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REVIEW ARTICLE

Combined training prescriptions for improving cardiorespiratory fitness, physical fitness, body composition, and cardiometabolic risk factors in older adults: Systematic review and meta-analysis of controlled trials

Prescriptions d'entraînement combiné pour améliorer la condition cardiorespiratoire, la condition physique, la composition corporelle et les facteurs de risque cardiométabolique chez les personnes âgées : revue systématique et méta-analyse d'essais contrôlés

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KEYWORDS
Combined training;
Older adults;
Cardiorespiratory fitness;
Physical fitness;
Meta-analysis

Summary
Background. — Improved physical fitness is important for preventing COVID-19-related mortality. So, combined training can effectively increase peak oxygen consumption, physical fitness, body composition, blood pressure, and the healthrelated characteristics of adults; however, its impact in the elderly remains unclear.
Methods. — This systematic review and meta-analysis aimed to evaluate the effects of combined training on older adults. Four electronic databases (PubMed, Scopus, Medline, and Web of Science) were searched (until April 2021) for randomized trials comparing the effect of combined training on cardiorespiratory fitness, physical fitness, body composition, blood pressure, and cardiometabolic risk factors in older adults.

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Results. — Combined training significantly improved peak oxygen consumption compared to no exercise (WMD = 3.10, 95% CI: 2.83 to 3.37). Combined resistance and aerobic training induced favorable changes in physical fitness (timed up-and-go = −1.06, 30-s chair stand = 3.85, sit and reach = 4.43, 6-minute walking test = 39.22, arm curl = 4.60, grip strength = 3.65, 10-m walk = −0.47, maximum walking speed = 0.15, one-leg balance = 2.71), body composition (fat mass = −2.91, body fat% = −2.31, body mass index = −0.87, waist circumference = −2.91), blood pressure (systolic blood pressure = −8.11, diastolic blood pressure = −4.55), and cardiometabolic risk factors (glucose = −0.53, HOMA-IR = −0.14, high-density lipoprotein = 2.32, total cholesterol = −5.32) in older individuals. Finally, the optimal exercise prescription was ≥ 30 min/session × 50—80% VO2peak, ≥ 3 times/week for ≥ 12 weeks and resistance intensity 70—75% one-repetition maximum, 8—12 repetitions × 3 sets.
Conclusions. — Combined training improved VO2peak and some cardiometabolic risk factors in older populations. The dose—effect relationship varied between different parameters. Exercise prescriptions must be formulated considering individual needs during exercise.

MOTS CLÉS
Entraînement combiné ;
Seniors ;
Aptitude cardiorespiratoire ;
Aptitude physique ;
Méta-analyse

Résumé
Contexte. — L'amélioration de la condition physique est importante pour prévenir la mortalité liée au COVID-19. Ainsi, l'entraînement combiné peut augmenter efficacement la consommation maximale d'oxygène, la forme physique, la composition corporelle, la tension artérielle et les caractéristiques liées à la santé des adultes; cependant, son impact chez les personnes âgées reste incertain.
Méthodes. — Cette revue systématique et cette méta-analyse visaient à évaluer les effets de l'entraînement combiné chez les personnes âgées. Quatre bases de données électroniques (PubMed, Scopus, Medline et Web of Science) ont été consultées (jusqu'en avril 2021) pour trouver des essais randomisés comparant l'effet d'un entraînement combiné sur l'aptitude cardiorespiratoire, la forme physique, la composition corporelle, la tension artérielle et les facteurs de risque cardiométabolique chez les personnes âgées.
Résultats. — Au total, 37 publications ont été incluses dans cette étude. L'entraînement combiné a considérablement amélioré la consommation maximale d'oxygène par rapport à l'absence d'exercice (DMP = 3,10, IC95 % : 2,83 à 3,37). La combinaison résistance + entraînement aérobie a entraîné des changements favorables dans la forme physique (démarrage chronométré = −1,06, position assise pendant 30 s = 3,85, position assise et lever = 4,43, test de marche de 6 minutes = 39,22, flexion des bras = 4,60, adhérence force = 3,65, marche de 10 m = −0,47, vitesse de marche maximale = 0,15, équilibre sur une jambe = 2,71), composition corporelle (masse grasse = −2,91, pourcentage de graisse corporelle = −2,31, indice de masse corporelle = −0,87, taille circonférence = −2,91), tension artérielle (pression artérielle systolique = −8,11, pression artérielle diastolique = −4,55) et facteurs de risque cardiométabolique (glucose = −0,53, HOMA-IR = −0,14, lipoprotéines de haute densité = 2,32, cholestérol total = −5,32) chez les personnes âgées. Enfin, la prescription d'exercice optimale était ≥ 30 min/séance × 50—80 % VO2pic, ≥ 3 fois/semaine pendant ≥ 12 semaines et résistance à une intensité de 70—75 % une répétition maximale, 8—12 répétitions × 3 séries.
Conclusions. — L'entraînement combiné a amélioré la VO2pic et certains facteurs de risque cardiométabolique chez les populations âgées. La relation dose-effet variait entre les différents paramètres. Les prescriptions d'exercice doivent être formulées en tenant compte des besoins individuels pendant l'exercice.

1. Abbreviations

COVID-19 coronavirus disease 2019
VO2peak peak oxygen uptake
BMI body mass index
TUG timed up-and-go
6MWT 6-minute walking test
BF% body fat percentage
WC waist circumference
WHR waist-to-hip ratio
SBP systolic blood pressure
DBP diastolic blood pressure
PP pulse pressure
HDL high-density lipoprotein
LDL low-density lipoprotein
HOMA-IR homeostasis model assessment for insulin resistance

WMD weighted mean differences

2. Introduction

As a result of advances in medical care and technology, human life spans are gradually increasing globally. Specifically, 8.5% of the world's population is over 65 years of age, and by 2050, the elderly population is expected to have grown by 17% [1]. Physical fitness, as indicated by muscle strength, 6-minute walk, etc., gradually declines with age, and poor physical fitness is an independent risk factor for premature death. Clinical muscle loss is not only a component of the ''disaster duet'', it also comprises the ''disaster quintet'', along with falls, brittle fractures, debilitating syndrome, and osteoporosis, which can seriously harm the health of the elderly [2]. The maintenance of muscle strength, muscle flexibility, muscle endurance, and cardiopulmonary fitness plays an important role in the health of the elderly [3]. Importantly, in the context of older adults and the adverse effects of increased fat mass on healthy aging, exercise is essential if a decrease in fat mass is to be achieved. Therefore, fat mass and physical performance have been identified as two important independent health indicators for promoting the health of older adults. Strategies to prevent age-related decline in physical performance and increased fat mass may help to prevent or slow the progression of sarcopenia and the associated functional decline in older adults.

As fat mass is increased and physical fitness is reduced in the elderly, the importance of exercise in this population is evident [4]. The American College of Sports Medicine has recommended 20—30 min of moderate-to-vigorous aerobic training for the elderly for at least 3 days a week and the inclusion of resistance training for 1 or 2 days a week [5]. New data also indicate that physical activity may reduce the risk of acute respiratory distress syndrome, which is a major cause of death in patients with coronavirus disease 2019 (COVID-19) [6]. Especially in the context of COVID-19, the promotion of physical activity among the elderly plays an important role in preventing COVID-19-related mortality rates. And because of the older adults have been identified as the most vulnerable age-group to get infected by COVID-19, Further, it is necessary to study the elderly over 60 years of age [7]. Therefore, it is necessary to increase the physical activity of the older adults.

In recent years, aerobic exercise combined with resistance exercise has led to better health outcomes in older adults. Studies have shown that combined training can significantly improve muscle protein synthesis and cardiomyocyte quality in the obese elderly, and it is much better than aerobic exercise or resistance exercise alone and can compensate for the lack of time [8]. The 6-week combined training proposed by Kim et al. can also significantly improve upper body muscular strength/endurance, physical function, insulin, and the homeostatic model assessment of insulin resistance (HOMA-IR) in the elderly [9]. In 2019, a meta-analysis by Hurst et al. showed that combined training significantly improved VO_{2peak}, 30-s chair stand, and 6-min walk in adults over 50 years of age [10]. Chaabene et al., in their systematic review and meta-analysis, found that home-based single-mode strength training had moderate effects on muscle strength (SMD = 0.51, 95% CI: 0.17 to 0.84) and balance (SMD = 0.65, 95% CI: 0.27 to 1.03), while combined training had no significant effects on muscle strength and balance in healthy older adults [11]. However, most existing studies have explored the effect of combined training on a certain dimension of health, such as physical fitness, muscle strength, and body composition, and the results of some studies were inconsistent. Moreover, the units of outcome indicators included in the meta-analysis by Chaabene et al. were inconsistent between studies, which may have affected the results. The effects of combined training on physical fitness, body composition, blood pressure, and cardiometabolic risk factors have not been comprehensively and systematically analyzed.

In this study, first, the influence of combined training on VO_{2peak} of the elderly over 60 years old was systematically analyzed. Second, the effect of combined training on physical fitness of the elderly is analyzed. Finally, the optimal exercise prescription is proposed.

