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Effect of Home-Based Exercise and Influence of Training Principles on Cardiorespiratory Fitness in Sedentary Healthy People and Patients With Cardiovascular Disease: A Systematic Review With Meta-Analysis

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ABSTRACT

The effectiveness of home-based exercise programmes may vary depending on compliance to exercise training principles. Therefore, the aim of this review was to investigate the effect of unsupervised home-based exercise programmes on cardiorespiratory fitness (CRF) in healthy sedentary individuals and patients with cardiovascular disease (CVD) taking into account the influence of exercise training principles. PubMed, Embase and Web of Science were searched up to July 2025. Controlled studies that performed a home-based aerobic training or combined training, and directly measured peak oxygen uptake (VO_2 peak) were included. The mean difference (MD) with its 95% confidence interval (CI) was used as the effect size index. Random-effects models were used to conduct pooled analyses. Heterogeneity analyses were performed using the chi-square test and the I^2 index. The results showed an improvement in the VO_2 peak in the intervention group compared to the control group (MD = 2.70 mL·kg^{-1}·min^{-1} [CI = 1.78, 3.62] $p < 0.001$), with no difference between healthy participants and patients with CVD. Heterogeneity tests reached statistical significance ($p < 0.001$), and inconsistency was high ($I^2 = 85\%$). We found a greater improvement in VO_2 peak in favour of the intervention group in those studies that met the overload principle and in those which used the ventilatory threshold-based method for determining aerobic training intensity in healthy sedentary people and patients with CVD. Overload and individualisation principles should be considered for increasing the effect of unsupervised home-based exercise training on VO_2 peak.

Trial Registration: The study protocol was prospectively registered in the PROSPERO database (CRD42024516257)

1 | Introduction

A sedentary lifestyle and lack of physical activity are major modifiable risk factors for the development of cardiovascular disease (CVD) and mortality (Lavie et al. 2019), and CVD remains one of the leading causes of death and disease worldwide (Go et al. 2014; Jones and Greene 2013; Lackland et al. 2014). Current guidelines recommend exercise training for rehabilitation in patients with CVD (McGuire 2011; Pearson et al. 2002; Smith et al. 2011), as exercise induce favourable changes in biomarkers and cardiorespiratory fitness (CRF) (Lin et al. 2015). CRF, commonly assessed by peak oxygen uptake (VO_2 peak) (Dalleck and Dalleck 2008), reflects the ability of the respiratory and cardiovascular systems to deliver oxygen to muscles during sustained exercise (Lin et al. 2015), which has been identified as an independent predictor of CVD risk (Lin et al. 2015), overall mortality

Highlights

- Home-based exercise improves VO_2 peak in healthy individuals and patients with CVD.
- Overload principle enhances the effects of unsupervised exercise training.
- Prescribing according to ventilatory thresholds improves VO_2 peak more effectively.
- Limited information on compliance to FITT components limits interpretation.
- Aerobic and combined training offer similar improvements in cardiorespiratory fitness.

(Kodama et al. 2009; D. C. Lee et al. 2011), and health status (Grant et al. 2013).

There are several types of exercise training programmes that are effective in improving CRF. Aerobic training, the most used exercise modality, includes low-intensity aerobic training (LIT)—for example, 60 min of aerobic exercise performed at intensities below 64% of maximum heart rate (HR)—and moderate-intensity aerobic training (MIT), such as 30–60 min of aerobic exercise at 64%–76% of maximum HR (Bishop et al. 2024), both effective for improving aerobic capacity (Fletcher et al. 2001) in sedentary individuals and patients with CVD (Manresa-Rocamora, Ribeiro, et al. 2021; Manresa-Rocamora, Sarabia, et al. 2021). In the same line, high-intensity aerobic training (HIT), characterised by intensities ≥ 77% of maximum HR and session durations of approximately 30 min (Bishop et al. 2024), has been shown to produce rapid and substantial improvements in CRF in healthy individuals and patients with CVD (Blackwell et al. 2018; Wen et al. 2019). Furthermore, combined aerobic and resistance training (i.e., combined training) provides additional benefits by improving both aerobic capacity and muscle strength in healthy individuals and patients with CVD (J. Lee et al. 2020; Schumann et al. 2022). Cardiac rehabilitation and regular exercise-based programmes improve CRF in patients with coronary artery disease (CAD), chronic heart failure (CHF) and sedentary individuals (Piepoli et al. 2004; Taylor et al. 2004; Warburton et al. 2006), and evidence suggest that the intensity and duration required to improve CRF do not differ substantially between sedentary individuals and patients with CVD (Wen et al. 2019; Yue et al. 2022). Improvements in VO_2 peak are achieved through specific physiological adaptations. More precisely, patients with CAD have shown improved coronary perfusion, increased peripheral oxygen extraction capacity, improved endothelial function (Hambrecht et al. 2000), increased myocardial efficiency (Redwood et al. 1972) and reduced myocardial oxygen demand (Bowles and Laughlin 2011). In patients with CHF, exercise training increases cardiac output, improves skeletal muscle oxidative capacity (Belardinelli et al. 1995), reduces peripheral vascular resistance (Coats et al. 1992) and improves endothelial function (Fuertes-Kenneally et al. 2023). In healthy sedentary individuals, regular physical exercise increases both cardiac cavity volume and wall thickness (Pluim et al. 2000), reduces resting heart rate (HR resting) and improves coronary circulation.

Although the efficacy of exercise training programmes for improving CRF has been widely reported, there is evidence showing high heterogeneity in the individual response to exercise training (Manresa-Rocamora, Sarabia, et al. 2021). In this regard, the application of exercise training principles (i.e., overload, progression, individualisation, periodisation and specificity) is essential to maximise the benefits of any exercise programme aimed at improving CRF (Fleck and Kraemer 2014). The overload principle aims to expose tissues to higher levels of training stress than they are used to. In addition, progressive overload ensures a gradual increase in exercise volume and intensity to avoid plateaus in progress and reduce the risk of injury (Kasper 2019). Individualisation takes into account individual differences in abilities and needs, thus optimising each person's results (Kasper 2019). Periodisation deals with the deliberate and systematic modification of training variables over time (Kasper 2019) based on specific models ('American College of Sports Medicine position stand. Progression models in resistance training for healthy adults,' 2009). Specificity involves selecting exercises that specifically improve the relevant component for a particular task and type of fitness (i.e., strength, power, endurance or flexibility) (Kasper 2019). Finally, reversibility proposes that once a training stimulus is removed, fitness levels will decrease. They will eventually return to their initial values (Kasper 2019). On the other hand, exercise programme prescription based on the FITT (frequency, intensity, time and type of exercise) components and participants' compliance to that prescription should be properly reported (Medicine 2013) to determine the exercise-induced effect on CRF. FITT describes the components of exercise training programmes that influence physical fitness. In addition, participants' compliance to each of the prescribed FITT components must be reported to show the actual dose administered (i.e., performed exercise) (Campbell et al. 2012).

Applying these training principles may be more challenging in unsupervised home-based exercise programmes (i.e., there is no instructor present to guide each session (Mañas et al. 2021)) than in supervised programmes, which may partly explain why supervised exercise programmes tend to induce greater improvements in CRF (Bigot et al. 2019), even though they are home-based exercise training programmes. However, the efficacy of home-base exercise training for improving wellbeing (Warburton et al. 2006) and cardiovascular health (Buckingham et al. 2016) has been proven. The effectiveness of unsupervised exercise programmes may vary depending on compliance to exercise training principles. Understanding how these principles are applied and their impact on the exercise-induced effect on CRF may provide valuable information for designing more effective interventions. In this context, compliance to training principles refers to whether programmes applied sufficient relative intensity and progression, tailored exercise to individual capacity, aligned exercise mode with the targeted cardiorespiratory outcome and structured load over time. Therefore, the aim of this review was to investigate the effect of unsupervised home-based exercise programmes on CRF in healthy sedentary individuals and patients with CVD while taking into account the influence of exercise training principles.

2 | Method

The current systematic review with meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (Page et al. 2021), and the study protocol was prospectively registered in the PROSPERO database (CRD42024516257).

2.1 | Data Search and Sources

We conducted a comprehensive search of Pubmed, Embase and Web of Science (i.e., core collection) databases from their earliest records to July 2025 to identify relevant studies. Free-text terms based on the PIO (participants, intervention and outcomes) strategy were searched. No language restrictions were applied during this phase. The electronic search strategy for each individual database was adjusted as necessary (see Electronic Supplementary Material [ESM]). Moreover, we manually reviewed previous systematic reviews and the references of included studies to identify additional relevant studies. Finally, we emailed the authors of selected studies to identify unpublished or ongoing studies that met our selection criteria.

