = -3.03, 95%CI: -4.85 to -1.22, $p < 0.05$, $I^2 = 65.5\%$) with a mean age ≥45 years.

Other subgroup analyses found that BMI (P = 0.146, I^2 = 0.0%), LM (P = 0.883, I^2 = 0.0%), FM (P = 0.429, I^2 = 0.0%), WHR (P = 0.256, I^2 = 0.0%), and HC (P = 0.429, I^2 = 0.0%) were neither heterogeneous nor significant. In contrast, PBF (I^2 = 93.6%) and WC (I^2 = 27.0%) were heterogeneous. However, separate subgroup analyses revealed multiple sources of heterogeneity, which could not be adequately explained by only one pair of subgroup analyses.

Sensitivity analysis of PBF

PBF exhibited high heterogeneity. Therefore, the robustness of the results was assessed through sensitivity analyses to identify potential sources of heterogeneity. A leave-one-out sensitivity analysis was performed, revealing that the direction of the combined estimates did not change significantly with the removal of any individual study. This finding suggests that the meta-analysis was robust and not unduly influenced by any single study [61]. The results show that the 95%CI excludes 0 (**Fig. 3**). This means that the results are robust, the sensitivity is small, and the original meta-analysis results are statistically significant.

Publication bias

Publication bias was evaluated for the inclusion of more than 10 studies [62]. The risk of bias for the BW outcome measures was assessed using funnel plots and Egger's regression test [30]. Based on Egger's regression test (P = 0.841 > 0.05), no significant publication bias was detected. The visual inspection of the funnel plot (**Fig. 4**) further supports this conclusion.

GRADE Assessment

The quality of evidence for each outcome was evaluated using the GRADE system. The results indicated that the quality of evidence was moderate for BW and WC, low for BMI, LM, FM, WHR, and HC, and very low for PBF (Table 3). Primary reasons for downgrading included small sample sizes in the included studies, 95%CI crossing equivalence thresholds, and high heterogeneity.

Table 3 GRADE quality of evidence

Outcomes	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Quality of evidence
BW	not serious	not serious	not serious	serious [a]	none	⨁⨁⨁◯ Moderate
BMI	not serious	not serious	not serious	very serious [a,b]	none	⨁⨁◯◯ Low
PBF	not serious	very serious [c]	not serious	very serious [a,b]	none	⨁◯◯◯ Very low
LM	not serious	not serious	not serious	very serious [a,b]	none	⨁⨁◯◯ Low
FM	not serious	not serious	not serious	very serious [a,b]	none	⨁⨁◯◯ Low
WHR	not serious	not serious	not serious	very serious [a,b]	none	⨁⨁◯◯ Low
WC	not serious	not serious	not serious	serious [a]	none	⨁⨁⨁◯ Moderate
HC	not serious	not serious	not serious	very serious [a,b]	none	⨁⨁◯◯ Low

Note: a. small sample sizes in the included studies; b. 95% CI crossing equivalence thresholds; c. high heterogeneity.

Discussion

This study systematically reviewed the effects of WAs on body composition in obesity and overweight people. The results showed that WAs had a positive impact on body composition [63], with significant effects on reducing BW and WC [18, 64]. Specifically, the findings were: (1) WAs significantly reduced BW and WC in females;

(2) WAs with a trial duration of 10 weeks or more (i.e., 12 weeks) showed significant reduction in BW and WC; (3) Continuous WAs in middle-aged and older individuals (average age ≥ 45 years) led to better reductions in BW and WC [65, 66].

The results of the subgroup analyses provide more detailed insights into the factors influencing the effects of WAs on obesity and overweight people. According to the subgroup analysis of BW, WAs with a trial duration greater than 10 weeks (i.e., 12 weeks) resulted in a more significant reduction in BW, while those with a duration of 10 weeks or less showed no significant effect. This suggests that short-term WAs (e.g., six weeks) had a limited impact on BW and body composition [52, 67] , whereas longer interventions (12 weeks or more) were more effective [22, 68]. It has been suggested that WAs are effective for reducing BW in overweight older males [20]. However, the present study found that WAs reduced BW significantly in female and not in male, probably due to the small number of males included in the study, resulting in non-significant differences. WAs were more effective in reducing BW in middle-aged and older adults (average age ≥ 45 years). Aerobic exercise in water is beneficial for middle-aged and elderly people, improving body composition while easing the joint loads associated with land-based exercise [69].

In addition, subgroup analyses based on WC revealed that the WAs intervention significantly reduced WC in obesity and overweight people. WC is a key indicator of abdominal obesity [70, 71], and 12 weeks of WAs were particularly effective in reducing WC in obese and overweight females [64]. Further subgroup analysis showed that WAs with a trial duration greater than 10 weeks (i.e., 12 weeks) had a more

significant impact on WC, while trials lasting 10 weeks or less had no significant effect on WC. Due to the small number of male participants in the included studies, the effect of WAs on male WC requires further confirmation. WAs also had a greater effect on reducing WC in middle-aged and older individuals (average age ≥ 45 years), while no significant effect was observed in other (average age < 45 years) people.

Obesity and overweight people can receive many health benefits through exercise. However, the subgroup analyses showed that the effect of WAs on BMI and PBF was not significant in obesity and overweight people. Previous studies have suggested that 8 weeks of continuous training may be insufficient to observe significant benefits, and that beneficial effects on anthropometric parameters typically become evident after training periods of 12 to 32 weeks [72]. If subgroups were divided according to trial period, sex, and age for several other body components (LM, FM, WHR, HC), the number of studies in each subgroup would be small, producing results with less confidence. Therefore, several other body components were not analyzed in this study.