3. Materials and methods

This study followed the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines. The following steps were implemented by two independent raters. Any discrepancies were resolved by discussion or in consensus with a third rater (WZJ).

3.1. Literature search strategy

A literature search was performed for articles up to April 15, 2021 using scientific databases (Scopus, PubMed, ScienceDirect, Medline, and Web of Science). The initial search terms included ''resistance and aerobic exercise'' OR ''combined aerobic and resistance training'' OR ''combined exercise training'' OR ''strength and endurance training'' OR ''combined training''. The second search terms included ''cardiovascular function'' OR ''cardiorespiratory fitness'' OR ''VO_{2peak}'' OR ''maximal oxygen uptake'' OR ''maximal $VO_{2''}$. The third search terms included ''functional fitness'' OR ''body Composition'' OR ''blood Pressure'' OR ''physical functions'' OR ''cardiometabolic risk factors''. The fourth search terms included ''combined training VS aerobic-exercise'' OR ''combined training VS resistance-exercise''. The fifth search terms included ''older adults'' OR ''older'' OR ''health older adults''. The sixth search terms included ''randomized controlled trial'' OR ''RCT''. Finally, the six search terms were combined using the AND operator. Further, references of the included articles and related reviews were scanned for potentially relevant studies.

3.2. Study inclusion and exclusion criteria

The inclusion criteria were as follows: (a) healthy subjects aged ≥ 60 years — their inclusion was not restricted by body mass index (BMI), sex, or ethnic origin, but high-level athletes were excluded; (b) combined exercise interventions (aerobic training + resistance training); (c) randomized controlled trials or controlled clinical trials; (d) ≥ 6-week interventions; and (e) outcome indicators, with the primary outcome being VO_{2peak} (mL/kg/min), physical fitness, body composition, blood pressure, blood lipids, and glucose. Secondary outcomes considered were 30-s chair-stand (repetitions), timed up-and-go (TUG, s), 6-minute walking test (6MWT, m), sit-and-reach (cm), arm curl (repetitions), grip strength (kg), 10-m walk (s), maximum walking speed (m/s), one-leg balance (s), BMI (kg/m^2), weight (kg), lean mass (kg), fat mass (kg), body fat percentage (BF%), waist circumference (WC, cm), waist-to-hip ratio (WHR), systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), pulse pressure (PP, mmHg), glucose (mmol/L), triglycerides (mmol/L), total cholesterol (mmol/L), high-density lipoprotein (HDL, mmol/L), low-density lipoprotein (LDL, mmol/L), insulin (mmol/L), and HOMA-IR. The exclusion criteria were as follows: (a) articles written in Chinese; (b) one-time acute exercise studies; and (c) interventions including high-intensity interval training.

3.3. Data collection or data synthesis

The first author (WZJ) extracted data from the studies with advice from FL on the selection criteria. First, the title and abstract were screened, and if data were missing or interesting, the full text was analyzed. The data were then extracted if they met our criteria. Requests for missing data (VO_{2peak}, 30-s chair stand, TUG, 6MWT, sit and reach, arm curl, grip strength, 10-m walk, maximum walking speed, one-leg balance, BMI, weight, lean mass, fat mass, BF%, WC, WHR, SBP, DBP, PP, triglycerides, glucose, total cholesterol, HDL, LDL, insulin and HOMA-IR, number of male and female subjects before and after the protocol, and age at the beginning of the study) were sent to the corresponding authors as appropriate.

3.4. Risk of bias assessment

The Cochrane collaboration tool for assessing the risk of bias (Revman 5.3, London, UK) was used to evaluate the quality of the included literature primarily considering 6 domains: selection (sequence generation and allocation concealment), performance (blinding of participants/personnel), detection (blinding outcome assessors), attrition (incomplete outcome data), report (selective reporting), and other potential biases (e.g., recall bias). For each indicator, a ''low risk of bias'', ''unclear risk of bias'', and ''high risk of bias'' were used as judgments. The quality of the included literature was classified into three levels: A ($\geq$4 items of low risk were met), B (2—3 items of low risk were met), and C ($\leq$1 items of low risk were met). The Egger test was used to detect publication bias with bias indicated if $P < 0.05$.

3.5. Statistical analysis

Using VO_{2peak}, 30-s chair stand, TUG, 6MWT, sit and reach, arm curl, grip strength, 10-m walk, maximum walking speed, one-leg balance, BMI, weight, lean mass, fat mass, BF%, WC, WHR, SBP, DBP, PP, triglycerides, glucose, total cholesterol, HDL, LDL, and insulin and HOMA-IR, and given the consistency of variable units between the same outcome indicators among the continuous variables in the included studies, we compared the changes from baseline to end-point data among groups using weighted mean differences (WMDs). Ninety-five percent confidence intervals (CIs) were used for pooled effect sizes. Statistical heterogeneity among the included studies was examined using the I^2 test and Cochran's Q-test. When the P-value was < 0.1, heterogeneity existed among studies; otherwise, homogeneity existed among the studies. Heterogeneity between studies was quantitatively evaluated by I^2, with 0%—24% indicating no heterogeneity, 25%—49% mild heterogeneity, 50%—74% moderate heterogeneity, and 75%—100% high heterogeneity. When heterogeneity was evident, a random-effects model was used to pool the data; otherwise, a fixed-effects model was used. An effect size greater than 0 with a 95% CI lower boundary also greater than 0 would indicate an increased effect; otherwise, it would indicate a decreased effect. The optimal exercise prescription was presented according to the effect size of the significant indexes. Statistical analysis was performed using Stata 14.0 (Meta-template) software.

4. Results

4.1. Study selection

The initial search retrieved 8377 peer-reviewed articles from the various databases with 129 duplicates eliminated using the literature manager and 8248 irrelevant articles eliminated by reading the titles and abstracts. Ultimately, 263 eligible articles remained, and 37 controlled experiments were ultimately included after reading the full text (Fig. 1).

4.2. Study characteristics

Table 1 outlines the characteristics of the included studies, which comprised 1213 participants (mean age 60.2—76.4 years). Thirty-seven articles were included in the study, and 1 of those studies contained 2 experiments; 17 studies exclusively included women [12—28], 10 studies exclusively included men [29—38], 9 studies included both sexes [9,39—45], while sex was not reported in 1 study [46]. The training frequency was 2—7 sessions/week, the training session length was 20—120 min, and the cycle was 6—48 weeks. The combined training method was either continuous cardio and resistance (in no particular order) or separate (2 days of cardio and 1 day of resistance). Most studies used continuous aerobic and resistance training. Exercise intensity measurement methods varied, such as maximal heart rate, maximum repetition test, Borg's rating of perceived exertion, VO_{2peak}, etc.

Fig. 2 shows the method quality evaluation chart for the included studies. According to the literature quality evaluation criteria, 16 studies met $\geq$4 items of low risk, and 21 studies met 2—3 items of low risk.

4.3. Meta-analysis

4.3.1. Effect of combined exercise training on VO_{2peak}

Fifteen studies compared VO_{2peak} changes in older adults after combined exercise training. Between-study heterogeneity (τ) was small ($Q = 22.04$, $df = 14$, $I^2 = 36.5\%$,

Table 1 Characteristics of studies and subjects included in the review.

First author	Published years	Country	Sample ratio (T/C)	Sex ratio (M/F)	Age (years)	Experimental period	Sessions/ week	Session length (min)	Outcome measures
Ferketich	1998	USA	7/6	0/13	67.2 ± 1.5	12 weeks	3	45	a
Rubenstein	2000	USA	31/28	59/0	76.4 ± 4.9	12 weeks	3	90	j,l,q
Delecluse	2004	Belgium	22/13	35/0	63.8 ± 3.8	20 weeks	2	55	a,d,f,g,u
Takeshima	2004	Japan	18/17	15/20	68.3 ± 4.9	12 weeks	3	50	c,v,w,x,y
Englund	2005	Sweden	24/24	0/48	72.8 ± 3.6	48 weeks	2	50	b,c,d,e,n,p,q
Park	2008	Japan	25/25	0/50	68.4 ± 3.4	48 weeks	3	41	a,f
Kim	2008	Korea	10/10	0/20	Over 75	12 weeks	4	80	a,b,c,d,f,g,n,o,r,s,u,v,x
Carvalho	2008	Portugal	32/25	0/57	68.4 ± 2.9	32 weeks	2	60	i,j,k,l,m
Ahtiainmen	2009	USA	7/7	14/0	64 ± 3	21 weeks	4	120	a,c,d,f
Park	2010	Korea	10/10	0/20	66.9 ± 4.2	12 weeks	3	70	a,b,f,h,j,o,r,s,v,w,x,y
Marques	2011	Portugal	30/30	0/60	70.1 ± 5.4	32 weeks	2	60	b,d,e,f,g,i,j,l,n
Campos	2013	Brazil	5/3	0/8	Over 60	12 weeks	3	35	f,l
Sousa	2013	Portugal	16/17	33/0	69.1 ± 5	36 weeks	3	30	b,f,j,l,r,s
Sousa	2014	Portugal	20/20	40/0	69.1 ± 5	32 weeks	3	30	i,j,k,l,m
Wilhelm	2014	Brazil, UK	15/15	30/0	63.2 ± 3.2	12 weeks	2	45	a,k
Wang	2015	Taiwan	17/12	8/21	70.3 ± 4.6	12 weeks	3	60	l
Lee	2015	Korea	14/13	0/27	68.4 ± 3	8 weeks	5	50	b,c,d,e,f,h
Rossi	2015	Brazil	32/18	0/50	61 ± 0.6	16 weeks	7	57	b,c,d,e,f,w,x,y
Sh	2016	Iran	12/12	0/24	74.2 ± 4.5	12 weeks	3	30	b,f,h
Osuka	2017	Japan	28/28	18/38	69.6 ± 3.5	12 weeks	4	60	a,c,m,u,v,w,x,y,z,aa
Lima	2017	Canada	15/14	7/22	67.8 ± 5.2	10 weeks	3	30	d,e,g,r,s,u,z,aa
Park	2017	Korea	21/20	0/41	71.1 ± 4.6	24 weeks	5	50—80	a,b,d,f,h,i,j,m,n,p,r,s
Park	2017	Korea	25/25	0/50	73.5 ± 7.1	24 weeks	5	50—80	f,g,i,j,n,p,r,s,v,w,x,y
Ozaki	2017	Japan	6/6	0/12	61 ± 0.3	8 weeks	3	—	a,b,c