2.2 | Study Selection

The eligibility criteria were established in accordance with the PICOS (participants, intervention, comparison, outcomes and study design) guideline as follows: (a) Participants: Sedentary healthy individuals and patients with CVD (i.e., CAD and CHF) regardless of sex, and aged $\geq$ 18 years; (b) Interventions: Unsupervised home-based (i.e., interventions carried out without concurrent professional guidance, excluding both face-to-face interaction and real-time remote monitoring); aerobic training or combined training lasting at least 8 weeks. Studies that included a familiarisation period of supervised exercise lasting up to 1 week were also included; (c) Comparisons: Nonexercise control groups. Studies permitting participants allocated to the control group to maintain their usual levels of physical activity were included; (d) Outcomes: VO_2 peak (primary outcome) and/or oxygen uptake at the first ventilatory threshold (VO_2 VT1) (secondary outcome); (e) Study design: Randomised and nonrandomised controlled studies. Studies written in English or Spanish were eligible for inclusion. The inclusion of studies with multiple articles based on the same sample population was restricted to the original publication.

Two authors independently conducted the study selection process. Disagreements were resolved through consensus. When necessary, a third author assessed the study to reach an agreement.

2.3 | Data Extraction and Coding Study Characteristics

Two authors utilised a standardised data extraction form to code the characteristics of the included studies. In case of disagreement, a third author was consulted. The following information was extracted: (a) Study characteristics (i.e., journal, publication year, study design [randomised or nonrandomised], country and sample size); (b) Participant characteristics (i.e., health status [healthy participants, CAD, or CHF], sex [males, females and mixed sample], male percentage, age, body mass, body mass index, HR resting and VO_2 peak at baseline); (c) Intervention characteristics (i.e., exercise type, aerobic training method [LIT, MIT or HIT], exercise mode, intervention duration, training frequency, aerobic and resistance intensity methods, training control device and sessions details); (d) Exercise test characteristics (i.e., exercise mode); and (e) Statistical information (e.g., mean and standard deviation).

2.4 | Exercise Training Principles and FITT Components

Two reviewers independently classified these principles according to the established criteria (Table 1). Disagreements were resolved by consensus or consultation with a third reviewer. The principles were judged as follows: (a) Informed/Applied (+); (b) Uninformed/Not applied (−); and (c) Unclear (?) (Stassen et al. 2022). Each principle classified as informed/applied (+) received a score of ‘1’, whereas those classified as uninformed/not applied (−) or unclear (?) received a score of ‘0’. In addition, for the individualisation principle, three levels of individualisation were established as follows: (a) Level 1, prescribing exercise intensity as a percentage in relation to the percentage of maximal HR or VO_2 peak (i.e., HR/VO_2 peak percentages) (percentage-based method); (b) Level 2, prescribing exercise intensity as a percentage in relation to HR reserve or oxygen uptake reserve (i.e., HR/VO_2 reserve percentages) (percentage of reserve-based method); and (c) Level 3, prescribing exercise intensity by the use of metabolic thresholds (ventilatory-threshold method) (Mann et al. 2013). In this case, the value of the level was added. Therefore, individualisation principle ranged from 0 (no individualisation) to 4 (maximal level of individualisation) points. The scores obtained were summed for each study, and the percentages of intervention descriptions that informed/applied each principle were calculated relative to the total number (Stassen et al. 2022). More detailed information on the exercise training principles can be found in the ESM.

The criteria used to assess the application of the components of exercise training prescription are shown in Table 2. The reporting of each of the four FITT components and participants' compliance were judged as documented (+), not reported (NR) or unclear/inconsistent (?).

2.5 | Methodological Quality Assessment

The methodological quality of the included studies was assessed using the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) scale (Smart et al. 2015). This scale comprises 12 items, with a maximum score of 15 points. However, one point was removed from Item 8 because only one endpoint was included in our review. The specific criteria utilised for conducting the methodological quality assessment are detailed in Supporting Information S1: Table S1 (see ESM). The

TABLE 1 | Exercise training principles.

Principle	Criteria for this review	Example
Overload: For a training programme to lead to improvements, it must exceed the current limits of what you are accustomed to.	The training protocol provided information related to sufficient intensity in relation to their initial physical condition.	Person with low physical condition should walk at 60% of HR max.
Progression: Gradually and systematically increasing training stress to sustain tissue strain and stimulate ongoing training adaptation.	The programme described a progression of training variables (i.e., frequency, intensity and volume).	A walking intervention 3×/week at 65% of HR max for 20 min, adds 10 min/week over 8 weeks.
Individualisation: Adjust the training programme to fit the person's unique ability and response.	The programme describes the exercise prescription according to the relative intensity of cardiovascular or metabolic stress.	A walking intervention at 65% of HR max (Bourg score 12) for 20 min.
Periodisation: Deliberate and systematic variation of a training programme over time using microcycles, mesocycles and macrocycles.	The programme describes and names the most common periodisation models based on volume and intensity (e.g., linear, inverse and undulating periodisation).	An 8-week walking intervention follows a linear periodisation during the programme.
Specificity: Specific movement patterns and intensities relevant to a particular task and type of fitness (strength, power, endurance or flexibility).	The relevance for the target population and intervention, depending on the primary and secondary outcome being addressed.	Aerobic training such as brisk walking is considered more suitable for improving cardiovascular fitness compared to flexibility training.
Reversibility: The removal of the exercise stimulus leads to the loss of beneficial fitness and performance adaptations.	Follow-up assessments were conducted on the participants who decreased or discontinued exercise training after the conclusion of the intervention.	Participants who maintained training after an exercise intervention preserved VO_2 peak, whereas those who stopped exercising returned to baseline.

Abbreviations: HR max, maximal heart rate; min, minutes; VO_2 peak, peak oxygen uptake.

TABLE 2 | Criteria for this review on components applied to exercise training prescription (FITT).

Component	Description	Compliance
Frequency	Refers to how often an exercise or activity is performed, typically measured in sessions, episodes or bouts per week.	Studies reported the number or percentage of exercise sessions attended
Intensity	Indicates the amount of effort or work required to perform an activity or exercise.	Studies reported the intensity of exercise achieved during the sessions
Time	The duration or length of time an activity or exercise is performed, usually recorded in minutes.	Studies indicated the average duration completed during exercise sessions
Type	For example, running or swimming for cardiorespiratory endurance; free weights or strength machines for muscular strength or endurance.	Studies indicated the specific type of exercise performed

methodological quality was judged as excellent (12–14), good (9–11), fair (6–8), or poor (< 6). The assessment of methodological quality was carried out independently by two reviewers. In cases of disagreement, a third author reviewed the specific item to facilitate consensus.

2.6 | Computation of Effect Size and Statistical Analyses

Mean difference (MD) with its 95% confidence interval (CI) served as the effect size (ES) index. MD was calculated by subtracting the mean change of the control group from the mean change of the intervention group and then corrected by a small sample factor (Hedges and Olkin 2014). When necessary, means and standard deviations (SD) were estimated from reported data (e.g., median, interquartile range, and sample size) (Wan et al. 2014). In studies with more than two assessments, results from the initial two measurements were used to calculate the MD. In studies with more than one intervention group and a shared control group, the sample size of the control group was divided by the number of control groups to avoid overinflation of the sample size (Higgins et al. 2019). Subsequently, pooled analyses were conducted using random-effects models (Borenstein et al. 2010) and the prediction interval (PI) was also obtained.

Heterogeneity tests were conducted using the chi-square test and I^2 index. I^2 values of 25%, 50% and 75% were interpreted as indicating low, moderate and high heterogeneity, respectively (Higgins et al. 2003). In cases of substantial heterogeneity (i.e., $p \leq 0.050$ and/or $I^2 \geq 50\%$), subgroup analyses were used to analyse the influence of potential moderator variables (i.e., health status, type of exercise, aerobic training method, training frequency, intervention length and training principles) on the exercise-induced effect (Higgins et al. 2003). Subgroup analyses were conducted if at least 10 analysis units were included.

Sensitivity analyses were conducted by performing the leave-one-out cross-validation method and removing those studies judged as having poor methodological quality (TESTEX < 6). Additionally, contour-enhanced funnel plots and Egger's tests were used to carry out publication bias analyses (Egger et al. 1997; Peters et al. 2008; Sterne et al. 2011). Subgroup, publication bias and sensitivity analyses were performed if at least 10 analysis units were pooled. STATA software (version 16.0; Stata Corp LLC, College Station, TX, United States) was used to conduct all analyses.

2.7 | Dealing With Missing Data

When necessary, corresponding authors were contacted via email to request missing information. The authors of unpublished studies (e.g., conference abstracts) were contacted to request additional information that was not reported in the abstract. If no response was received, the unpublished record was excluded from the review.

2.8 | Deviations From the Registered Protocol

A detailed mapping of the key registry fields from PROSPERO to the final manuscript is provided in Supporting Information S1: Table S2 (see ESM).