The GRADE assessment revealed that the certainty of evidence was low for BMI, LM, FM, WHR, and HC, and very low for PBF. The downgrading of evidence was primarily due to small sample sizes, which reduced statistical power and the precision of effect estimates. In addition, high heterogeneity among studies, particularly in PBF outcomes, indicated variability in study populations, methodologies, and intervention effects. Imprecision, as evidenced by wide confidence intervals crossing equivalence thresholds, further contributed to the reduced quality of evidence.

These findings have significant implications for clinical practice. However, there

are several limitations to this study. Studies of registered or ongoing RCTs were not included in the search for articles, and only studies published in English were considered. Judgments made using the RoB tools for literature quality assessment are inherently subjective. Some of the studies had short (6-week) duration of trials, small sample sizes, and less research data. A small number of participants in the study dropped out of the trial halfway through. There were differences in the age, sex ratio, and geographic location of participants across the studies. The low certainty of evidence for BMI, WHR, HC, and other secondary outcomes, and very low certainty for PBF suggests that current evidence was insufficient to reliably inform clinical guidelines for using WAs to improve these parameters. Health professionals should approach these results with caution and prioritize interventions with stronger evidence when aiming to target these specific outcomes. However, the moderate certainty of evidence for BW and WC supports the use of WAs as an effective interventions for reducing overall body weight and central obesity, which were critical factors in managing obesity-related health risks [73, 74].

Conclusions

The results of this systematic review and meta-analysis suggest that WAs is an effective intervention for reducing BW and WC in overweight and obesity adults. Specifically, WAs interventions lasting over 10 weeks significantly reduced BW and WC, with a more pronounced effect observed in females. Middle-aged and elderly individuals also showed better improvements in body composition following WAs interventions. The

certainty of evidence, as assessed using the GRADE framework, was moderate for both BW and WC, indicating that these findings are robust but would benefit from further research to enhance confidence. In contrast, the certainty of evidence for other outcomes was rated as low or very low, primarily due to small sample sizes, high heterogeneity, and imprecision in the included studies. Future research should aim to address these limitations by conducting larger, well-designed RCTs with standardized methodologies and diverse populations. Additionally, investigating the long-term effects of WAs and comparing its efficacy with other exercise modalities will provide valuable insights. In conclusion, WAs is an important form of exercise for overweight and obesity people, offering significant benefits in improving body composition and overall health.

Abbreviations

PROSPERO: International Prospective Register of Systematic Reviews
WAs: Water aerobics
RCTs: randomized controlled trials
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PICOS：Population, Intervention, Comparison, Outcome, Study type
MeSH: Medical Subject Headings
GRADE: Grading of Recommendations Assessment, Development, and Evaluation
BW: body weight
BMI: body mass index
PBF: percent body fat
LM: lean mass
FM: fat mass
WHR: waist–hip ratio
WC: waist circumference
HC: hip circumference
SEM: standard error of the mean
SD: standard deviation
Risk of Bias 2.0: RoB 2
Mix: mixed sex

M: male
F: female
CI: confidence interval
N: numbers
WMD: weighted mean differences

Supplementary information

Additional file 1. Supplementary information 1.
Additional file 2. Supplementary information 2.

Acknowledgements

Thanks to all those who helped with this paper.

Author contributions

Study conception and design: ZD, JP. Acquisition, analysis or interpretation of data: ZD, ZG, HZ. Drafting the manuscript: ZD, HZ, ZG. Critical revision of the manuscript for important intellectual content: JP. Statistical analysis: ZD, ZG, HZ. Supervision: JP. Guarantor: JP. All authors have read and agreed to the published version of the manuscript.

Funding

This study had no funding.

Competing interests

The authors declare that they have no competing interests.

Patient and Public Involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication

Not applicable.

Ethics approval

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

All data relevant to the study are included in thearticle or uploaded as supplementary information.

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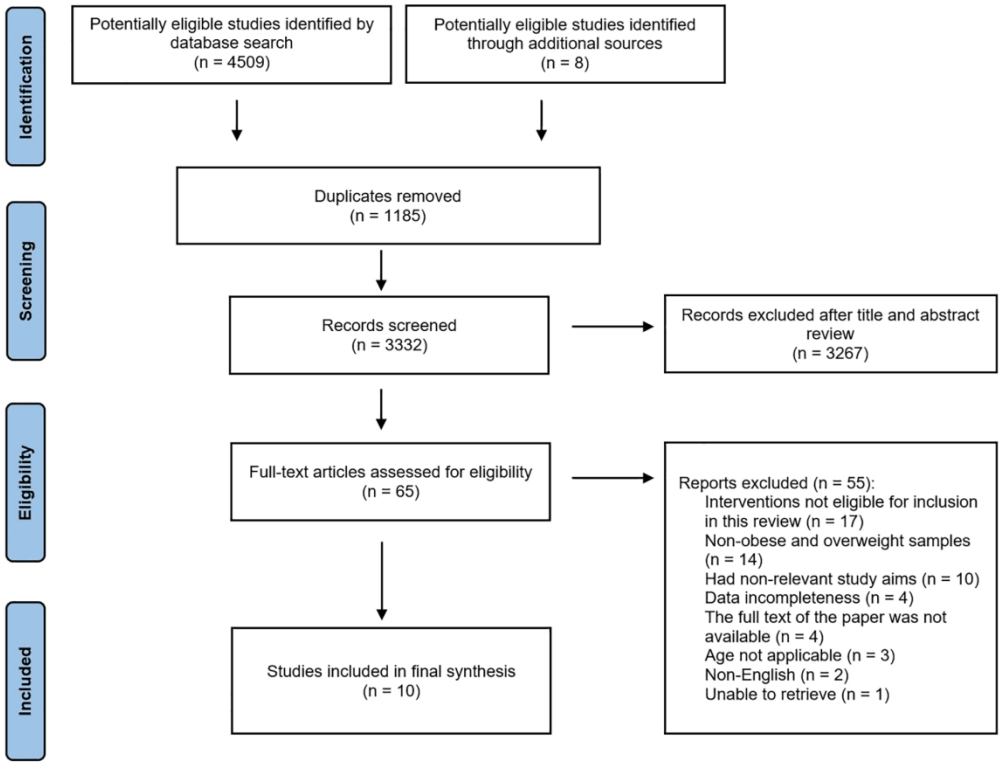
Figure legends:

Fig. 1 Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.

