

The Impact of Exercise Training in a Hypobaric/Normobaric Hypoxic Environment on Cardiometabolic Health in Adults with Overweight or Obesity: A Systematic Review and Meta-Analysis

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Abstract: This systematic review and meta-analysis aims to comprehensively evaluate the effects of hypoxic training (HT) versus normoxic training (NT) on cardiometabolic health parameters in overweight or obese adults. Searches were performed in PubMed, Web of Science, Embase, Scopus, and the Cochrane Library. A meta-analysis was performed using Stata 18 and RevMan 5.4 software. Seventeen randomized controlled studies involving 517 participants were included. HT significantly improved cardiorespiratory fitness (CRF) and reduced systolic blood pressure (SBP) and diastolic blood pressure (DBP). Compared with NT, HT demonstrated a significant difference in CRF, but no significant differences were observed in SBP and DBP. The subgroup analysis of CRF revealed that HT significantly outperformed NT in six aspects: participants aged < 45 years (Hedges' $g = 0.50$), an intervention duration of 8 weeks (Hedges' $g = 0.43$), three sessions per week (Hedges' $g = 0.40$), each session lasting < 45 min (Hedges' $g = 0.23$), FiO_2 levels > 15% (Hedges' $g = 0.69$), and high-load-intensity exercise (Hedges' $g = 0.57$). HT demonstrated favorable effects in improving cardiometabolic health among overweight or obese adults. Compared with NT, this advantage was primarily reflected in CRF while the impacts on SBP and DBP were similar.

Keywords: hypoxic training; normoxic training; obesity; cardiometabolic health; meta-analysis



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1. Introduction

Obesity is internationally recognized as a complex chronic disease [1]. Studies indicate that the global prevalence of obesity among adults nearly doubled between 1999 and 2021, and projections suggest that, by 2050, over 3.8 billion adults aged 25 and older worldwide will be affected by obesity [2]. Obesity is associated with a decline in cardiorespiratory fitness and an excessive accumulation of visceral fat, both of which are independent risk factors for cardiovascular disease (CVD) [3]. CRF is a critical marker of cardiovascular risk and mortality [4]. VO_{2max} is one of the core indicators of CRF [5]. It not only reflects the ability of the respiratory and circulatory systems to supply oxygen to muscles during prolonged exercise [6] but is also widely recognized as a robust independent predictor of cardiovascular disease risk and mortality [7,8]. Researchers can measure the VO_{2max} through a cardiopulmonary exercise test (CPET) [9]. The CPET has witnessed a

growing prevalence in clinical research and sports performance, and it is also considered as the gold standard for evaluating CRF and exercise capacity [10]. VO_2max exhibits an inverse correlation with the incidence of cardiovascular disease and all-cause mortality [11]. Obese individuals frequently experience hypertension, resulting in elevated systolic blood pressure (SBP) and diastolic blood pressure (DBP). SBP is an independent risk factor for cardiovascular disease [12].

Insufficient physical activity and sedentary behavior are strongly associated with increased risks of all-cause mortality, cardiovascular mortality, and cancer mortality [13]. Exercise is a potent non-pharmacological intervention for the treatment and prevention of a variety of chronic diseases [14], as well as an effective strategy for the prevention and management of obesity [15]. Regular exercise not only enhances cardiovascular health [14,16,17] and cardiometabolic function but also induces anabolic processes (e.g., increased skeletal muscle anabolism) and metabolic adaptations, thereby reducing mortality rates and improving quality of life [18–20]. Exercise can also increase the secretion of endorphins, regulate emotions, and enhance the treatment compliance of patients [21]. Numerous studies have demonstrated that exercise can reduce body mass index (BMI) in overweight and obese adults, decrease cardiovascular disease risk, and improve cardiometabolic health [22,23]. For example, aerobic training of moderate intensity improved an individual's cardiopulmonary health [22]. The intensity and duration ranges were 60–70% of VO_2max and 60–90 min, respectively [24]. HIIT features brief high-intensity exercise bouts alternating with low-intensity passive or active recovery periods [25]. HIIT can generate a potent stimulus to increase the gene expression involved in mitochondrial biogenesis and the regulation of oxidative enzymes in skeletal muscle [26]. HIIT has been shown to improve physiological and psychological adaptations related to cardiometabolic health in overweight and obese adults [27,28]. Additionally, resistance training combined with aerobic or endurance training can reduce fat mass and promote cardiometabolic benefits in obese individuals [29–31].