Notably, although oxygen uptake at the second ventilatory threshold (VT2) was initially registered as the secondary outcome, the revised manuscript uses VO_2 at VT1. Most of the selected studies only disclosed that the anaerobic threshold was measured, which refers to VT1. Based on the assessment method, we carefully checked that VO_2 VT1 was reported in the selected studies. Additionally, VO_2 VT1 is a more relevant physiological marker and represents the moderate intensity typically prescribed, which improves clinical comparability between studies (Anselmi et al. 2021). Secondly, we added the extraction of FITT components, as they greatly influence clinical outcomes. Therefore, extracting this information helps to (i) interpret the heterogeneity between studies, (ii) assess the plausibility of the observed effects (whether participants did what was prescribed) and (iii) improve the clinical applicability of the findings.

3 | Results

3.1 | Study Selection

The study selection process is presented in Figure 1. Briefly, the electronic database search retrieved 3226 after removing duplicates ($n = 1035$). After reviewing titles and abstracts, 62 studies were eligible for full-text analysis of which 16 were included

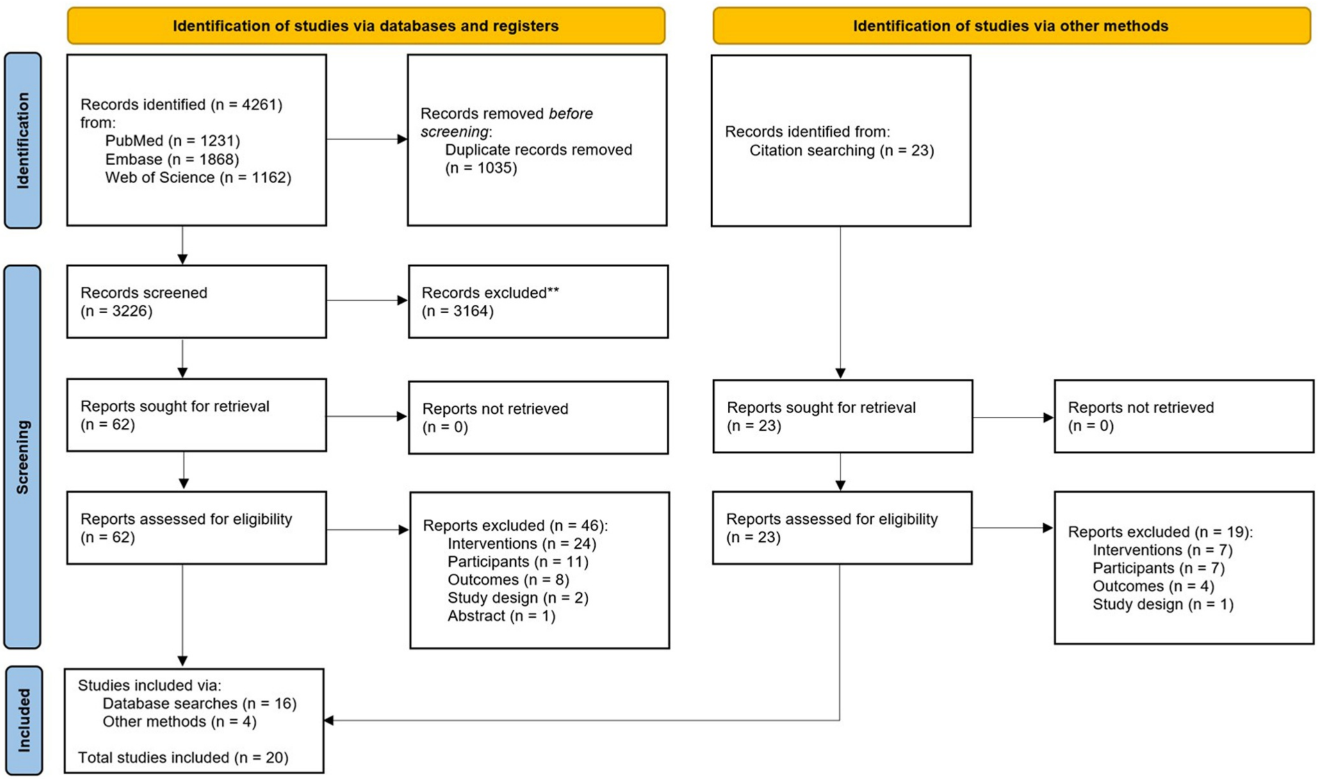

FIGURE 1 | Flow chart of the study selection process.

(Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Fosstveit et al. 2024; Gossard et al. 1986; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Skobel et al. 2017; Wu et al. 2006) and 46 were excluded (see Figure 1 for reasons). After reviewing the reference list of the included studies, four additional studies fulfiled our inclusion criteria and were also selected (Dracup et al. 2007; King et al. 1991; Salvetti et al. 2008; Servantes et al. 2012). Therefore, 20 studies were finally included in the qualitative synthesis (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006).

3.2 | Study Characteristics

Study and participant characteristics are delivered in Table 3. Included studies were published from 1986 to 2025. Out of the 20 included studies, 19 (95%) were randomised (Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006) and one (5%) nonrandomised (Adachi et al. 1996). Eighteen (90%) studies recruited male and female participants (i.e., mixed sample) (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006) and two (10%) only selected male participants (Gossard et al. 1986; King et al. 1991). Five (25%) studies recruited healthy participants (Casanova-Lizón et al. 2025; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Rogers et al. 1987) and 15 (75%) enroled patients with CVD of which 10 (67%) included patients with CHF (Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Liu et al. 2023; McKelvie et al. 2002; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Servantes et al. 2012) and five (33%) patients with CAD (Adachi et al. 1996; Noites et al. 2017; Salvetti et al. 2008; Skobel et al. 2017; Wu et al. 2006). Four studies (20%) included two intervention groups and one control group (i.e., multi-intervention studies) (Adachi et al. 1996; Gossard et al. 1986; King et al. 1991; Servantes et al. 2012), whereas the remaining 16 studies (80%) included one intervention group and one control group (Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Skobel et al. 2017; Wu et al. 2006). Therefore, 24 intervention groups and 20 control groups were included in the qualitative synthesis (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006).

The final numbers of participants in the intervention and control groups were 1281 and 1102, respectively. Sample size in the intervention and control groups ranged from 10 to 422 patients and from eight to 422 participants, respectively. The number of studies (groups) that provided the following information is shown in brackets. The mean ± SD age in the intervention groups ($n = 18$) was 58.2 ± 6.9 years (min–max: 40.5–67.6), whereas the mean ± SD age in the control groups ($n = 16$) was 59.4 ± 7.4 years (min–max: 36.9–68.0). The mean ± SD BMI in the intervention ($n = 16$) and control ($n = 14$) groups was 27.1 ± 1.4 $kg{\cdot}m^{-2}$ (min–max: 24.9–30.1) and 26.9 ± 1.4 $kg{\cdot}m^{-2}$ (min–max: 24.5–29.1), respectively. Finally, the mean ± SD VO_2 peak at baseline was 21.7 ± 6.6 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ (min–max: 13.8–33.3) in the intervention groups ($n = 24$) and 21.1 ± 6.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ (min–max: 13.3–32.2) in the control groups ($n = 20$).

Intervention characteristics are shown in Supporting Information S1: Table S3 (see ESM). The mean ± SD intervention length was 17.9 ± 11.3 weeks (min–max: 8–48). Out of all the 24 intervention groups, 16 (66.7%) performed aerobic training (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Passino et al. 2008; Piotrowicz et al. 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Wu et al. 2006) and eight (33.3%) combined training (Dracup et al. 2007; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Piotrowicz et al. 2020; Servantes et al. 2012; Skobel et al. 2017). Regarding the aerobic training method, 18 (75%) groups performed MIT (Adachi et al. 1996; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017) and six (25%) HIT (Adachi et al. 1996; Casanova-Lizón et al. 2025; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Wu et al. 2006). Seventeen (85%) studies used a percentage-based method of which 15 used HR/VO_2 peak percentages (Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Rogers et al. 1987; Salvetti et al. 2008; Skobel et al. 2017; Wu et al. 2006) (Level 1 of individualisation) and two HR/VO_2 reserve percentages (e.g., %VO_2 peak) (Piotrowicz et al. 2020, 2015) (level two of individualisation). Only three (16%) studies used the ventilatory-threshold approach (Adachi et al. 1996; Liu et al. 2023; Servantes et al. 2012) (Level 3 of individualisation). Additional, out of all the eight studies that conducted combined training, four (50%) used 1RM to carry out resistance exercise prescription (Dracup et al. 2007; McKelvie et al. 2002; Oka et al. 2005; Servantes et al. 2012), one (12.5%) HR percentage (Noites et al. 2017), one (12.5%) rate of perceived exertion (RPE) (Liu et al. 2023) and two (25.0%) did not report this information (Piotrowicz et al. 2020; Skobel et al. 2017).