Fig. 2 Risk of bias.

Fig. 3 Sensitivity analysis of percentage body fat.

Fig. 4 Funnel plot for body weight.



Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram

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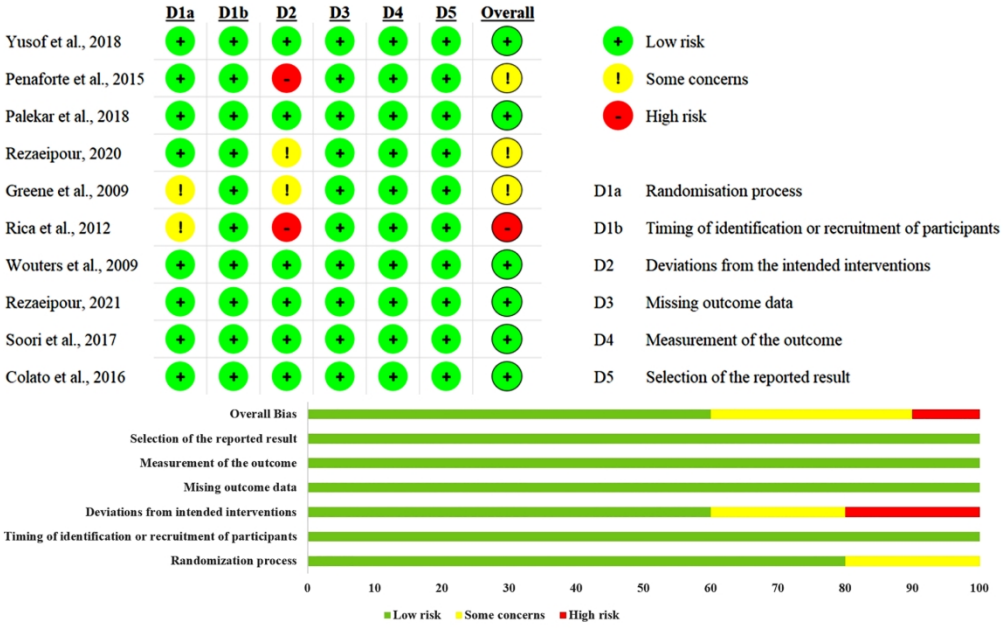

Risk of bias

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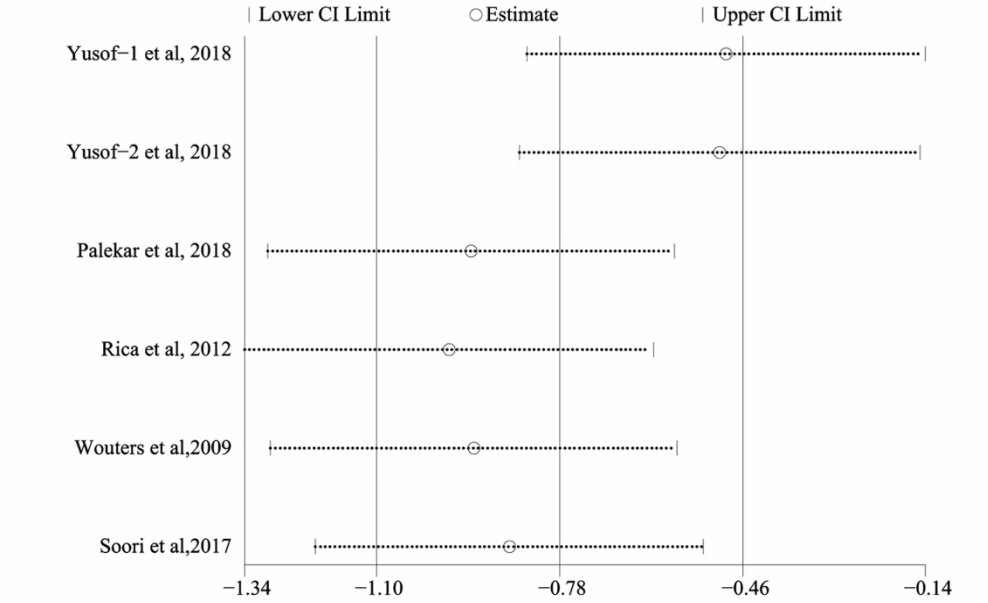