Table 1 (*Continued*)

First author	Published years	Country	Sample ratio (T/C)	Sex ratio (M/F)	Age (years)	Experimental period	Sessions/ week	Session length (min)	Outcome measures
Sousa	2017	Portugal	22/22	44/0	69 ± 4.9	32 weeks	3	60	b,i,k,l
Son	2017	Korea	10/10	0/20	75 ± 2	12 weeks	3	70	a,b,c,d,f,i,j,k,l,n,r,s,t
Shiotsu	2018	Japan	16/13	29/0	70.5 ± 3.5	10 weeks	2	—	b,c,d,f,g,j,k,n,o,q,r,s
Faramarzi	2018	Iran	12/9	0/21	60.3 ± 0.8	8 weeks	3	60	a,b,c,f,g,h,v,x
Shiotsu	2018	Japan	12/12	0/24	71 ± 4.4	10 weeks	2	40	b,c,d,f,g,j,k,o,q
Kim	2018	Korea	16/15	2/29	70.5 ± 4.8	6 weeks	3	90	b,c,d,f,g,i,k,l,m,q,u,z,aa
Timmons	2018	Ireland	21/21	18/24	69.3 ± 3.5	12 weeks	3	40	k
Kim	2019	Korea	10/10	20/0	68.8 ± 0.9	12 weeks	3	90	e,z,aa
Colleluori	2019	USA	12/12	13/11	70.5 ± 0.7	24 weeks	—	—	a,c,d,e
Ruangthai	2019	Thailand	16/12	10/18	67.3 ± 5.9	12 weeks	3	60	b,c,d,e,f,r,s,u,v,w,x,y
Park	2020	Korea	10/10	20/0	68.8 ± 0.9	12 weeks	3	90–120	b,c,d,f,r,s,t,u,v,w,x,y
Otsuki	2020	Japan	12/15	11/16	68 ± 2	6 weeks	3	30	a,b,j,r,s,t,u,v,x,y,z
Muller	2020	Brazil	20/20	—	64.2 ± 3.1	16 weeks	2	20	a

Data are expressed as mean ± standard deviation (SD). T: trial group; C: control group; M: man; F: female.

[a] VO_{2peak} (mL/kg/min).
[b] BMI: body mass index (kg/m^2).
[c] Weight (kg).
[d] LM, lean mass (kg).
[e] Fat mass (kg).
[f] BF%: body fat percentage.
[g] WC: waist circumference (cm).
[h] WHR: waist-to-hip ratio.
[i] 30-s chair stand (rps).
[j] Sit and reach (cm).
[k] TUG: timed up and go (s).
[l] 6MWT: 6-minute walking test (m).
[m] Arm curl (rps).
[n] Grip strength (kg).
[o] 10 m walk (s).
[p] Maximum walking speed (m/s).
[q] One-leg balance (s).
[r] SBP: systolic blood pressure.
[s] DBP: diastolic blood pressure.
[t] PP: pulse pressure.
[u] Glucose (mmol/L).
[v] Triglycerides (mmol/L).
[w] Total cholesterol (mmol/L).
[x] HDL: high-density lipoprotein (mmol/L).
[y] LDL: low-density lipoprotein (mmol/L).
[z] Insulin (mmol/L).
[aa] HOMA-IR.

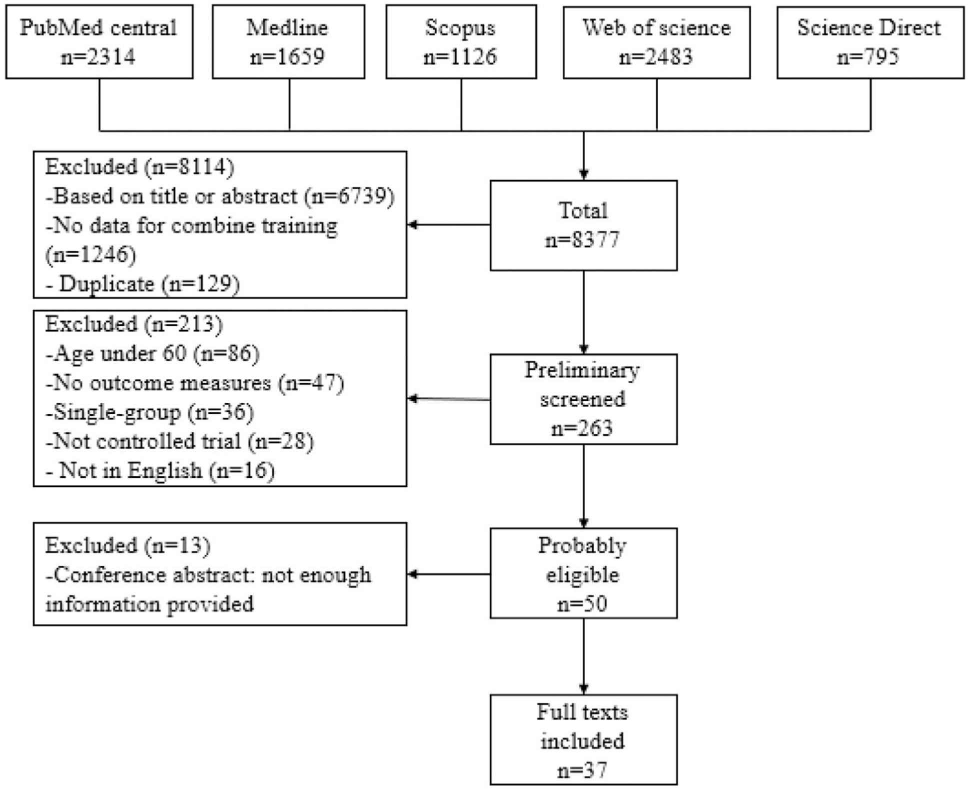

Figure 1 Flow diagram of literature search and study selection.

$P = 0.078$). As shown in Fig. 3, compared to no-exercise controls, VO_{2peak} showed a likely moderate (possibly large) beneficial effect (WMD = 3.10, 95% CI: 2.83 to 3.37, $P < 0.001$).

4.3.2. Effect of combined exercise training on physical fitness

Twelve studies compared TUG changes in older adults after combined exercise training. TUG (WMD = −1.06, 95% CI: −1.66 to −0.46; $I^2 = 93.7\%$, Q = 173.63, df = 11, $P < 0.01$) was significantly lower after combined exercise training. Eleven studies compared the changes in 30-s chair stand, and combined exercise training induced significantly higher values (WMD = 3.85, 95% CI: 2.86 to 4.84; $I^2 = 61.0\%$, Q = 25.67, df = 10, $P < 0.001$) when compared with the absence of exercise (Table 2). Nine studies compared the changes in sit and reach, and combined exercise training induced significantly higher values (WMD = 4.43, 95% CI: 1.84 to 7.02; $I^2 = 81.1\%$, Q = 42.44, df = 8, $P < 0.01$) when compared with the absence of exercise. Ten studies compared changes in 6WMT, and combined exercise training induced significantly higher values (WMD = 39.22, 95% CI: 19.49 to 58.94; $I^2 = 71.0\%$, Q = 31.06, df = 9, $P < 0.001$) when compared with the absence of exercise. Five studies compared changes in 10-m walk and 3 studies compared changes in maximum walking speed, the 10-m walk was significantly lower (WMD = −0.47, 95% CI: −0.65 to −0.29; $I^2 = 16.1\%$, Q = 4.77, df = 4, $P < 0.001$) and the maximum walking speed was significantly higher (WMD = 0.15, 95% CI: 0.01 to 0.29; $I^2 = 66.2\%$, Q = 5.92, df = 2, $P < 0.05$) after combined exercise training. Five studies described changes in arm curl, and 7 studies compared changes in grip strength. Combined exercise training resulted in significant increases in arm curl (WMD = 4.60, 95% CI: 1.49 to 7.71; $I^2 = 86.3\%$, Q = 29.27, df = 4, $P < 0.01$) and grip strength (WMD = 3.65, 95% CI: 2.69 to 4.62; $I^2 = 21.8\%$, Q = 7.67, df = 6, $P < 0.001$) in older adults. Six studies compared the changes in one-leg balance, and combined exercise training induced significant significantly higher values (WMD = 2.71, 95% CI: 0.72 to 4.71; $I^2 = 1.3\%$, Q = 5.07, df = 5, $P < 0.01$) when compared with the absence of exercise.