TABLE 3 | Study and participant characteristics.

Study (author, year)	Group; exercise type (aerobic method)	Study characteristics: Country; study design	Patient characteristics: Health status	Sex; final sample size; male percentage; age; body Mass; body Mass index	Resting HR; VO_2 peak;
Adachi et al. (1996)	IG; AT (MIT)	Japan; non-randomised	CAD	Both; 11; 91%; 62.4 ± 9.3 years; 59.3 ± 5.5 kg; NR	76.0 ± 13.0 bpm; 18.7 ± 4.2 mL·kg^{-1}·min^{-1}
	IG; AT (HIT)			Both; 10; 90%; 50.9 ± 11.4 years; 60.9 ± 8.2 kg; NR	76.0 ± 10.0 bpm; 21.9 ± 7.2 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 8; 75%; 61.8 ± 9.3 years; 65.8 ± 12.9 kg; NR	75.0 ± 9.0 bpm; 18.2 ± 3.7 mL·kg^{-1}·min^{-1}
Casanova-Lizón et al. (2025)	IG; AT (HIT)	Spain; randomised	Healthy participants	Both; 18; 44%; 40.5 ± 9.3 years; 71.1 ± 11.3 kg; 25.7 ± 3.9	71.3 ± 10.7 bpm; 33.3 ± 7.5 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 29; 31%; 36.9 ± 11.0 years; 73.1 ± 18.4 kg; 26.2 ± 5.2	70.5 ± 10.1 bpm; 32.2 ± 7.9 mL·kg^{-1}·min^{-1}
Chen et al. (2018)	IG; AT (MIT)	Taiwan; randomised	CHF	Both; 19; 89%; 61.0 ± 11.0 years; 67.3 ± 11.9 kg; 24.9 ± 2.6	NR; 18.2 ± 4.1 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 18; 78%; 60.0 ± 16.0 years; 67.8 ± 18.4 kg; 25.2 ± 5.7	NR; 18.9 ± 4.1 mL·kg^{-1}·min^{-1}
Corvera-Tindel et al. (2004)	IG; AT (MIT)	USA; randomised	CHF	Male; 32; 100%; 63.8 ± 10.1 years; NR; 30.1 ± 6.4	77.6 ± 15.1 bpm; 14.3 ± 3.7 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 31; 97%; 61.3 ± 11.1 years; NR; 28.8 ± 6.1	77.1 ± 16.1 bpm; 14.2 ± 3.4 mL·kg^{-1}·min^{-1}
Dracup et al. (2007)	IG; CT (MIT)	USA; randomised	CHF	Both; 87; 73%; 53.3 ± 12.7 years; NR; NR	75.5 ± 13.2 bpm; 13.8 ± 3.6 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 86; 70%; 54.6 ± 12.5 years; NR; NR	75.3 ± 13.7 bpm; 13.3 ± 3.3 mL·kg^{-1}·min^{-1}
Fosstveit et al. (2024)	IG; AT (HIT)	Norway; randomised	Healthy participants	Both; 98; 47%; 67.6 ± 5.9 years; 80.2 ± 13.5 kg; 27.2 ± 3.5	NR; 27.6 ± 3.6 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 103; 45%; 67.0 ± 5.2 years; 80.0 ± 14.8 kg; 27.4 ± 4.1	NR; 27.9 ± 4.8 mL·kg^{-1}·min^{-1}
Gossard et al. (1986)	IG; AT (MIT)	USA; randomised	Healthy participants	Male; 20; 100%; NR; NR; NR	72.0 ± 11.0 bpm; 33.3 ± 3.5 mL·kg^{-1}·min^{-1}
	IG; AT (HIT)			Male; 23; 100%; NR; NR; NR	68.0 ± 13.0 bpm; 32.2 ± 4.8 mL·kg^{-1}·min^{-1}
	CG; NA			Male; 20; 100%; NR; NR; NR	74.0 ± 11.0 bpm; 30.9 ± 4.8 mL·kg^{-1}·min^{-1}
King et al. (1991)	IG; AT (MIT)	USA; randomised	Healthy participants	Both; 74; 61%; NR; NR; 26.6 ± 3.6	NR; 27.5 ± 6.6 mL·kg^{-1}·min^{-1}
	IG; AT (HIT)			Both; 77; 55%; NR; NR; 27.6 ± 4.7	NR; 26.9 ± 6.3 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 75; 55%; NR; NR; 27.0 ± 5.5	NR; 27.2 ± 5.3 mL·kg^{-1}·min^{-1}
Liu et al. (2023)	IG; CT (MIT)	China; randomised	CHF	Both; 17; 71%; 64.94 ± 7.64 years; NR; 25.73 ± 3.52	NR; 19.55 ± 2.29 mL·kg^{-1}·min^{-1}
	CG; NA			Both; 20; 60%; 67.95 ± 4.65 years; NR; 24.46 ± 3.87	NR; 18.18 ± 4.0 mL·kg^{-1}·min^{-1}

(Continues)

TABLE 3 | (Continued)

Study (author, year)	Group; exercise type (aerobic method)	Study characteristics	Patient characteristics		
		Country; study design	Health status	Sex; final sample size; male percentage; age; body Mass; body Mass index	Resting HR; VO_2 peak;
McKelvie et al. (2002)	IG; CT (MIT)	Canada; randomised	CHF	Both; 58; 91%; 64.8 ± 10.44 years; 79.60 ± 17.08 kg; NR	NR; 15.1 ± 3.1 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 71; 88%; 66.1 ± 9.44 years; 80.5 ± 18.12 kg; NR	NR; 14.5 ± 2.7 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Noites et al. (2017)	IG; CT (MIT)	Portugal; randomised	CAD	Both; 16; 81%; 62.5 ± 4.6 years[a]; 75.0 ± 11.4 kg; 28.4 ± 2.6[a]	70.0 ± 12.5 bpm[a]; 26.0 ± 9.6 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$[a]
	CG; NA			Both; 16; 75%; 59.5 ± 7.25 years[a]; 74.9 ± 14.2 kg; 27.6 ± 4.6[a]	73.0 ± 7.5 bpm[a]; 28.8 ± 7.3 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$[a]
Oka et al. (2005)	IG; CT (MIT)	USA; randomised	CHF	Both; 12; 85%; NR; NR; NR	NR; 18.37 ± 4.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 12; 70%; NR; NR; NR	NR; 19.0 ± 3.75 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Passino et al. (2008)	IG; AT (MIT)	Italy; randomised	CHF	Both; 71; 87%; 61.0 ± 16.9 years; NR; 25.2 ± 3.37	NR; 14.8 ± 5.1 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 19; 74%; 63.0 ± 8.72 years; NR; 25.6 ± 3.05	NR; 14.7 ± 4.8 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Piotrowicz et al. (2020)	IG; CT (MIT)	Poland; randomised	CHF	Both; 422; 89%; 62.6 ± 10.8 years; NR; 28.7 ± 5.0	NR; 16.9 ± 6.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 422; 88%; 62.2 ± 10.2 years; NR; 29.1 ± 4.7	NR; 16.6 ± 6.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Piotrowicz et al. (2015)	IG; AT (MIT)	Poland; randomised	CHF	Both; 75; 85%; 54.4 ± 10.9 years; NR; 28.0 ± 3.0	67.0 ± 11.0 bpm; 16.1 ± 4.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 32; 97%; 62.1 ± 12.5 years; NR; 28.0 ± 3.0	67.0 ± 10.0 bpm; 17.4 ± 3.3 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Rogers et al. (1987)	IG; AT (MIT)	USA; randomised	Healthy participants	Both; 51; 52.9%; NR; NR; NR	NR; 29.11 ± 5.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 49; 51.02%; NR; NR; NR	NR; 30.06 ± 5.93 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Salvetti et al. (2008)	IG; AT (MIT)	Brazil; randomised	CAD	Both; 19; 74%; 53.0 ± 8.0 years; NR; 27.0 ± 4.0	NR; 28.8 ± 6.4 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 20; 75%; 54.0 ± 9.0 years; NR; 27.0 ± 3.0	NR; 28.6 ± 6.6 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Servantes et al. (2012)	IG; AT (MIT)	Brazil; randomised	CHF	Both; 17; 47%; 51.76 ± 9.83 years; NR; 26.87 ± 4.69	NR; 15.4 ± 2.7 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	IG; CT (MIT)			Both; 17; 47%; 50.82 ± 9.45 years; NR; 27.98 ± 4.42	NR; 15.6 ± 2.7 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
	CG; NA			Both; 11; 45%; 53.0 ± 8.19 years; NR; 27.73 ± 3.66	NR; 15.7 ± 3.0 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$
Skobel et al. (2017)	IG; CT (MIT)	Germany; randomised	CAD	Both; 19; 91%; 60.0 ± 50, 65 years[b]; NR; 28.4 ± 25.3, 32[b]	72.0 ± 46, 107 bpm[b]; 21.5 ± 17.2, 24.8 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$[b]