Sensitivity analysis of percentage body fat

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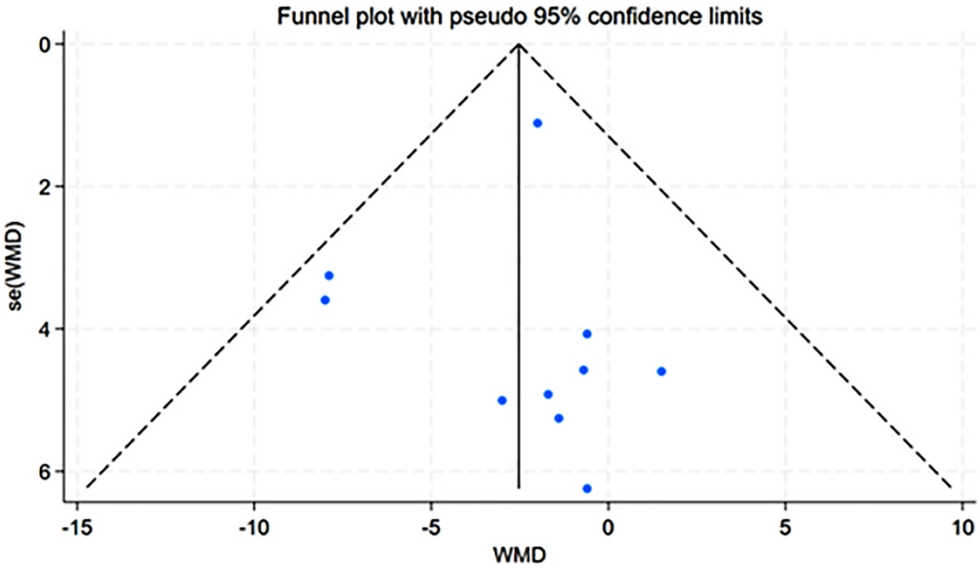