4.3.3. Effect of combined exercise training on body composition

Changes in body composition in no-exercise controls and combined exercise training groups after intervention are shown in Table 2. Seventeen studies described changes in weight, 7 studies compared changes in fat mass, 16 studies described changes in lean mass, 21 studies described changes in BF%, 19 studies compared changes in BMI, 11 studies described changes in WC, and 4 studies compared changes in WHR. Combined exercise training significantly decreased fat mass (WMD = −2.91, 95% CI: −5.58 to −0.23; $I^2 = 89.8\%$, Q = 58.76, df = 6, $P < 0.05$), BF% (WMD = −2.31, 95% CI: −2.76 to −1.87; $I^2 = 27.5\%$, Q = 27.59, df = 20, $P < 0.001$), BMI (WMD = −0.87, 95% CI: −1.35 to −0.40; $I^2 = 56.5\%$, Q = 41.41, df = 18, $P < 0.001$), and WC (WMD = −2.91, 95% CI: −4.05 to −1.78; $I^2 = 21.0\%$, Q = 12.65, df = 10, $P < 0.001$) in older adults. However, combined exercise training did not have a significant effect on weight (WMD = −1.86, 95% CI: −4.14 to 0.41; $I^2 = 93.0\%$, Q = 227.5, df = 16), lean mass (WMD = 0.44, 95% CI: −0.25 to 1.12; $I^2 = 0.0\%$, Q = 5.71,

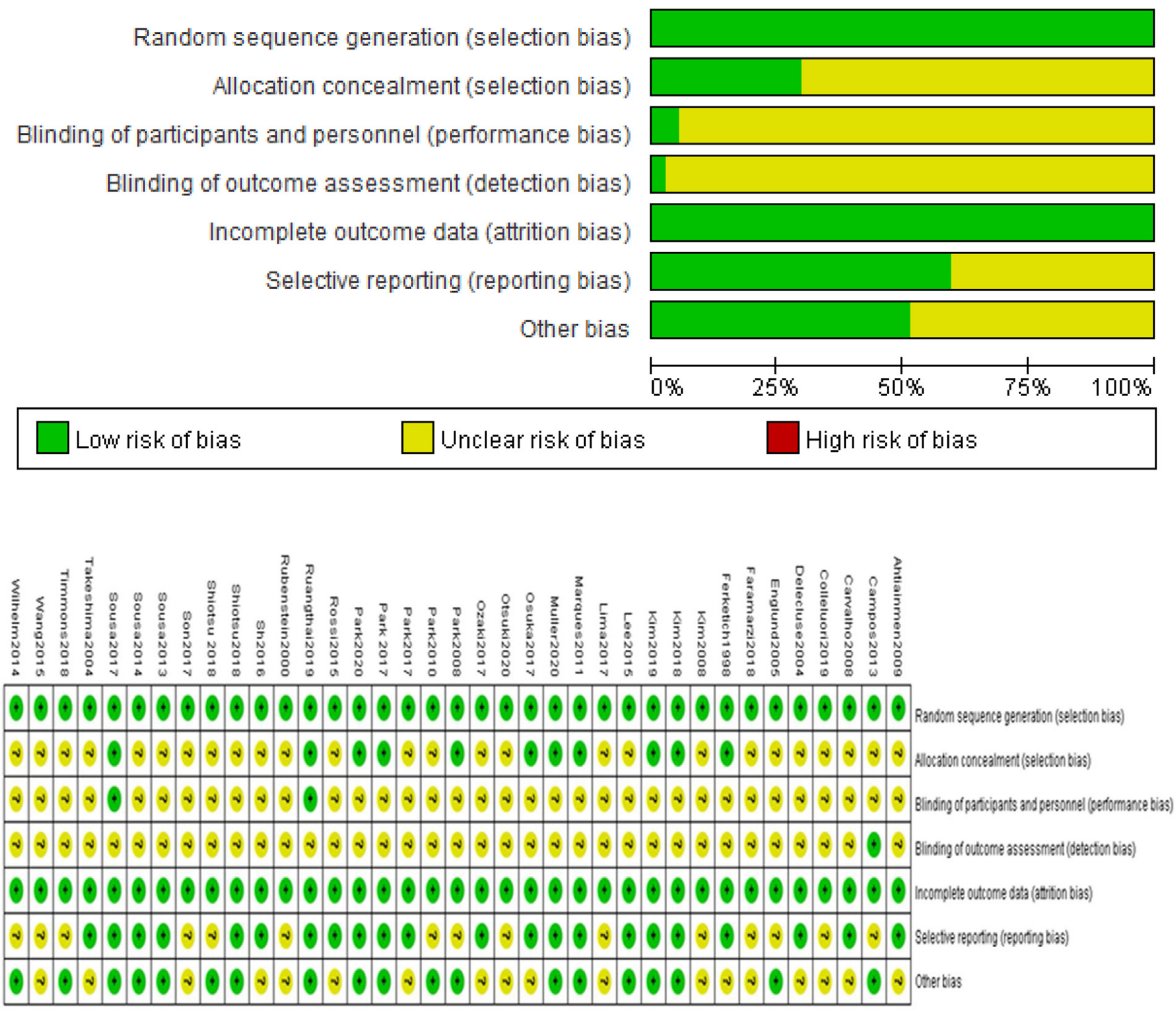

Figure 2 Risk of bias assessment for the included studies.

df = 15), and WHR (WMD = −0.005, 95% CI: −0.013 to 0.002; I^2 = 1.2%, Q = 3.03, df = 3) (P > 0.05; Table 2).

4.3.4. Effect of combined exercise training on blood pressure

Eleven studies explored the changes in SBP and DBP after combined exercise training (Table 2). Studies in this review showed a decrease in SBP of 8.11 mmHg (WMD = −8.11, 95% CI: −12.79 to −3.44; I^2 = 94.6%, Q = 186.81, df = 10, P = 0.001) and DBP of 4.55 mmHg (WMD = −4.55, 95% CI: −8.07 to −1.03; I^2 = 94.7%, Q = 187.33, df = 10, p = 0.011) following combined exercise training. PP was also evaluated by 3 studies in this review but did not demonstrate any significant changes with combined exercise training (WMD = −0.83, 95% CI: −3.29 to 4.95; I^2 = 92.1%, Q = 25.23, df = 2) (P > 0.05).

4.3.5. Effect of combined exercise training on blood lipids and glucose

Eight studies measured fasting blood glucose, 4 studies measured insulin, and 5 studies measured HOMA-IR. Nine, 7, 10, and 8 studies measured triglycerides, blood total cholesterol, HDL, and LDL, respectively (Table 2). The study found that fasting blood glucose (WMD = −0.53, 95% CI: −1.00 to −0.05; I^2 = 67.0%, Q = 21.24, df = 7, P = 0.029), HOMA-IR (WMD = −0.14, 95% CI: −0.24 to −0.05; I^2 = 33.8%, Q = 4.53, df = 3, P = 0.004), and total cholesterol (WMD = −5.32, 95% CI: −9.45 to −1.19; I^2 = 32.6%, Q = 8.91, df = 6, P = 0.011) were significantly lower after combined exercise training. An increase in HDL of 2.32 mmol/L (WMD = 2.32, 95%CI: 0.10 to 4.54; I^2 = 65.5%, Q = 26.22, df = 9, P = 0.040) was noted following combined exercise training. However, combined exercise training had no significant effect on LDL (WMD = −2.47, 95% CI: −10.25 to 5.30; I^2 = 72.1%, Q = 25.09, df = 7, P = 0.533), triglycerides (WMD = −0.16, 95% CI: −0.41 to 0.08; I^2 = 48.1%, Q = 15.4, df = 8, P = 0.182), and insulin (WMD = −0.66, 95% CI: −1.51 to 0.18; I^2 = 83.1%, Q = 23.69, df = 4, P = 0.126).