(Continues)

TABLE 3 | (Continued)

Study (author, year)	Group; exercise type (aerobic method)	Study characteristics Country; study design	Patient characteristics Health status	Sex; final sample size; male percentage; age; body Mass; body Mass index	Resting HR; VO_2 peak;
	CG; NA			Both; 42; 87%; 58.0 ± 52, 67 years[b]; NR; 27.7 ± 25.1, 30.8[b]	71.7 ± 44, 103 bpm[b]; 20.0 ± 17, 23 mL·kg^{-1}·min^{-1}[b]
Wu et al. (2006)	IG; AT (HIT)	Taiwan; randomised	CAD	Male; 18; 100%; 60.9 ± 7.6 years; 73.7 ± 6.3 kg; 26.0 ± 1.8	85.4 ± 6.5 bpm; 16.4 ± 3.5 mL·kg^{-1}·min^{-1}
	CG; NA			Male; 18; 100%; 62.2 ± 9.6 years; 72.2 ± 6.2 kg; 25.2 ± 2.2	87.2 ± 7.2 bpm; 16.0 ± 4.2 mL·kg^{-1}·min^{-1}

Note: Values are reported as mean ± standard deviation.
Abbreviations: AT, aerobic training; bpm, beats per minute; CAD, coronary artery disease; CG, non-exercise control group; CHF, chronic heart failure; CT, combined aerobic and resistance training; HIT, high-intensity training; HR, heart rate; IG, intervention group; LIT, low intensity training; MIT, moderate intensity training; MIIT, moderate intensity interval training; NA, no applicable; NR, no reported; USA, United States of America; VO_2 peak, peak oxygen uptake.
[a]Data are reported as the interquartile range.
[b]Data are reported as percentiles.

3.3 | Application of Exercise Training Principles

Analysis of exercise training principles can be found in Table 4, whereas the statements supporting the decisions are shown in Supporting Information S1: Table S4 (see ESM). Briefly, 18 (90%) studies met the overload principle (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006) and 20 (100%) the specificity principle (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006). Thirteen (65%) studies followed the progr ession principle (Casanova-Lizón et al. 2025; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; King et al. 1991; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006), whereas only three (15%) met the periodisation principle (Casanova-Lizón et al. 2025; Fosstveit et al. 2024; Skobel et al. 2017). All the included (100%) studies conducted an individualised intervention (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006). The specific level of individualisation has been reported above. None of the included (0%) studies assessed the reversibility principle. The application of exercise training principles was similar in healthy participants and in patients with CVD. The mean ± SD total score of training principles was 5.2 ± 1.1 points (min–max: 4–7).

3.4 | Prescription and Compliance of the Exercise Training

All the included (100%) studies provided information of all the FITT components (Adachi et al. 1996; Casanova-Lizón et al. 2025; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006). Regarding compliance to FITT components, 13 (65%) studies reported compliance to exercise frequency (Casanova-Lizón et al. 2025; Corvera-Tindel et al. 2004; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Oka et al. 2005; Piotrowicz et al. 2020, 2015; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012) and seven (35%) did not (Adachi et al. 1996; Chen et al. 2018; Dracup et al. 2007; Noites et al. 2017; Passino et al. 2008; Skobel et al. 2017; Wu et al. 2006). Six (30%) studies reported compliance to exercise intensity (Adachi et al. 1996; Casanova-Lizón et al. 2025; Fosstveit et al. 2024; Gossard et al. 1986; King et al. 1991; Rogers et al. 1987), one (5%) reported it unclearly (Piotrowicz et al. 2015) and 13 (65%) did not provide this information (Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006). Four (20%) studies provided compliance to exercise duration (Casanova-Lizón et al. 2025; Fosstveit et al. 2024; Gossard et al. 1986; Rogers et al. 1987), one (5%) reported unclear information (Piotrowicz et al. 2015) and 15 (75%) studies did not report this information (Adachi et al. 1996; Chen et al. 2018; Corvera-Tindel et al. 2004; Dracup et al. 2007; King et al. 1991; Liu et al. 2023; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Piotrowicz et al. 2020; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006). Finally, seven (35%) studies reported compliance to exercise type (Adachi et al. 1996; Casanova-Lizón et al. 2025; Corvera-Tindel et al. 2004; Fosstveit et al. 2024; Gossard et al. 1986; Oka et al. 2005; Piotrowicz et al. 2015), one (5%) provided unclear

TABLE 4 | Application of exercise training principles.

Study (author)	Principle						
	Overload	Progression	Individualisation	Periodisation	Specificity	Reversibility	Sum score
Adachi et al. (1996)	(+)	(−)	(+0.3)	(−)	(+)	(−)	6/9
Casanova-Lizón et al. (2025)[a]	(+)	(+)	(+0.1)	(+)	(+)	(−)	6/9
Chen et al. (2018)	(+)	(−)	(+0.1)	(−)	(+)	(−)	4/9
Corvera-Tindel et al. (2004)	(−)	(+)	(+0.1)	(−)	(+)	(−)	4/9
Dracup et al. (2007)	(−)	(+)	(+0.1)	(−)	(+)	(−)	4/9
Fosstveit et al. (2024)[a]	(+)	(+)	(+0.1)	(+)	(+)	(−)	6/9
Gossard et al. (1986)[a]	(+)	(−)	(+0.1)	(−)	(+)	(−)	4/9
King et al. (1991)[a]	(+)	(+)	(+0.1)	(−)	(+)	(−)	5/9
Liu et al. (2023)	(+)	(−)	(+0.3)	(−)	(+)	(−)	6/9
McKelvie et al. (2002)	(+)	(−)	(+0.1)	(−)	(+)	(−)	4/9
Noites et al. (2017)	(+)	(+)	(+0.1)	(−)	(+)	(−)	5/9
Oka et al. (2005)	(+)	(+)	(+0.1)	(−)	(+)	(−)	5/9
Passino et al. (2008)	(+)	(+)	(+0.1)	(−)	(+)	(−)	5/9
Piotrowicz et al. (2020)	(+)	(+)	(+0.2)	(−)	(+)	(−)	6/9
Piotrowicz et al. (2015)	(+)	(+)	(+0.2)	(−)	(+)	(−)	6/9
Rogers et al. (1987)[a]	(+)	(−)	(+0.1)	(−)	(+)	(−)	4/9
Salvetti et al. (2008)	(+)	(−)	(+0.1)	(−)	(+)	(−)	4/9
Servantes et al. (2012)	(+)	(+)	(+0.3)	(−)	(+)	(−)	7/9
Skobel et al. (2017)	(+)	(+)	(+0.1)	(+)	(+)	(−)	6/9
Wu et al. (2006)	(+)	(+)	(+0.1)	(−)	(+)	(−)	5/9
Proportion	90% (18/20)	65% (13/20)	60% (48/80)	15% (3/20)	100% (20/20)	0% (0/20)	56.67% (102/180)

Note: (+), informed/applied; (−) uninformed/not applied; (?) unclear.
[a]Healthy participants.

information (Liu et al. 2023) and 12 (60%) did not report this information (Chen et al. 2018; Dracup et al. 2007; King et al. 1991; McKelvie et al. 2002; Noites et al. 2017; Passino et al. 2008; Piotrowicz et al. 2020; Rogers et al. 1987; Salvetti et al. 2008; Servantes et al. 2012; Skobel et al. 2017; Wu et al. 2006). A summary of compliance to FITT components is shown in Figure 2.

3.5 | Methodological Quality Assessment

The results of the methodological quality assessment are reported in Supporting Information S1: Table S5 (see ESM). In summary, two (10%) studies were classified as having poor methodological quality (Adachi et al. 1996; Chen et al. 2018), 11 (55%) as fair (Casanova-Lizón et al. 2025; Corvera-Tindel et al. 2004; Gossard et al. 1986; King et al. 1991; McKelvie et al. 2002; Noites et al. 2017; Oka et al. 2005; Passino et al. 2008; Rogers et al. 1987; Skobel et al. 2017; Wu et al. 2006) and seven (35%) as good (Dracup et al. 2007; Fosstveit et al. 2024; Liu et al. 2023; Piotrowicz et al. 2020, 2015; Salvetti et al. 2008; Servantes et al. 2012).