Funnel plot for body weight

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Supplementary information 1

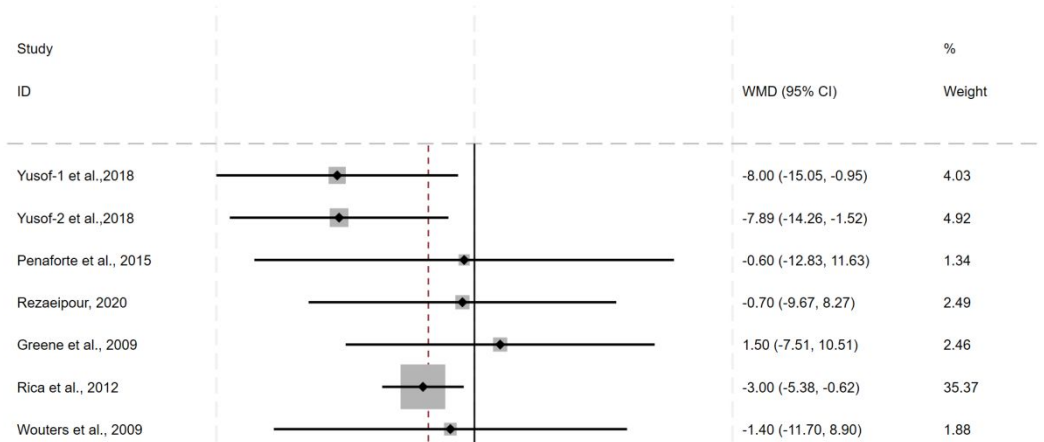

Fig. S1 Meta-analysis of body weight

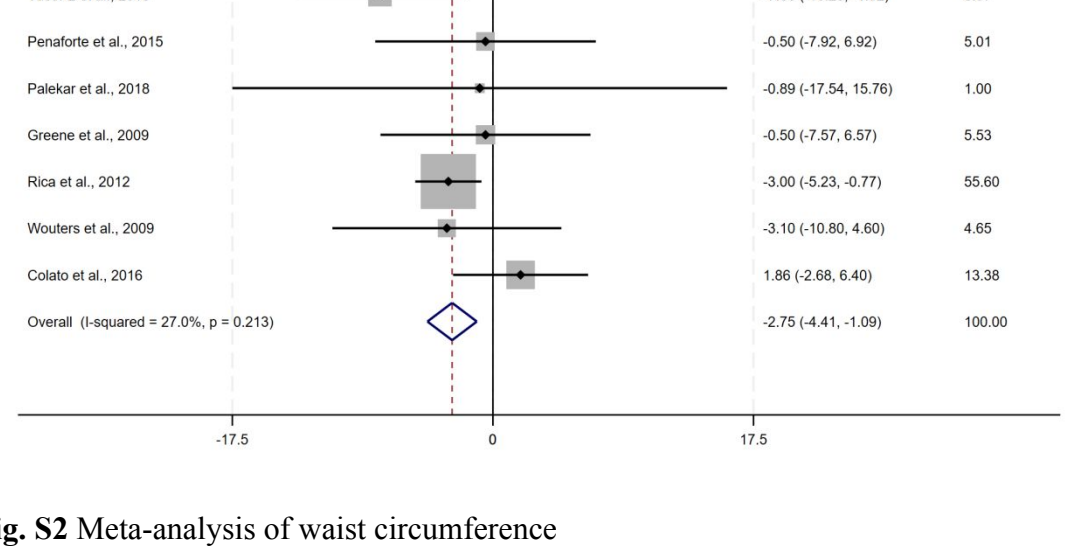

Fig. S2 Meta-analysis of waist circumference

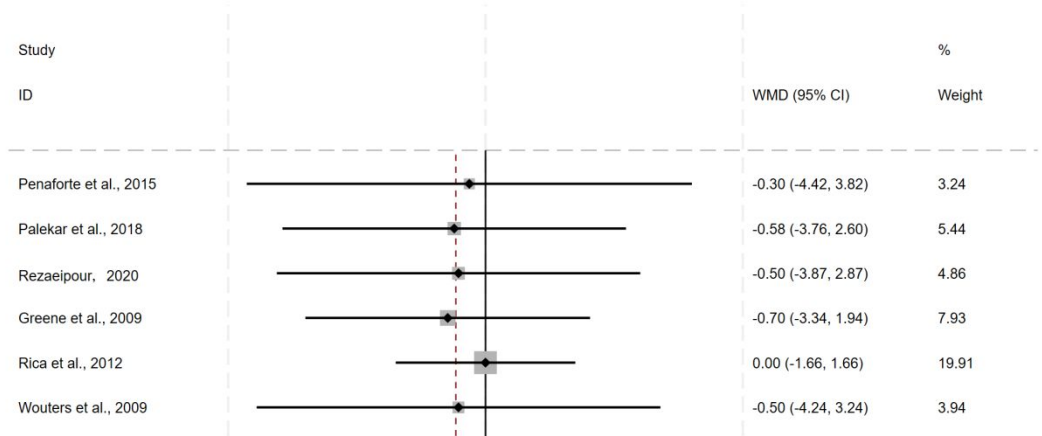

Fig. S3 Meta-analysis of body mass index

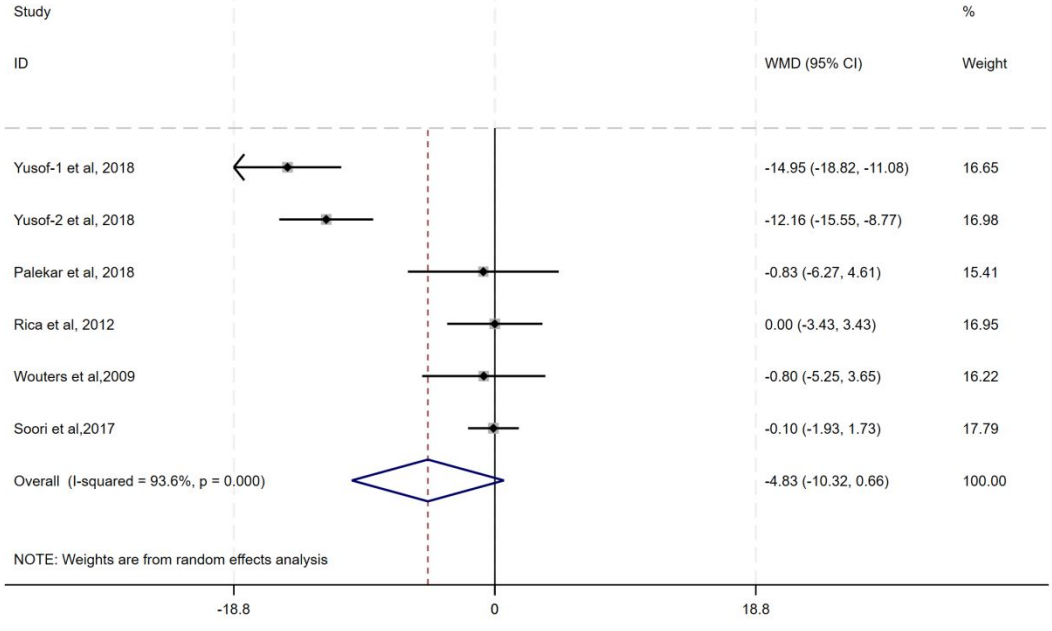

Fig. S4 Meta-analysis of percent body fat

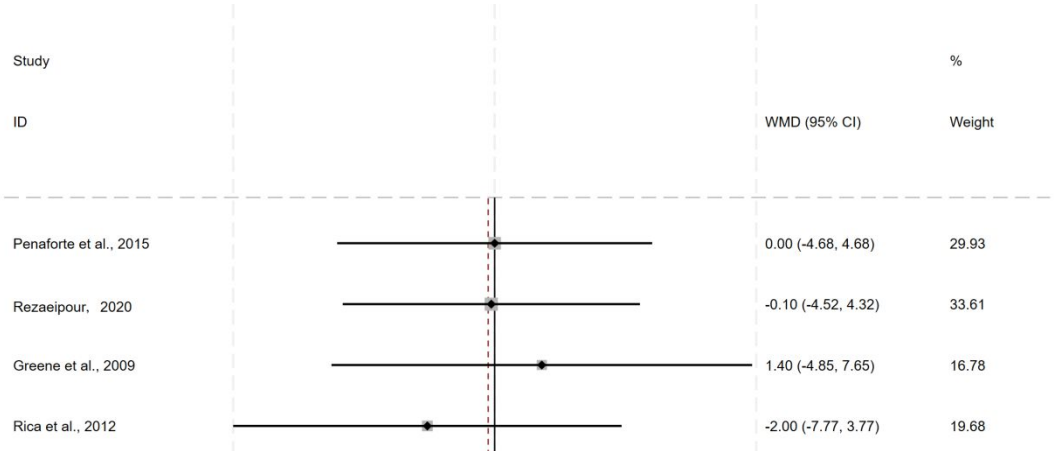

Fig. S5 Meta-analysis of lean mass

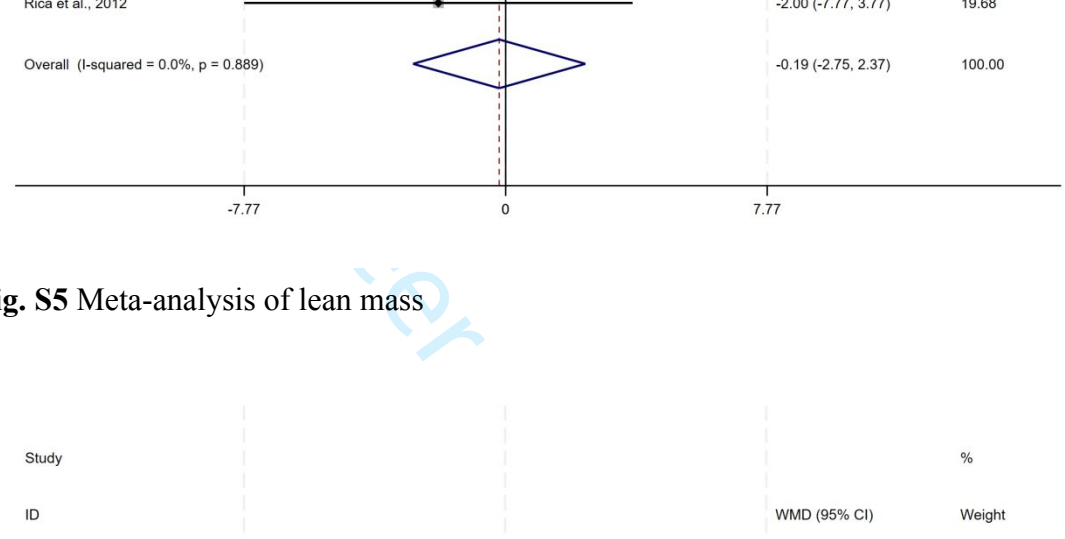