4.4. Results of subgroup analyses

Table 3 shows the results of the subgroup analyses on measures of physical fitness, body composition, blood pressure, blood lipids and glucose for 3 subcategories: training duration, session lengths, and frequency. The largest

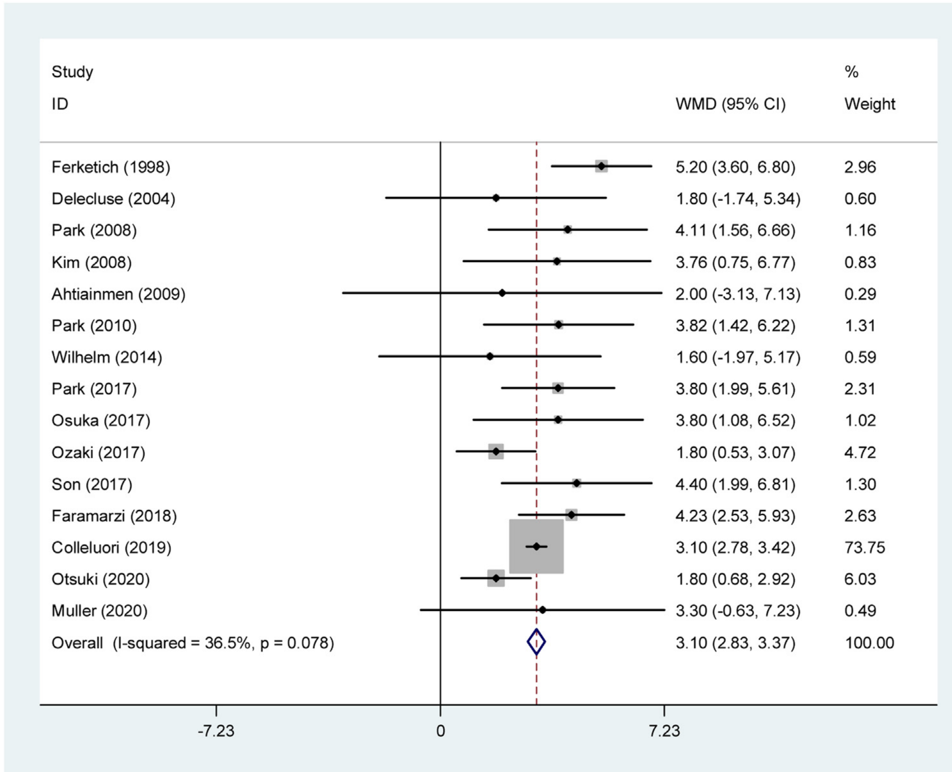

Figure 3 Meta-analysis of the effect of combined training versus no exercise on VO_{2peak}.

effects on measures of VO_{2peak} were found for training durations of > 12 weeks (WMD = 3.12), training frequencies of > 3 sessions/week (WMD = 3.64), and intervention times of > 60 min/session (WMD = 3.84). The largest effects on measures of TUG were found for training durations of > 12 weeks (WMD = −1.19), training frequencies of 3 sessions/week (WMD = −1.62), and intervention times of ≤ 60 min/session (WMD = −1.19). The largest effects on measures of 30-s chair stand were found for training durations of ≤ 12 weeks (WMD = 4.14), training frequencies of 2 sessions/week (WMD = 4.76), and intervention times of ≤ 60 min/session (WMD = 4.90). The largest effects on measures of chair sit and reach were found for training durations of ≤ 12 weeks (WMD = 3.93), training frequencies of 3 sessions/week (WMD = 5.73), and intervention times of ≤ 60 min/session (WMD = 6.38). The largest effects on measures of 6MWT were found for training durations of ≤ 12 weeks (WMD = 43.57), training frequencies of 3 sessions/week (WMD = 45.61), and intervention times of ≤ 60 min/session (WMD = 41.84). The largest effects on measures of arm curl were found for training durations of ≤ 12 weeks (WMD = 7.28), training frequencies of 2 sessions/week (WMD = 6.25), and intervention times of ≤ 60 min/session (WMD = 6.08). The largest effects on measures of grip strength were found for training durations of ≤ 12 weeks (WMD = 5.10), training frequencies of > 3 sessions/week (WMD = 4.21), and intervention times of > 60 min/session (WMD = 4.16). The largest effects on measures of 10-m walk were found for training durations of ≤ 12 weeks (WMD = −0.47), training frequencies of 3 sessions/week (WMD = −0.62), and intervention times of > 60 min/session (WMD = −0.65). The largest effects on measures of maximum walking speed were found for training durations of ≤ 12 weeks (WMD = 0.15), training frequencies of 2 sessions/week (WMD = 0.25), and intervention times of ≤ 60 min/session (WMD = 0.25). The largest effects on measures of one-leg balance were found for training durations of > 12 weeks (WMD = 22.80), training frequencies of 2 sessions/week (WMD = 18.74), and intervention times of ≤ 60 min/session (WMD = 18.74).

The largest effects on measures of fat mass were found for training durations of ≤ 12 weeks (WMD = −2.28), training frequencies of 3 sessions/week (WMD = −2.95), and intervention times of ≤ 60 min/session (WMD = −1.58). The largest effects on measures of BF% were found for training durations of ≤ 12 weeks (WMD = −2.39), training frequencies of > 3 sessions/week (WMD = −2.45), and intervention times of > 60 min/session (WMD = −2.47). The largest effects on measures of BMI were found for training durations of > 12 weeks (WMD = −1.49), training frequencies of 3 sessions/week (WMD = −0.92), and intervention times of > 60 min/session (WMD = −1.19). The largest effects on measures of WC were found for training durations of ≤ 12 weeks (WMD = −3.61), training frequencies of 2 sessions/week (WMD = −3.48), and intervention times of ≤ 60 min session (WMD = −3.28).

The largest effects on measures of blood pressure were found for training durations of ≤ 12 weeks, training frequencies of 3 sessions/week, and intervention times of ≤ 60 min/session. The largest effects on measures of total cholesterol were found for training durations of ≤ 12 weeks (WMD = −10.62), training frequencies of 3 sessions/week

Table 2 Combined results of physical fitness, blood pressure, blood lipid and glucose.

	No. of studies	Heterogeneity test			Effect size		
		Q	I^2 (%)	*P*	WMD	95% CI	WMD P
Physical fitness							
TUG (s)	12	173.63	93.7	0.000	−1.06	−1.66 to −0.46	0.001
30-s chair stand (rps)	11	25.67	61.0	0.004	3.85	2.86 to 4.84	0.000
Sit and reach (cm)	9	42.44	81.2	0.000	4.43	1.84 to 7.02	0.001
6MWT (m)	10	31.06	71.0	0.000	39.22	19.49 to 58.94	0.000
Arm curl (rps)	5	29.27	86.3	0.000	4.60	1.49 to 7.71	0.004
Grip strength (kg)	7	7.67	21.8	0.263	3.65	2.69 to 4.62	0.000
10 m walk (s)	5	4.77	16.1	0.312	−0.47	−0.65 to −0.29	0.000
Maximum walking speed (m/s)	3	5.92	66.2	0.052	0.15	0.01 to 0.29	0.036
One-leg balance (s)	6	5.07	1.3	0.408	2.71	0.72 to 4.71	0.008
Body composition							
Weight (kg)	17	227.5	93.0	0.000	−1.86	−4.14 to 0.41	0.109
Fat mass (kg)	7	58.76	89.8	0.000	−2.91	−5.58 to −0.23	0.033
LM (kg)	16	5.71	0.0	0.984	0.44	−0.25 to 1.12	0.209
BF (%)	21	27.59	27.5	0.119	−2.31	−2.76 to −1.87	0.000
BMI	19	41.41	56.5	0.001	−0.87	−1.35 to −0.40	0.000
WC (cm)	11	12.65	21.0	0.244	−2.91	−4.05 to −1.78	0.000
WHR	4	3.03	1.2	0.386	−0.005	−0.013 to 0.002	0.167
Blood pressure							
SBP (mm Hg)	11	186.81	94.6	0.000	−8.11	−12.79 to −3.44	0.001
DBP (mm Hg)	11	187.33	94.7	0.000	−4.55	−8.07 to −1.03	0.011
PP (mm Hg)	3	25.23	92.1	0.000	0.83	−3.29 to 4.95	0.694
Blood lipids and glucose							
Total cholesterol	7	8.91	32.6	0.179	−5.32	−9.45 to −1.19	0.011
HDL	10	26.11	65.5	0.002	2.32	0.10 to 4.54	0.040
LDL	8	25.09	72.1	0.001	−2.47	−10.25 to 5.30	0.533
Triglycerides	9	15.40	48.1	0.052	−0.16	−0.41 to 0.08	0.182
Glucose	8	21.24	67.0	0.003	−0.53	−1.00 to −0.05	0.029
Insulin	5	23.69	83.1	0.000	−0.66	−1.51 to 0.18	0.126
HOMA-IR	4	4.53	33.8	0.209	−0.14	−0.24 to −0.05	0.004

The data shown are mean ± 95% CI; the size of the plotted squares reflects the statistical weight of each study. WMD: weighted mean differences; TUG: timed up and go; 6MWT: 6-minute walking test; BF%: body fat percentage; BMI: body mass index; LM: lean mass; WC: waist circumference; WHR: waist-to-hip ratio; SBP: systolic blood pressure; DBP: diastolic blood pressure; PP: pulse pressure; HDL: high-density lipoprotein; LDL: low-density lipoprotein.

(WMD = −13.59), and intervention times of > 60 min/session (WMD = −6.53). The largest effects on measures of glucose were found for training durations of ≤ 12 weeks (WMD = −0.57), training frequencies of 3 sessions/week (WMD = −0.72), and intervention times of > 60 min/session (WMD = −0.61). The largest effects on measures of HOMA-IR were found for training durations of ≤ 12 weeks (WMD = −0.14), training frequencies of 3 sessions/week (WMD = −0.15), and intervention times of > 60 min/session (WMD = −0.15). However, the HDL subgroup showed no significant effects.