3.6 | Outcome Measures

Meta-analysed data from 24 analysis units (1271 and 1096 participants in the intervention and control group, respectively) showed a VO_2 peak improvement of 2.70 $mL \cdot kg^{-1} \cdot min^{-1}$ (CI = 1.78, 3.62; $p < 0.001$) in the intervention group compared to the control group (Figure 3). The heterogeneity test reached statistical significance ($p < 0.001$) with high inconsistency ($I^2 = 85.3\%$) and an estimated between-study variance of 3.87. Given this substantial heterogeneity, the PI was calculated, ranging from −1.49 to 6.90 $mL \cdot kg^{-1} \cdot min^{-1}$. The results of the subgroup analyses are reported in Supporting Information S1: Table S6 (see ESM). A greater improvement in VO_2 peak was found in favour of the intervention group in those studies that met the overload principle (3.02 $mL \cdot kg^{-1} \cdot min^{-1}$ [CI = 2.10, 3.93]) compared to those that did not (−0.07 $mL \cdot kg^{-1} \cdot min^{-1}$ [CI = −0.83, 0.68]). The remaining subgroup analyses did not reach statistical significance ($p > 0.050$). Contour-enhanced funnel plot, which can be found in Figure 4, was slightly asymmetric. However, Egger's test did not reach statistical significance ($p = 0.310$). Therefore, publication bias is unlikely to be a major threat against our finding on VO_2 peak.

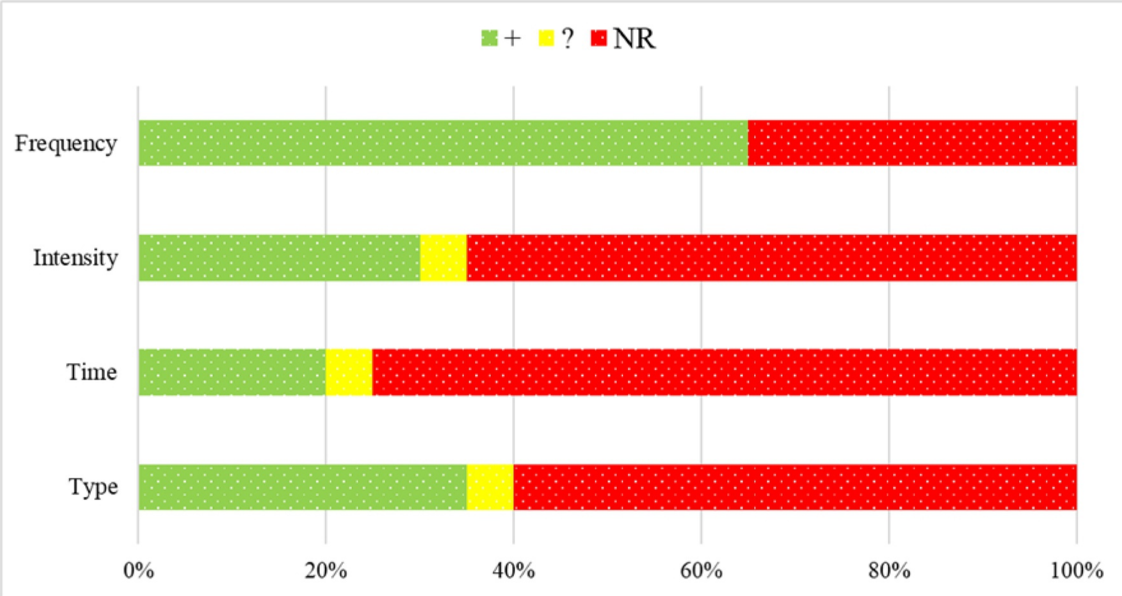

FIGURE 2 | Compliance to the FITT components. The reviewers' evaluations of the study sample's compliance to the exercise prescription based on the FITT components are presented as percentages across all included studies. +, reporting compliance to each element within the exercise prescription. The compliance to each component of the exercise prescription was reported unclearly; NR, no reporting was provided on compliance to each individual part of the exercise prescription.

Regarding sensitivity analyses, no influential studies were found using the leave-one-out cross-validation method. Additionally, after removing studies with poor methodological quality (Adachi et al. 1996; Chen et al. 2018), the pooled result (2.74 mL·kg^{-1}·min^{-1} [CI = 1.77, 3.71]) and heterogeneity ($I^2 = 86.9\%$) did not change. However, subgroup analyses showed greater improvement in VO_2 peak in those studies which used the ventilatory-threshold method (7.05 mL·kg^{-1}·min^{-1} [CI = 5.74, 8.36]) compared to those which used HR/VO_2 reserve percentages (1.60 mL·kg^{-1}·min^{-1} [CI = 0.06, 3.14]) or HR/VO_2 peak percentages (1.99 mL·kg^{-1}·min^{-1} [CI = 1.22, 2.76]). The results of the subgroup analyses after removing studies with poor methodological quality are reported in Supporting Information S1: Table S7 (see ESM).

Regarding VO_2 VT1, pooled data from nine analysis units (238 and 241 in the intervention and control group, respectively) showed an improvement of 2.17 mL·kg^{-1}·min^{-1} (CI = 0.53, 3.81; $p = 0.010$) in favour of the intervention group. High inconsistency was found ($p < 0.001$; $I^2 = 91.7\%$). However, nine analysis units were pooled and, therefore, heterogeneity analyses were not conducted.

4 | Discussion

This systematic review with meta-analysis was conducted to investigate the effect of unsupervised home-based exercise programmes on CRF in healthy sedentary individuals and patients with CVD, taking into account the influence of exercise training principles. Most of the included studies met exercise training principles such as individualisation, specificity and overload. However, most of them failed to report compliance to intensity, time and type of exercise. We found an improvement of 2.70 mL·kg^{-1}·min^{-1} (CI = 1.78, 3.62) in VO_2 peak in the intervention group compared to the control group. This finding aligns with previous evidence that has shown that structured exercise can lead to significant physiological improvements (Anderson and Durstine 2019; Thompson et al. 2012). Furthermore, the magnitude of this change takes on an additional dimension when considering that an increase of only 1 mL·kg^{-1}·min^{-1} in VO_2 peak has been associated with an approximate 9% reduction in the relative risk of all-cause mortality (Laukkanen et al. 2016). However, high heterogeneity in the results of included studies was identified. Importantly, the estimated PI crosses zero (−1.49–6.90 mL kg^{-1}·min^{-1}). This implies that, despite the overall beneficial mean effect, the substantial between-study variance could lead to null or slightly negative effects on VO_2 peak in some future comparable settings. This finding strongly underscores the necessity of optimizing training variables to guarantee efficacy. In this regard, we found an improvement of 3.02 mL·kg^{-1}·min^{-1} (CI = 2.10, 3.93) in VO_2 peak in studies that met the overload principle, whereas no improvement was found in studies that did not meet this exercise training principle. The low number of studies that did not meet the overload principle limits the scope of this finding. After removing poor methodological quality studies, we also found higher exercise-induced effect on VO_2 peak in studies that used VT to establish training zones and conduct aerobic training prescription. On the contrary, participant and exercise training variables showed no influence on the effect of exercise training on VO_2 peak. Future high-quality studies that carefully follow all the exercise training principles are needed. Additionally, compliance to FITT components should be reported to properly analyse the influence of training variables on the effect of exercise.

The application of exercise training principles varies across the studies included in our review, revealing critical areas in need of