Fig. S6 Meta-analysis of fat mass

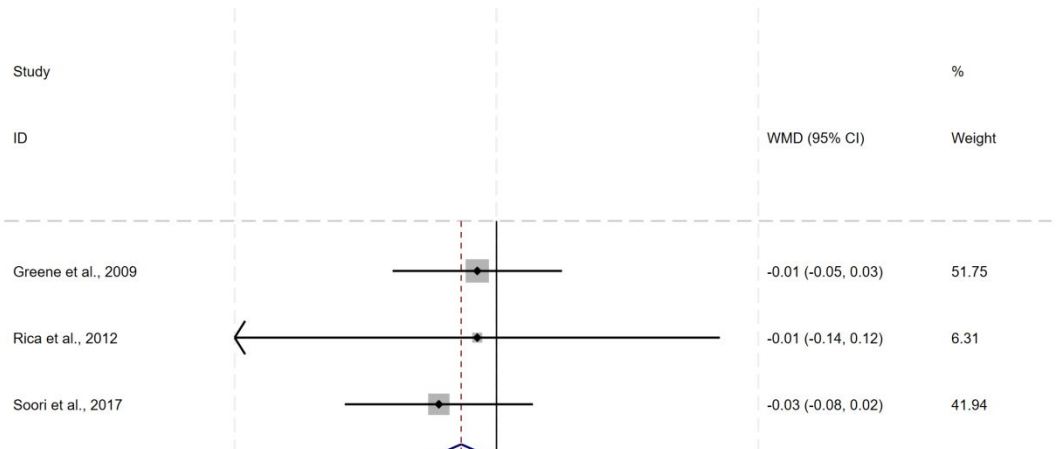

Fig. S7 Meta-analysis of waist–hip ratio

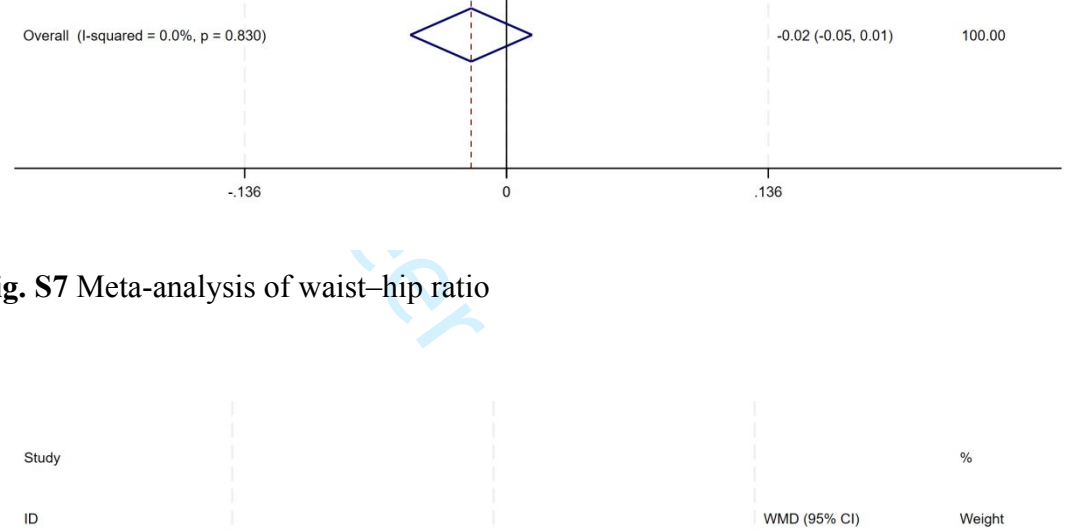

Fig. S8 Meta-analysis of hip circumference

Supplementary information 2

Table S1 Minor changes

Numbers	Changes
1	Delete “body fat mass” and add “waist-to-hip ratio, waist circumference, and hip circumference”.
2	Delete “mean baseline, follow-up” from the data extraction content.
3	Statistical software Change the “Review Manager” to “Stata”.
4	Add water aerobics subgroup analysis.