Significant indices were further analyzed to explore the effect size of combined training between studies, and the exercise prescription with the maximum effect size was traced back to provide the optimal exercise program for the elderly (Table 4). Generally, training prescriptions for health promotion in the elderly comprised training duration ≥ 12 weeks, session ≥ 3/week, aerobic exercise intensity 50—80% VO_{2peak}/60—75% heart rate reserve (HRR), session time ≥ 30 min/session, resistance intensity 70—75% one-repetition maximum (1RM), and 8—12 repetitions × 3 sets.

4.5. Publication bias

Egger's test, developed by Matthias Egger et al. in 1997, was used to assess publication bias to overcome the shortcomings of the funnel method. In practice, one determines the intercept and 95% CI of the linear regression equation and determines if there is publication bias by reviewing whether its 95% CI contains a 0. If the intercept corresponds to $P < 0.05$ or if the 95% CI does not include 0, it indicates publication bias; otherwise, it indicates no publication bias. As shown in Table 5, the *P*-values for VO_{2peak}, TUG, 30-s chair stand, sit and reach, 6MWT, arm curl, grip strength, 10-m walk, maximum walking speed, one-leg balance, weight, fat mass, lean mass, BF%, BMI, WC, WHR, SBP, DBP, PP, total cholesterol, HDL, LDL, triglycerides, glucose, insulin, and HOMA-IR were all greater than 0.05, and the 95% CIs all contained 0. Therefore, no publication bias was noted in the included studies.

Table 3 Results of subgroup analyses (WMD [95% CI]).

	Duration		Frequency			Session length	
	≤ 12 weeks	> 12 weeks	2 sessions/ week	3 sessions/ week	> 3 sessions/ week	≤ 60 min	> 60 min
Physical fitness							
VO_{2peak}	3.02 [2.42, 3.61]	3.12 [2.81, 3.43]	2.78 [1.11, 4.45]	3.05 [2.44, 3.66]	3.64 [2.16, 5.12]	3.21 [2.51, 3.91]	3.84 [2.72, 4.96]
TUG (s)	−1.00 [−1.82, −0.19]	−1.19 [−1.67, −0.70]	−0.53 [−0.90, −0.16]	−1.62 [−2.80, −0.45]	—	−1.19 [−1.90, −0.47]	−0.31 [−0.60, −0.03]
30-s chair stand (rps)	4.14 [3.08, 5.23]	4.08 [3.43, 4.73]	4.76 [3.97, 5.55]	4.19 [3.22, 5.15]	2.12 [0.81, 3.44]	4.90 [4.24, 5.57]	2.31 [1.31, 3.31]
Sit and reach (cm)	3.93 [1.44, 6.42]	4.88 [−1.74, 11.51]	4.66 [−1.47, 10.79]	5.73 [2.03, 9.44]	1.79 [−0.21, 3.79]	6.38 [0.67, 12.09]	3.06 [1.74, 4.39]
6MWT (m)	43.57 [10.71, 76.43]	34.93 [10.12, 59.75]	25.11 [1.79, 48.42]	45.61 [17.90, 73.33]	—	41.84 [17.58, 66.09]	34.98 [−1.14, 71.09]
Arm curl (rps)	7.28 [3.27, 11.29]	3.17 [−0.36, 6.7]	6.25 [0.96, 11.54]	5.72 [3.88, 7.55]	—	6.08 [3.28, 8.87]	2.02 [−2.66, 6.71]
Grip strength (kg)	5.10 [2.69, 7.51]	3.37 [2.32, 4.43]	2.49 [0.73, 4.24]	2.90 [−2.59, 8.39]	4.21 [3.03, 5.40]	2.49 [0.73, 4.24]	4.16 [3.00, 5.31]
10 m walk (s)	−0.47 [−0.65, −0.29]	—	−0.42 [−0.62, −0.21]	−0.62 [−1.00, −0.24]	−1.38 [−3.39, 0.64]	−0.42 [−0.62, −0.21]	−0.65 [−1.02, −0.27]
Maximum walking speed (m/s)	0.15 [0.01, 0.29]	—	0.25 [0.04, 0.46]	0.12 [−0.06, 0.30]	—	0.25 [0.04, 0.46]	0.12 [−0.06, 0.30]
One-leg balance (s)	2.53 [0.52, 4.54]	22.80 [1.72, 43.88]	18.74 [1.68, 35.8]	2.49 [0.48, 4.50]	—	18.74 [1.68, 35.8]	2.49 [0.48, 4.50]
Body composition							
Fat mass (kg)	−2.28 [−3.95, −0.60]	−3.46 [−8.19, 1.27]	−0.30 [−4.67, 4.07]	−2.95 [−5.06, −0.83]	−1.29 [−2.89, 0.32]	−1.58 [−2.98, −0.17]	−2.44 [−5.45, 0.58]
BF (%)	−2.39 [−3.36, −1.43]	−1.84 [−2.56, −1.13]	−1.88 [−3.06, −0.70]	−2.12 [−3.04, −1.21]	−2.45 [−3.67, −1.23]	−2.19 [−2.78, −1.60]	−2.47 [−3.14, −1.81]
BMI	−0.73 [−1.28, −0.18]	−1.49 [−2.32, −0.67]	−0.32 [−1.38,0.73]	−0.92 [−1.53, −0.30]	−1.09 [−2.39, 0.21]	−0.72 [−1.13, −0.31]	−1.19 [−2.15, −0.23]
WC (cm)	−3.61 [−5.25, −1.96]	−2.29 [−3.85, −0.72]	−3.48 [−5.73, −1.23]	−3.23 [−5.14, −1.34]	−2.24 [−4.06, −0.42]	−3.28 [−4.87, −1.69]	−2.53 [−4.15, −0.91]
Blood pressure							
SBP (mm Hg)	−8.42 [−13.91, −2.92]	−6.96 [−14.96, 1.03]	−2.50 [−14.22, 9.22]	−9.40 [−15.27, −3.53]	−5.86 [−12.80, 1.08]	−9.99 [−19.20, −0.78]	−7.34 [−13.34, −1.35]
DBP (mm Hg)	−4.91 [−8.92, −0.89]	−3.29 [−8.27, 1.69]	−2.80 [−11.56, 5.96]	−5.46 [−9.68, −1.24]	−2.03 [−5.60, 1.54]	−4.42 [−8.53, −0.32]	−4.49 [−9.05, 0.08]

Table 3 (*Continued*)

	Duration		Frequency			Session length	
	≤ 12 weeks	> 12 weeks	2 sessions/ week	3 sessions/ week	> 3 sessions/ week	≤ 60 min	> 60 min
Blood Lipids and glucose							
Total cholesterol	−10.62 [−17.32, −3.92]	−2.08 [−7.32, 3.16]	1.7 [−13.49, 16.89]	−13.59 [−21.05, −6.13]	−2.08 [−7.32, 3.16]	1.05 [−9.28, 11.38]	−6.53 [−11.03, −2.03]
HDL	2.31 [−0.48, 5.11]	2.24 [−0.96, 5.44]	0.70 [−6.13, 7.53]	0.98 [−1.48, 3.44]	5.01 [−0.27, 10.30]	0.82 [−2.16, 3.79]	3.71 [0.65, 6.76]
Glucose	−0.57 [−1.13, −0.02]	−0.31 [−1.00, 0.38]	0.04 [−0.57, 0.64]	−0.72 [−1.34, −0.10]	−0.93 [−1.86, 0.00]	−0.47 [−1.32, 0.37]	−0.61 [−1.03, −0.18]
HOMA-IR	−0.14 [−0.24, −0.05]	−	0.0 [−0.39, 0.39]	−0.15 [−0.25, −0.05]	−	−0.01 [−0.37, 0.35]	−0.15 [−0.25, −0.05]

5. Discussion

In the current context of the COVID-19 pandemic, high BF% is a major risk factor for severe forms of COVID-19 infection [47]. Obesity is associated with an increased susceptibility to infections, and there is an increased risk of comorbidities and mortality associated with increased BMI. Social isolation can also worsen lifestyle behaviors and result in much lower levels of activity or even complete immobilization, which may greatly accelerate the loss of muscle mass and function, which favors weight gain and adversely affects cardiovascular health in adults. Furthermore, some governmental recommendations on social isolation have advised stringency in older adults, who are deemed clinically vulnerable, meaning that physical fitness in this group may even be further reduced compared to the general population. Therefore, it is crucial to explore the effects of combined training at home on physical function, body composition, and cardiometabolic parameters in older adults. The main findings of this study indicated that combined training significantly improved physical fitness, body composition, and cardiometabolic risk factors in older adults and had notable benefits for cardiovascular health.

5.1. Effects of combined training on measures of physical fitness

Physical fitness levels have been analyzed by the American College of Sports Medicine, and in cases of its reduction or decline, the effects of aging accelerators are implicated [6]. The importance of maintaining physical fitness through regular exercise needs to be better understood in its dimensions; thus, it can be properly recognized as an essential activity to health and an excellent strategy considering its positive effects on cardiovascular, metabolic health. Further, older adults have been identified as the most vulnerable age group for COVID-19 infection. Improved physical function can reduce the risk of infection and improve health in older people.