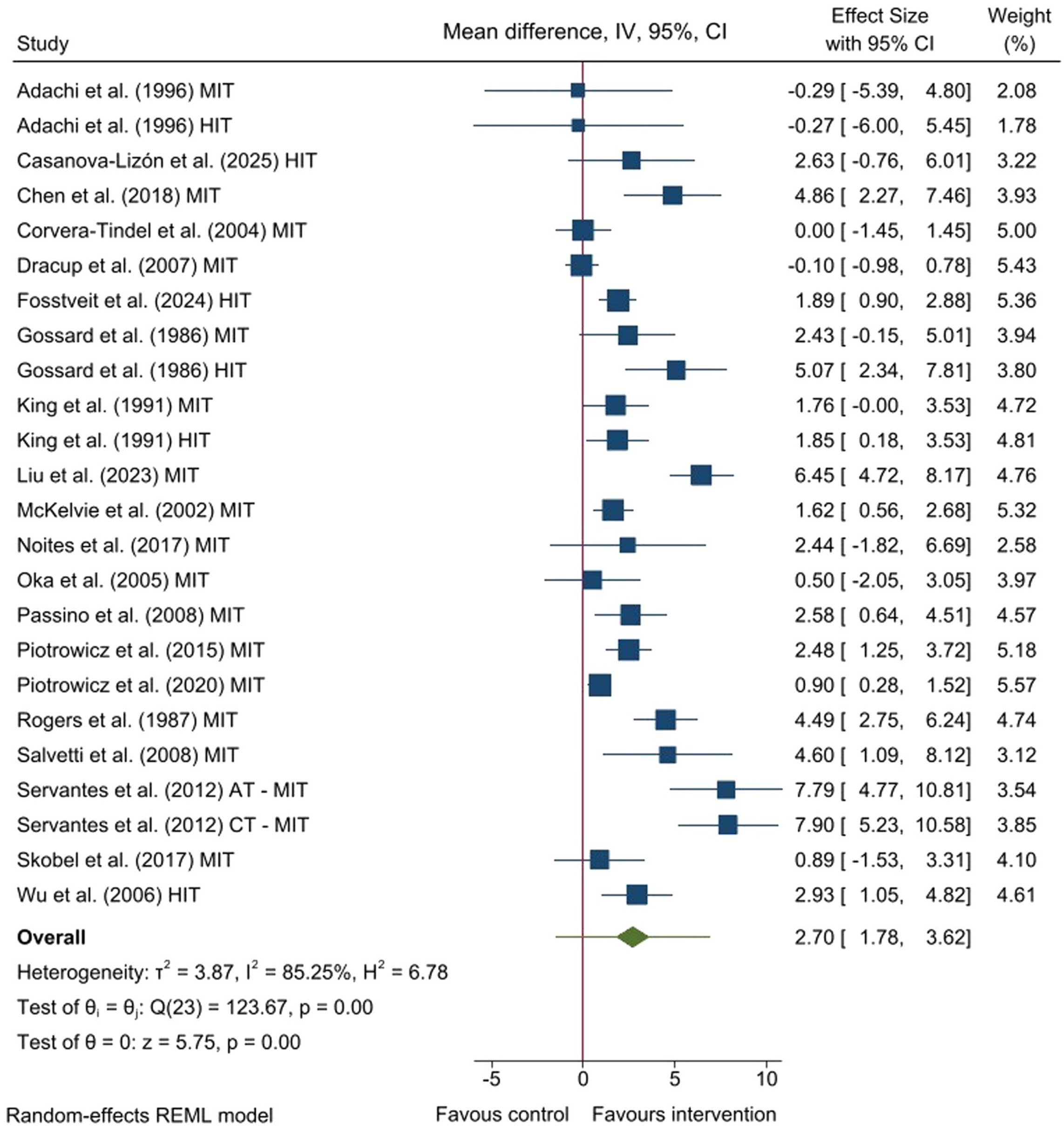

FIGURE 3 | Forest plot of the mean difference between intervention and control groups for peak oxygen uptake. AT, aerobic training; CI, confidence interval; CT, combined training; HIT, high-intensity training; IV, inverse variance; MIT, moderate-intensity training.

improvement. We found that 90% and 65% of the studies adhered to the overload and progression principles, respectively. Greater compliance to these principles has been reported in healthy people (94% and 70%, respectively) (Stassen et al. 2022). On the contrary, lower compliance rates have been found in clinical settings (Ammann et al. 2014; Baschung Pfister et al. 2015; Burton and McCormack 2021; Campbell et al. 2012; Fairman et al. 2017; Minshull and Gleeson 2017; Neil-Sztramko, Medysky, et al. 2019; Neil-Sztramko, Winters-Stone, et al. 2019; Winters-Stone et al. 2014). All the studies included in the current review adhered to the individualisation and specificity principles, showing a commitment to tailoring exercise interventions to individual needs. Individualisation is particularly important in clinical populations, where variations in health status and physical capacity require personalised adjustments to exercise training (Hansen et al. 2019). Nonetheless, a detailed description of how individualisation was implemented was missing, making replication and interpretation difficult (Hoffmann et al. 2013; Slade et al. 2014, 2016). Stassen et al. (2022) reported a compliance to the specificity principle of 78% in healthy employees, whereas it ranged from 72.4% to 100% in the clinical population (Ammann et al. 2014; Baschung Pfister et al. 2015; Burton and McCormack 2021; Campbell et al. 2012; Fairman et al. 2017; Neil-Sztramko, Medysky, et al. 2019; Neil-Sztramko, Winters-Stone, et al. 2019; Winters-Stone et al. 2014). The application of specificity increases the likelihood that improvements are directly due to the intervention. Future research should adjust exercise prescriptions according to baseline fitness (Winters-Stone et al. 2014), ensuring appropriate stimuli without prescribing excessive or insufficient intensity (Neil-Sztramko, Medysky, et al. 2019). In addition, effective progression is critical to optimise exercise-induced benefits (Baschung Pfister et al. 2015; Winters-Stone et al. 2014), as well as to reduce injury risk and increase efficacy and motivation (Neil-Sztramko,

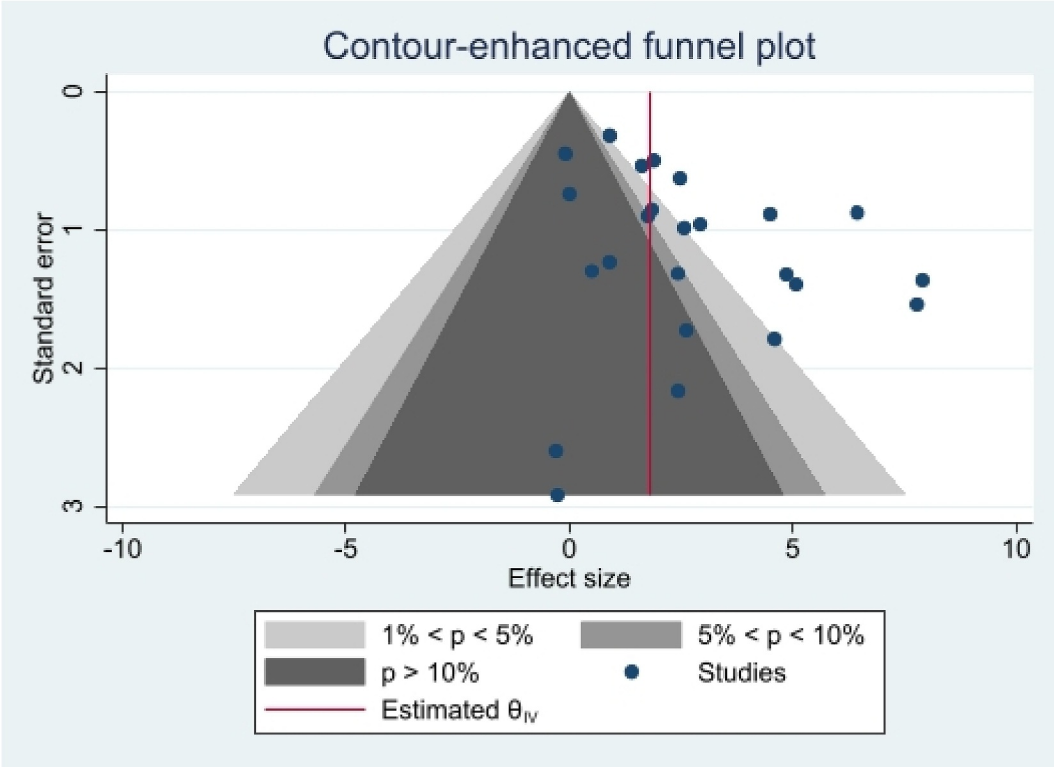

FIGURE 4 | Contour-enhanced funnel plot for peak oxygen uptake.

Medysky, et al. 2019). Therefore, authors should clearly outline the progression performed to enable the replication of the exercise programme in other settings and minimise implementation errors (Campbell et al. 2012). Finally, providing more detailed information on individualisation methods would improve their practical applications in clinical and community settings.

On the other hand, only 15% of studies adhered to the periodisation principle. Stassen et al. (2022) also reported a low compliance rate of 39% in healthy employees. There is also evidence showing no compliance to the periodisation principle in clinical settings (Ammann et al. 2014; Baschung Pfister et al. 2015; Burton and McCormack 2021; Campbell et al. 2012; Fairman et al. 2017; Neil-Sztramko, Medysky, et al. 2019; Winters-Stone et al. 2014). However, systematic variations over time improve adaptations and increase motivation and compliance (Baz-Valle et al. 2019), which is particularly relevant for recreational or health promotion settings (Lorenz et al. 2010; Rhea and Alderman 2004; Williams et al. 2017). Finally, none of the studies included in the current review adhered to the principle of reversibility, which was also observed in previous research (Burton and McCormack 2021; Fairman et al. 2017; Minshull and Gleeson 2017; Neil-Sztramko, Medysky, et al. 2019; Stassen et al. 2022). The principle of reversibility is not typically described because it does not specifically pertain to exercise prescription but rather emphasises the consideration that if the training process is interrupted, the achieved adaptations and improvements will diminish over time. Therefore, although it may be interesting to analyse the rate of loss of these adaptations through a follow-up of participants, it might be more relevant to assess whether the interventions conducted in the studies have resulted in greater compliance to exercise, ensuring that participants continue exercising beyond the research study.