Table S2 Database search terms

Database	Search terms	Results
PubMed Medline	((((((((((((((((((((((((((((((aerobics) OR (Exercises)) OR (cycling)) OR (Physical Activity)) OR (Activities, Physical)) OR (Activity, Physical)) OR (Physical Activities)) OR (Exercise, Physical)) OR (Exercises, Physical)) OR (Physical Exercise)) OR (Physical Exercises)) OR (Acute Exercise)) OR (Acute Exercises)) OR (Exercise, Acute)) OR (Exercises, Acute)) OR (Exercise, Isometric)) OR (Exercises, Isometric)) OR (Isometric Exercises)) OR (Isometric Exercise)) OR (Exercise, Aerobic)) OR (Aerobic Exercise)) OR (Aerobic Exercises)) OR (Exercises, Aerobic)) OR (Exercise Training)) OR (Exercise Trainings)) OR (Training, Exercise)) OR (Trainings, Exercise)) AND ("Water"[Mesh])) OR ((((((((((water aerobics) OR (waterobics)) OR (aquarobics)) OR (aquatic fitness)) OR (aquafitness)) OR (aquafit)) OR (aqua zumba)) OR (water yoga)) OR (aqua aerobics)) OR (aqua jog))) AND ((("Obesity"[Mesh]) OR ((fat) OR (obese))) OR ("Overweight"[Mesh]))) AND (("Randomized Controlled Trials as Topic"[Mesh]) OR ((((((Randomised controlled trial) OR (controlled trial)) OR (randomized controlled study)) OR (Clinical Trials, Randomized)) OR (Trials, Randomized Clinical)) OR (Controlled Clinical Trials, Randomized)))	375
Embase	('randomised controlled trial'/exp OR 'randomised controlled trial' OR 'randomized controlled trials as topic'/exp OR 'randomized controlled trials as topic' OR 'controlled trial'/exp OR 'controlled trial' OR 'randomized controlled study'/exp OR 'randomized controlled study' OR 'clinical trials, randomized' OR 'trials, randomized clinical' OR 'controlled clinical trials, randomized') AND ('obesity'/exp OR 'obesity' OR 'fat'/exp	2169

	OR 'fat' OR 'obese' OR 'overweight'/exp OR 'overweight') AND ('water aerobics'/exp OR 'water aerobics' OR 'waterobics' OR 'aquarobics' OR 'aquatic fitness' OR 'aquafitness' OR 'aquafit' OR 'aqua zumba' OR 'water yoga' OR 'aqua aerobics' OR 'aqua jog' OR (('water'/exp OR 'water') AND ('exercise'/exp OR 'exercise' OR 'aerobics'/exp OR 'aerobics' OR 'exercises' OR 'cycling'/exp OR 'cycling' OR 'physical activity'/exp OR 'physical activity' OR 'activities, physical' OR 'activity, physical'/exp OR 'activity, physical' OR 'physical activities' OR 'exercise, physical' OR 'exercises, physical' OR 'physical exercise'/exp OR 'physical exercise' OR 'physical exercises' OR 'acute exercise'/exp OR 'acute exercise' OR 'acute exercises' OR 'exercise, acute' OR 'exercises, acute' OR 'exercise, isometric'/exp OR 'exercise, isometric' OR 'exercises, isometric' OR 'isometric exercises' OR 'isometric exercise'/exp OR 'isometric exercise' OR 'exercise, aerobic'/exp OR 'exercise, aerobic' OR 'aerobic exercise'/exp OR 'aerobic exercise' OR 'aerobic exercises' OR 'exercises, aerobic' OR 'exercise training'/exp OR 'exercise training' OR 'exercise trainings' OR 'training, exercise' OR 'trainings, exercise')))	
Ovid MEDLINE	1 "Randomised controlled trial ".mp. 2 exp Randomized Controlled Trials as Topic/ 3 " controlled trial".mp. 4 " randomized controlled study ".mp. 5 "Clinical Trials, Randomized".mp. 6 "Trials, Randomized Clinical".mp. 7 "Controlled Clinical Trials, Randomized".mp. 8 1 or 2 or 3 or 4 or 5 or 6 or 7 9 exp Obesity/ 10 exp Fats/ 11 "obese".mp. 12 exp Overweight/ 13 9 or 10 or 11 or 12 14 "water aerobics ".mp. 15 "aquarobics ".mp. 16 "aquatic fitness ".mp. 17 "aquafitness ".mp. 18 "aquafit".mp. 19 " water yoga".mp. 20 "aqua aerobics".mp. 21 14 or 15 or 16 or 17 or 18 or 19 or 20 22 exp Water/ 23 exp Exercise/ 24 "aerobics ".mp. 25 "Exercises".mp. 26 "cycling".mp.	19

	27 "Physical Activity".mp. 28 "Activities, Physical".mp. 29 "Activity, Physical".mp. 30 "Physical Activities".mp. 31 "Exercise, Physical".mp. 32 "Exercises, Physical".mp. 33 "Physical Exercise".mp. 34 "Physical Exercises".mp. 35 "Acute Exercise".mp. 36 "Acute Exercises".mp. 37 "Exercise, Acute".mp. 38 "Exercises, Acute".mp. 39 "Exercise, Isometric".mp. 40 "Exercises, Isometric".mp. 41 "Isometric Exercises".mp. 42 "Isometric Exercise".mp. 43 "Exercise, Aerobic".mp. 44 "Aerobic Exercise".mp. 45 "Aerobic Exercises".mp. 46 "Exercises, Aerobic".mp. 47 "Exercise Training".mp. 48 "Exercise Trainings".mp. 49 "Training, Exercise".mp. 50 "Trainings, Exercise".mp. 51 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 52 22 and 51 53 21 or 52 54 8 and 13 and 53	
Scopus	((TITLE-ABS-KEY ("randomised controlled trial ") OR TITLE-ABS-KEY ("randomized controlled trials as topic ") OR TITLE-ABS-KEY (" controlled trial") OR TITLE-ABS-KEY (" randomized controlled study ") OR TITLE-ABS-KEY ("clinical trials, randomized") OR TITLE-ABS-KEY ("trials, randomized clinical") OR TITLE-ABS-KEY ("controlled clinical trials, randomized"))) AND ((TITLE-ABS-KEY (obesity) OR TITLE-ABS-KEY (fat) OR TITLE-ABS-KEY (obese) OR TITLE-ABS-KEY (overweight))) AND (((TITLE-ABS-KEY (water)) AND ((TITLE-ABS-KEY (exercise) OR TITLE-ABS-KEY (exercises) OR TITLE-ABS-KEY (cycling) OR TITLE-ABS-KEY ("physical activity") OR TITLE-ABS-KEY ("activities, physical") OR TITLE-ABS-KEY ("activity, physical") OR TITLE-ABS-KEY ("physical activities") OR TITLE-ABS-KEY ("exercise, physical") OR	468