Our data showed that combined training improved physical fitness in 6MWT, 30-s chair stand, chair sit and reach, arm curl, grip strength, maximum walking speed, one-leg balance, 10-m walk, and TUG. Changes in muscle strength and endurance were associated with increased physical function and independence during activities of daily living. The meta-analysis by Chaabene et al. was consistent with the results of this study [11]. They found that home-based exercise could improve components of health-related (e.g., muscle strength) and skill-related physical fitness (e.g., balance) in older adults.

The 6MWT is an indicator of muscle endurance that is associated with the functional capacity to perform various activities of daily living [48]. A meta-analysis by Hurst et al. showed that the combined training group demonstrated increased 6MWT (by 29.6 m) compared with the control group [10]. However, the improvement noted with 6MWT was better in our study (39.22 m), which may have been caused by the difference in the considered populations. Our study mainly included the elderly over 60 years of age, while Hurst et al. mainly included adults over 50 years of age. Muscle strength begins to decline around age 30 and at a rate of about 12—15% per decade after the fifth decade, and even faster rate after 60 years [49]. Our study showed that 30-s chair stand and arm curl increased by 3.85 and 4.60 repetitions, respectively, after combined training. Regarding flexibility and combined training, the chair sit and reach was significantly improved (by 4.43 cm). This indicates that the mechanical stimulation of the joints was more effective in combined training. Combined training can significantly improve the one-leg balance of the elderly. The balance time increased by 2.71 s, suggesting that the improved balance was due to increased muscle strength. These results indicate that combined training can significantly improve muscular strength, flexibility, and balance function in the elderly, and this can reduce fall risk and promote functional

Table 4 Optimal exercise prescription for each index.

	Optimal exercise prescription
VO_{2peak}	12 weeks, 3 days a week, aerobic exercise 30 min, exercise intensity 70—80%VO_{2peak}; Resistance exercise intensity 80% 1-RM, 10 Reps *2 set
30-s chair stand	12 weeks, 4 days a week (2 aerobic and 2 resistance), 45—60 min, aerobic exercise intensity 50% VO_{2peak}, resistance intensity 70% 1-RM, 12 Reps*3 set
Sit and reach	32 weeks, 3 days a week (1 aerobic and 2 resistance), aerobic intensity moderate, 40 min; resistance intensity 70% of 1-RM, 8—10 Reps * set
TUG	6 weeks, 3 days a week, resistance training followed by aerobic training, 30 min, aerobic intensity 60%—65% HRmax, resistance training 8—10 Reps *3 set
6MWT	12 weeks, 3 days a week, resistance training followed by aerobic training, 30 min, aerobic intensity 70%—75% HRmax, resistance intensity 50%—75% 1-RM
Arm curl	12 weeks, 4 days a week (2 aerobic and 2 resistance), 45—60 min, aerobic exercise intensity 50% VO_{2peak}, resistance intensity 70% 1-RM, 12 Reps*3 set
Grip strength	12 weeks, 4 days a week, aerobic training followed by resistance training, aerobic intensity 65%—75% HRR, 30 min; resistance intensity 75%1-RM, 8—12 Reps* 3 set
10 m walk	12 weeks, 4 days a week, aerobic training followed by resistance training, aerobic intensity 65%—75% HRR, 30 min; resistance intensity 75%1-RM, 8—12 Reps* 3 set
Maximum walking speed	12 months, 2 days a week, 50 min
One-leg balance	12 months, 2 days a week, 50 min
Fat mass	10 weeks, 3 days a week, resistance training followed by aerobic training, resistance intensity 50%—60%1RM, 15—20 Reps*9 set; aerobic training 30 min
BF	12 weeks, 4 days a week, aerobic training followed by resistance training, aerobic intensity gradually increases to 65%—75% HRR, 30 min; resistance intensity 75%1-RM, 8—12 Reps* 3 set
BMI	12 weeks, 3 days a week, resistance training followed by aerobic training, intensity gradually increases to 60%—70% HRR, resistance training 40 min, aerobic training 30 min
WC	12 weeks, 4 days a week, aerobic training followed by resistance training, aerobic intensity gradually increases to 65%—75% HRR, 30 min; resistance intensity 75%1-RM, 8—12 Reps* 3 set
SBP	9 months, 3 days a week (2 aerobic and 1 resistance), aerobic intensity moderate, 1 land environment and once a week in an aquatic environment, 40 min; resistance intensity gradually increases to 75% 1RM, 8—10 Reps* 3 set
DBP	9 months, 3 days a week (2 aerobic and 1 resistance), aerobic intensity moderate, 1 land environment and once a week in an aquatic environment, 40 min; resistance intensity gradually increases to 75% 1RM, 8—10 Reps* 3 set
Total cholesterol	12 weeks, 3 days a week, aerobic training followed by resistance training, 70 min, aerobic intensity RPE 12—13, resistance training 12—15 Reps *1 set
HDL	12 weeks, 4 days a week, aerobic training followed by resistance training, aerobic intensity 65%—75%HRR, 30 min; resistance intensity 75%1-RM, 8-12 Reps *3 set
Glucose	6 weeks, 3 days a week, 90 min, training intensity moderate, resistance training: 12—15 Reps * 1—3 set; aerobic training: Sky-walk 5 min *2 set, Cross-country 5 min*2 set
HOMA-IR	6 weeks, 3 days a week, 90 min, training intensity moderate, resistance training: 12—15 Reps * 1—3 set; aerobic training: Sky-walk 5 min *2 set, Cross-country 5 min*2 set

independence. Improved grip strength is particularly important in older adults, and a weak grip strength has been shown to significantly predispose to increased recurrent falls and fractures. Combined training significantly improved grip strength of the elderly by 3.65 kg. This means that combined training increases grip strength and reduces the risk of recurrent falls and fractures, helping to improve the quality of life for older adults.

Studies have shown that a reduction of 0.8—1.4 s in TUG significantly improves clinical function [50], and even a small improvement in TUG can reduce fall risk. The current study found that combined training significantly reduced TUG of the elderly by 1.06 s. When the gait speed was greater than 0.82 m/s, the mortality rate of the elderly was nearly 20% lower than that of those with moderate gait speed, and the survival rate of the elderly was highest when the gait speed exceeded 1.36 m/s [51]. A longitudinal study showed that every 0.10 m/s decrease in the gait speed of the elderly led to a decreased health status, decreased exercise ability, increased outpatient visits, and increased medical expenses [52]. However, a 1.36 m/s increase in gait speed may lead to reduced medical expenses. The current study found that 10-m walk time was decreased by 0.47 s and maximum walking speed was increased by 0.15 m/s in the elderly after combined training, indicating that combined training could improve their health status by improving their walking speed. Moreover, athletic ability increased, with decreased medical expenses. Considering these, physical exercise during the COVID-19 pandemic is essential to maintain physical fitness, aiding in muscle endurance, muscular

Table 5 Test for publication bias of each indicator.

Variable	β	Standard error	T	P > |t|	[95% conf. interval]	
VO_{2peak}	0.23	0.45	0.50	0.63	−0.75	1.20
TUG	−3.67	3.40	−1.08	0.31	−11.23	3.90
30-s chair stand	−1.13	1.22	−0.93	0.38	−3.89	1.63
Sit and reach	1.12	2.29	0.49	0.64	−4.29	6.52
6MWT	7.11	6.01	1.18	0.27	−6.74	20.96
Arm curl	3.02	5.59	0.54	0.63	−14.78	20.81
Grip strength	0.68	0.85	0.80	0.46	−1.50	2.87
10 m walk	−1.18	1.27	−0.93	0.42	−5.21	2.86
Maximum walking speed	2.72	4.94	0.55	0.68	−60.04	65.49
One-leg balance	0.82	0.35	2.36	0.08	−0.15	1.79
Weight	1.07	1.15	0.93	0.37	−1.39	3.53
Fat mass	−7.58	0.91	−8.30	0.00	−9.92	−5.23
LM	0.44	0.62	0.72	0.49	−0.88	1.76
BF%	0.51	0.53	0.96	0.35	−0.60	1.61
BMI	1.00	0.73	1.36	0.19	−0.55	2.54
WC	−0.49	0.91	−0.53	0.61	−2.55	1.57
WHR	−0.89	0.83	−1.08	0.39	−4.44	2.66
SBP	2.33	1.88	1.24	0.25	−1.93	6.59
DBP	4.06	1.78	2.28	0.05	−0.04	8.12
PP	1.39	5.85	0.24	0.85	−73.00	75.78
Total cholesterol	−0.21	0.99	−0.21	0.84	−2.75	2.34
HDL	0.81	0.96	0.84	0.42	−1.41	3.03
LDL	0.84	1.49	0.57	0.59	−2.79	4.48
Triglycerides	−0.81	0.67	−1.22	0.26	−2.39	0.77
Glucose	−1.32	0.76	−1.73	0.13	−3.18	0.54
Insulin	−0.28	1.10	−0.26	0.81	−3.77	3.20
HOMA—IR	−0.49	1.08	−0.46	0.69	−5.12	4.14

TUG: timed up and go; 6MWT: 6-minute walking test; BF%: body fat percentage; BMI: body mass index; LM: lean mass; WC: waist circumference; WHR: waist-to-hip ratio; SBP: systolic blood pressure; DBP: diastolic blood pressure; PP: pulse pressure; HDL: high-density lipoprotein; LDL: low-density lipoprotein.

strength, flexibility, balance and improvement of several physical variables. It also promotes a better quality of life and general health, in addition to reducing the risk of cardiovascular and metabolic diseases at any time, including during the COVID-19 pandemic [53]. The recommended exercise parameters noted in this study for improving physical function were duration ≤ 12 weeks, session 2—3/week, and session time ≤ 60 min.