As widely documented, and in line with our findings, unsupervised home-based exercise training increases VO_2 peak in healthy people and patients with CVD (Tsuji et al. 2023; Zwisler et al. 2016). Nonetheless, the results of the included studies were controversial, and heterogeneity sources were investigated. We found a mean VO_2 peak increase of 3.01 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$, 2.19 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ and 2.69 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ in patients with CHF, patients with CAD and healthy people, respectively. In this regard, Kodama et al. (2009) reported a 13% reduction in all-cause mortality risk and a 15% reduction in CVD mortality risk for each 3.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ increase in CRF. Taken together, these findings show that unsupervised home-based exercise training is a nonpharmacological treatment for diminishing mortality risk. Interestingly, the magnitude of the improvement was higher in patients with CHF, whose mortality risk is higher (Wehbe et al. 2020), although magnitude effect differences based on the pathology were not found. On the other hand, the results also showed the importance of the application of exercise training principles. Specifically, those interventions that did not meet the overload principle did not improve VO_2 peak. The importance of progressive overload in improving CRF has been previously highlighted (Robert Bell et al. 2024). However, the low number of studies limit the scope of this finding, and future studies are needed. On the other hand, all the included studies conducted an individualised intervention. Nonetheless, only three of them used a VT-based approach for determining aerobic training intensity (Adachi et al. 1996; Liu et al. 2023; Servantes et al. 2012). The study by Adachi et al. (1996) was removed from sensitivity analyses due to poor methodological quality. Following its removal, studies which used a VT-based approach reported a VO_2 peak increase of 7.05 $mL \cdot kg^{-1} \cdot min^{-1}$ (CI = 5.74, 8.76), which could considerably reduce mortality risk (Kodama et al. 2009). Additionally, these studies improved VO_2 peak to a greater extent than those that used percentage-based methods. The low number of studies included in our meta-analysis prevented us from conducting pooled analyses and, therefore, the results should be interpreted with caution. In this regard, Anselmi et al. (2021) compared training zones established by ventilatory-based and percentage-based methods in healthy people and patients with CVD. The authors found lower agreement between the two methods in patients with CVD than healthy people. Moreover, they highlighted that the ventilatory-threshold method should be used for determining aerobic training intensity, mainly in patients with CVD. In the same line, Hansen et al. (2019) analysed whether percentage-based methods agree with the exercise-induced physiological response in patients with CVD. Patients showed different metabolic responses within each percentage range, and what was remarked in those whose physical capacity was lower. Therefore, it seems that percentage-based methods should be avoided in sedentary people and patients with CVD. Nonetheless, as previously commented, most of the included studies used this method for determining aerobic training intensity, which may partially explain the heterogeneity found in their findings. Thus, future studies that use the VT-based method are needed to study the exercise-induced effect while reducing the impact of physiological individual differences. Furthermore, clinicians and physical trainers should also use this method to individualise exercise training programmes and, therefore, increase the effect of unsupervised home-based exercise training on VO_2 peak.

Briefly, regarding the FITT components, all the included studies reported information of the FITT components. Nonetheless, compliance to these components was poorly informed. Specifically, the most reported information was compliance to exercise frequency (65%), which is in line with the results of previous studies in patients with different pathologies (Ammann et al. 2014; Baschung Pfister et al. 2015; Campbell et al. 2012; Minshull and Gleeson 2017; Neil-Sztramko, Medysky, et al. 2019; Neil-Sztramko, Winters-Stone, et al. 2019; Winters-Stone et al. 2014). On the contrary, despite the impact of intensity on exercise-induced adaptations (Hughes et al. 2018), only 30% of the included studies reported compliance to exercise intensity. Previous studies also failed to report compliance to this FITT component, showing values between 8% and 16% (Ammann et al. 2014; Campbell et al. 2012; Neil-Sztramko, Medysky, et al. 2019; Neil-Sztramko, Winters-Stone, et al. 2019; Winters-Stone et al. 2014). Finally, only 20% and 35% of the included studies reported compliance to time and type of exercise, respectively, which is consistent with previous results (Ammann et al. 2014; Baschung Pfister et al. 2015; Campbell et al. 2012; Neil-Sztramko, Medysky, et al. 2019; Neil-Sztramko, Winters-Stone, et al. 2019; Winters-Stone et al. 2014). The lack of information about the exercise performed by the participants in the empirical studies limits the interpretation of their findings. Furthermore, as we have seen above, the results of the included studies showed high inconsistency, with no influence of some of the exercise training principles and training variables. Compliance to FITT components is essential to optimise the implementation and effectiveness of exercise programmes (Campbell et al. 2012), ensuring that interventions are adequately monitored and comparable across diverse studies (Ammann et al. 2014; Winters-Stone et al. 2014). Therefore, we hypothesise that differences between prescribed and performed exercise training may partially explain the inconsistency of the results of included studies. Future studies reporting this information are needed to facilitate the interpretation of their findings and allow future researchers to investigate the influence of exercise training variables and principles on the exercise-induced effect on VO_2 peak.

Finally, we also found that both aerobic training, regardless of the aerobic training method used (i.e., MIT and HIT), and combined training (i.e., aerobic and resistance exercise) enhance VO_2 peak to a greater extent than usual care, with no difference between the two exercise modalities, which agree with previous findings (Edwards et al. 2023; Hurst et al. 2019; van Baak et al. 2021). Aerobic training is the most used exercise modality for improving CRF (Edwards et al. 2023; J. Lee et al. 2020). Combined training, while not adversely affecting aerobic adaptations, provides unique benefits by combating muscle weakness and preserving strength (Mandic et al. 2012; Volaklis and Tokmakidis 2005), which may improve endurance and increase VO_2 peak values (Karavirta et al. 2011). In line with our findings, Manresa-Rocamora, Sarabia, et al. (2021) also found that both MIT and HIT are suitable for improving CRF in patients with CVD. On the other hand, HIT stands out for its efficiency, as it induces aerobic and anaerobic adaptations in less time through the activation of Type II muscle fibres and increased metabolic demands (Lindner et al. 2023), leading to improvements in VO_2 peak through central (e.g., increased cardiac output) and peripheral (e.g., increased muscle oxidative capacity and arteriovenous oxygen difference) adaptations (Montero and Díaz-Cañestro 2016). On the other hand, although statistical significance was not reached, studies whose intervention length was lower or equal to 12 weeks showed a mean VO_2 peak improvement of 3.26 $mL \cdot kg^{-1} \cdot min^{-1}$ (1.93, 4.58), whereas those whose length was more than 12 weeks reported an increase of 1.80 $mL \cdot kg^{-1} \cdot min^{-1}$ (0.85, 2.74). The greater effectiveness of short programmes may be explained by an initial 'fast adaptation' phase (Wen et al. 2019). Therefore, future long-term studies should modify the training load to induce long-term adaptations and avoid a plateau in exercise-induced adaptations.

To the best of the author's knowledge, the current meta-analysis is the first to study the influence of the application of exercise training principles on the exercise-induced effect of exercise on VO_2 peak in healthy people and patients with CVD. Additionally, this is the first study to determine the compliance to the FITT principles in previous empirical studies. Nonetheless, some limitations should also be noted. First, although heterogeneity sources were investigated, the low number of studies included in some analyses limits the scope of these findings. Second, the influence of participant characteristics on the exercise-induced effect was not investigated. However, we decided to analyse only the influence of study-level characteristics. Third, we included both healthy participants and patients with CVD. Nonetheless, subgroup analyses were performed based on health status.

5 | Conclusion

Unsupervised aerobic and combined training programmes performed at home are suitable for improving CRF in healthy sedentary individuals and patients with CVD. Additionally, the VT-based method should be used to determine aerobic training intensity and prescribe individualised exercise training programmes in heathy participants and patients with CVD. In this regard, the misleading use of percentage-based approaches may explain the inconsistency found in the results of empirical studies, as well as the heterogeneity of exercise-induced individual adaptations. On the other hand, from a clinical perspective, low exercise intensity (e.g., MIT) might be suitable for initiating the exercise training programme (i.e., short-term effect) and progressing to higher exercise intensity (e.g., HIT), considering the same progression if resistance training is also prescribed. This approach might allow clinicians and physicians to apply progression and overload principles, inducing long-term CRF adaptations in people with low physical capacity, such as sedentary individuals and patients with CVD.

Author Contributions

Conceptualization: A.C.-L., A.M.-R. and M.M.-R.; methodology: A.C.-L., A.M.-R., J.M.S.; formal analysis: A.C.-L., A.M.-R., J.M.S., and M.M.-R.; investigation: A.C.-L., A.M.-R., J.M.S., and M.M.-R.; data curation: A.C.-L., A.M.-R., and J.M.S.; writing – original draft preparation: A.C.-L., A.M.-R., J.M.S., and M.M.-R.; writing – review and editing: A.C.-L., A.M.-R., and M.M.-R.; supervision: M.M.-R.; project administration: M.M.-R.; funding acquisition: M.M.-R. All authors have read and agreed to the published version of the manuscript.

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Ethics Statement

The authors have nothing to report.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Permission to Reproduce Material From Other Sources

The authors have nothing to report.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.
Supporting Information S1: ejsc70158-sup-0001-suppl-data.docx.