	TITLE-ABS-KEY ("exercises, physical") OR TITLE-ABS-KEY ("physical exercise") OR TITLE-ABS-KEY ("physical exercises") OR TITLE-ABS-KEY ("acute exercise") OR TITLE-ABS-KEY ("acute exercises") OR TITLE-ABS-KEY ("exercise, acute") OR TITLE-ABS-KEY ("exercises, acute") OR TITLE-ABS-KEY ("exercise, isometric") OR TITLE-ABS-KEY ("exercises, isometric") OR TITLE-ABS-KEY ("isometric exercises") OR TITLE-ABS-KEY ("isometric exercise") OR TITLE-ABS-KEY ("exercise, aerobic") OR TITLE-ABS-KEY ("aerobic exercise") OR TITLE-ABS-KEY ("aerobic exercises") OR TITLE-ABS-KEY ("exercises, aerobic") OR TITLE-ABS-KEY ("exercise training") OR TITLE-ABS-KEY ("exercise trainings") OR TITLE-ABS-KEY ("training, exercise") OR TITLE-ABS-KEY ("trainings, exercise")))) OR ((TITLE-ABS-KEY ("water aerobics ") OR TITLE-ABS-KEY ("waterobics ") OR TITLE-ABS-KEY ("aquarobics ") OR TITLE-ABS-KEY ("aquatic fitness ") OR TITLE-ABS-KEY ("aquafitness ") OR TITLE-ABS-KEY ("aquafit") OR TITLE-ABS-KEY (" aqua zumba") OR TITLE-ABS-KEY (" water yoga") OR TITLE-ABS-KEY ("aqua aerobics") OR TITLE-ABS-KEY (" aqua jog")))))	
The Cochrane Library	#1 MeSH descriptor: [Randomized Controlled Trials as Topic] explode all trees #2 MeSH descriptor: [Randomized Controlled Trial] explode all trees #3 " controlled trial" #4 " randomized controlled study " #5 "Clinical Trials, Randomized" #6 "Trials, Randomized Clinical" #7 "Controlled Clinical Trials, Randomized" #8 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 #9 MeSH descriptor: [Obesity] explode all trees #10 MeSH descriptor: [Fats] explode all trees #11 obese #12 MeSH descriptor: [Overweight] explode all trees #13 #9 OR #10 OR #11 OR #12 #14 "water aerobics " #15 waterobics #16 aquarobics #17 "aquatic fitness " #18 aquafitness #19 aquafit #20 " aqua zumba" #21 " water yoga" #22 "aqua aerobics" #23 " aqua jog"	1284

	#24 #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 #25 MeSH descriptor: [Water] explode all trees #26 MeSH descriptor: [Exercise] explode all trees #27 Exercises #28 cycling #29 "Physical Activity" #30 "Activity, Physical" #31 "Exercise, Physical" #32 "Exercises, Physical" #33 "Physical Exercise" #34 "Physical Exercises" #35 "Acute Exercise" #36 "Acute Exercises" #37 "Exercise, Acute" #38 "Exercises, Acute" #39 "Exercise, Isometric" #40 "Exercises, Isometric" #41 "Isometric Exercises" #42 "Isometric Exercise" #43 "Exercise, Aerobic" #44 "Aerobic Exercise" #45 "Aerobic Exercises" #46 "Exercises, Aerobic" #47 "Exercise Training" #48 "Exercise Trainings" #49 "Training, Exercise" #50 "Trainings, Exercise" #51 #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50 #52 #25 AND #51 #53 #24 OR #52 #54 #8 AND #13 AND #53	
Web of science	((((((((((((((((((((((((((TS=(Exercise)) OR TS=(Exercises)) OR TS=(cycling)) OR TS=("Physical Activity")) OR TS=("Activities, Physical")) OR TS=("Activity, Physical")) OR TS=("Physical Activities")) OR TS=("Exercise, Physical")) OR TS=("Exercises, Physical")) OR TS=("Physical Exercise")) OR TS=("Physical Exercises")) OR TS=("Acute Exercise")) OR TS=("Acute Exercises")) OR TS=("Exercise, Acute")) OR TS=("Exercises, Acute")) OR TS=("Exercise, Isometric")) OR TS=("Exercises, Isometric")) OR TS=("Isometric Exercises")) OR TS=("Isometric Exercise")) OR	194

	TS=("Exercise, Aerobic")) OR TS=("Aerobic Exercise")) OR TS=("Aerobic Exercises")) OR TS=("Exercises, Aerobic")) OR TS=("Exercise Training")) OR TS=("Exercise Trainings")) OR TS=("Training, Exercise")) OR TS=("Trainings, Exercise")) AND TS=(water) OR (((((((((TS=("water aerobics ")) OR TS=("waterobics ")) OR TS=("aquarobics ")) OR TS=("aquatic fitness ")) OR TS=("aquafitness ")) OR TS=("aquafit")) OR TS=(" aqua zumba")) OR TS=(" water yoga")) OR TS=("aqua aerobics")) OR TS=(" aqua jog") AND ((((((TS=("Randomised controlled trial ")) OR TS=("Randomized Controlled Trials as Topic")) OR TS=(" controlled trial")) OR TS=(" randomized controlled study ")) OR TS=("Clinical Trials, Randomized")) OR TS=("Trials, Randomized Clinical")) OR TS=("Controlled Clinical Trials, Randomized")AND (((TS=(obesity)) OR TS=(fat)) OR TS=(obese)) OR TS=(Overweight)	