Our results provide a significant update to the current understanding of the effects of combined aerobic and resistance training. We confirmed the positive effects of combined training on cardiorespiratory and functional fitness reported in previous meta-analyses and extended these findings by showing benefits for body composition, physical fitness, and cardiovascular risk factors. The present review showed that combined training VO_{2peak} increased by 3.10 mL/kg/min when compared to no-exercise controls. Hurst et al. showed that compared with the inactive group, combined training had a moderate effect on VO_{2peak} in middle-aged and elderly people over 50 years, with an increase of 3.6 mL/kg/min [10]. A meta-analysis by Scapini et al. also showed that combined training significantly increased VO_{2peak} in patients requiring hemodialysis for end-stage renal disease (WMD = 5.00, 95% CI: 3.50 to 6.50) [54]. These research results are basically consistent with our findings, indicating that combined training is important for improved cardiorespiratory fitness. Combined training is considered effective for improving VO_{2peak} in the elderly. However, the mechanism contributing to increased VO_{2peak} is unclear. The studies suggest that combined exercise can significantly improve cardiac ejection fraction, which is an indicator of cardiac systolic function and is correlated with VO_{2peak}. This may be one of the mechanisms by which combined training improves VO_{2peak}. Furthermore, improved lower body strength may lead to increased time to exhaustion on an incremental exercise test, thereby increasing observed VO_{2peak}. Thus, the recommended exercise parameters for improving VO_{2peak} are duration > 12 weeks, session > 3/week, and session time > 60 min. These findings are consistent with the exercise prescription recommended by the American College of Sports Medicine.

5.2. Effects of combined training on measures of body composition

In the current context of the COVID-19 pandemic, high BF% and increased body weight are major risk factors for severe forms of COVID-19 infection, and a high proportion of patients with obesity demonstrate an increased risk of complications and mortality in intensive care units [55]. With age, body weight and BF% gradually increase, while lean body mass decreases. These changes in body composition lead to weakness, muscle loss, and metabolic syndrome. The current study found that combined training significantly reduced fat mass, BF%, BMI, and WC in the elderly by 2.91 kg, 2.31%, 0.87 kg/m^2, and 2.91 cm, respectively. Thus, physical exercise can prevent negative changes in the body composition of older adults. Although most studies suggest that combined training can also significantly reduce body weight and WHR and increase lean mass in the elderly, the results of this meta-analysis show that body weight and WHR tended to decrease and lean mass tended to increase after combined training, but non-significantly. A meta-analysis showed that aerobic training plus resistance training improved body composition (fat mass, body weight, and BMI), which is basically consistent with our results [56]. Yarizadeh et al., in their studies, showed that combined training significantly reduced subcutaneous abdominal adipose tissue by 28.82 cm^2 (WMD = −28.82, 95% CI: −30.83 to −26.81), which is not consistent with our results [57]. Since the studies were conducted using different measurement indicators (studies with adipose tissue volume, WC, and weight), it is possible that their results varied because of this issue. Therefore, the changes in body composition we observed may have resulted from combined training, especially because resistance exercise induced muscle protein synthesis in the combined training group. Thus, the recommended exercise parameters for improving BF% are duration ≤ 12 weeks, session > 3/week, and session time > 60 min.

5.3. Effects of combined training on cardiometabolic risk factors

Cardiometabolic disorders are among the most important chronic underlying conditions worsening COVID-19 outcomes [58]. Among them decreased HDL and increased LDL increase cardiovascular disease risk because the components of LDL-cholesterol are more readily oxidized and have greater accumulation in arterial walls, while HDL-cholesterol carries cholesterol in the reverse direction. This study found that total cholesterol (WMD = −5.32, 95% CI: −9.45 to −1.19) was significantly decreased and HDL was significantly increased by 2.32 mmol/L after combined training. Triglycerides and LDL were not significantly affected. Generally, decreased total cholesterol and increased HDL are associated with a lower risk of cardiovascular disease. In addition, improvements in the lipid profile due to combined training may depend on loss of fat mass. Moreover, Sillanpaa et al. study found that HDL was negatively correlated with body weight, BMI, WC, and BF%. During combined training groups, however, the reduction in fat mass, BMI, BF% and WC were related to increased HDL, which emphasizes the influence of concomitant body composition changes during combined aerobic and resistance training on blood lipids.

Eight of the current studies described changes in blood glucose, with 5 measuring insulin and 4 measuring HOMA-IR. Although studies suggested that 12-week combined training significantly reduced insulin and HOMA-IR [20], our meta-analysis found that combined training significantly reduced blood glucose and HOMA-IR by 0.53 mmol/L and 0.14 mmol/L, respectively, but had no significant effect on insulin content. The mechanisms are likely related to the reductions in body fat, improvements in muscle oxidative capacity, decreases in muscle lipid content, and increases in whole-body rates of fat oxidation and turnover. Moreover, in this study, body composition (BMI, WC, fat mass, and BF%) were correlated at baseline with blood glucose and HOMA-IR. Our results are more reliable because it considered several studies. Thus, the recommended exercise parameters for improving cardiometabolic risk factors are duration ≤ 12 weeks, session 3/week, and session time > 60 min.

A reduction in systolic blood pressure (< 5 mmHg) has been shown to reduce cardiovascular disease risk. A study suggested that the maintenance of the SBP reductions of 2 mmHg would result in a 6% reduction in mortality due to cerebrovascular accidents and a 4% reduction in mortality due to coronary artery disease [59]. A previous study with a longer term and larger population revealed that a reduction of 10.4 mmHg in SBP in older adults was associated with a 13% reduction in overall mortality, 18% reduction in chronic heart disease-related death, and 26% reduction in stroke [60]. The current study showed that combined training significantly reduced SBP in the elderly by 8.11 mmHg. This suggests that combined training can consistently reduce the risk of SBP, chronic heart disease-related death, and stroke. DBP was less responsive than SBP, although it showed significant reductions after combined training. There was no significant effect on PP. The mechanism of reduced atherosclerosis has been suggested to cause the reduction in SBP. In this context, the present study suggests that a decrease in SBP may reduce atherosclerosis in the elderly. The decreased blood pressure may be because combined training enhances endothelial-dependent dilation, which reduces peripheral arterial resistance and vascular tone and helps to reduce SBP and DBP. Thus, the recommended exercise parameters for improving blood pressure are duration ≤ 12 weeks, session 3/week, and session time ≤ 60 min.

5.4. Study limitations

First, since the intensity of aerobic and resistance training described in various studies is different, it was impossible to determine the influence of training intensity and amount on the effect of combined training. Second, only differences in physical function, body composition, and cardiometabolic risk factors between combined training and the control groups were compared, and no differences between combined training and aerobic or resistance training are shown.

6. Conclusions

Combined training is effective for improving VO_{2peak}, physical fitness, and several cardiometabolic risk factors such as fat mass, BF%, BMI, WC, SBP, DBP, total cholesterol, HDL, glucose, and HOMA-IR in older adults. Considering COVID-19, a combination of aerobic and resistance training can result in significant, positive, physiological adaptations that improve cardiometabolic health and reduce the development and progression of disease-related risk factors in adults. The training parameters for promoting the health of older adults comprised the following: duration ≥ 12 weeks, session ≥ 3/week, aerobic exercise intensity

50–80%VO_{2peak}/60–75% HRR, session time ≥ 30 min, and resistance intensity 70–75% 1RM, 8–12 repetitions × 3 sets. To improve physical function, the optimal training parameters were duration ≤ 12 weeks, session 2–3/week, and session time ≤ 60 min. To improve body composition, the optimal training parameters comprised duration ≤ 12 weeks, session > 3/week, and session time > 60 min. Regarding blood glucose and lipid improvement, the optimal training parameters included duration ≤ 12 weeks, session 2–3/week, and session time ≤ 60 min. For blood pressure improvement, the optimal training parameters were duration ≤ 12 weeks, session 3/week, and session time ≤ 60 min. The parameters presented in this investigation should help practitioners and clinicians make informed decisions relating to future training prescriptions in older adults. Future studies investigating intensity, length of individual training sessions, combined type, or order in older adults are needed.

Disclosure of interest

The authors declare that they have no competing interest.

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Ethics approval and consent to participate

This study is a systematic review and does not involve ethical consent.

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