Hypoxia is defined as a reduction in arterial oxygen saturation, resulting in decreased oxygen supply to tissues [32]. In recent years, hypoxic exposure, also known as hypoxia conditioning, has gained increasing attention as a novel therapeutic strategy for enhancing human health [33]. Studies have demonstrated that hypoxic environments provide unique benefits, including weight loss, increased energy expenditure, enhanced fat oxidation, and improved cardiovascular function [27,34,35]. Hypoxic conditions lead to an increase in the diameter of arterioles, induce peripheral vasodilation, and result in a reduction in arterial blood pressure [21]. As an effective non-pharmacological intervention, HT does not induce side effects in obese individuals [36]. Instead, it can promote significant weight loss through negative energy balance while enhancing exercise adherence [37]. HT can confer various health benefits for overweight or obese individuals, including reduced fat mass, improved lipid profiles, regulated blood glucose levels, and enhanced insulin sensitivity [24]. The underlying mechanism can be attributed to the fact that HT has the potential to augment mitochondrial quantity, capillary density [38], the activity of glycolytic enzymes, and the expression level of glucose transporter GLUT-4 [21]. Additionally, HT has been associated with significant improvements in cognitive function in both healthy individuals and the elderly [39,40]. HT has also been shown to effectively enhance VO_2max in athletes [41,42]. Some studies have suggested that HT does not lead to significant improvements in cardiorespiratory function in obese populations [5]. However, other studies have demonstrated that HT can significantly enhance CRF [43]. Given that CRF is a critical marker of cardiovascular risk and mortality, it is essential to synthesize existing evidence through systematic reviews and meta-analyses to elucidate the effects of HT on cardiometabolic health in overweight or obese populations.

To date, only one systematic review and meta-analysis has investigated the effects of normobaric hypoxia training on cardiometabolic health in overweight or obese populations; however, it did not evaluate the benefits of CRF indicators [23]. Building on the previous research, this study aims to evaluate the effects of hypobaric/normobaric hypoxia training on cardiometabolic health in overweight or obese adults through a meta-analysis. Meanwhile, it intends to elucidate its advantages over normoxic training and further provide more precise exercise prescriptions for this population.

2. Materials and Methods

2.1. Design

This study was conducted in accordance with the PRISMA guidelines [44]. This study was registered in PROSPERO under the registration number CRD420251003429.

2.2. Literature Search

A comprehensive systematic search was conducted across five databases—PubMed, Web of Science, Embase, Scopus, and the Cochrane Library—for studies published from the inception of each database until 22 February 2025. Relevant search terms were combined using Boolean logic operators (AND, OR) to refine the search strategy. The specific search strategies and results are provided in Table S1. Additionally, the reference lists of the included studies and relevant meta-analyses were manually screened to identify potentially eligible studies that were omitted from the initial search.

2.3. Inclusion and Exclusion Criteria

The eligible studies were selected independently by two authors (HC and PL). Disagreements were resolved by a third author (XJ). The inclusion criteria were based on the PICOS principles: (1) The participants included overweight or obese adults aged ≥ 18 years with no physical constraints or health circumstances that would impede the evaluation and the exercise-related intervention. (2) The experimental group underwent training under hypobaric or normobaric hypoxia conditions, whereas the control group trained under normoxic conditions. (3) The hypoxic environment was defined as an $\text{FiO}_2 \leq 17.4\%$ or an altitude ≥ 1500 m. (4) Only randomized controlled trials (RCTs) were included. (5) The outcome measures comprised CRF (including $\text{VO}_{2\text{max}}/\text{VO}_{2\text{peak}}$), SBP, DBP, with at least one of these outcomes reported in the selected study.

The exclusion criteria were as follows: (1) studies not involving overweight or obese adults; (2) reviews, systematic reviews, and meta-analyses; (3) full-text articles unavailable; (4) full-text articles lacking the specified outcome measures; (5) studies irrelevant to the research topic; (6) studies from which outcome measures could not be extracted; and (7) non-English language studies. In the conduct of this review, only English-language studies were included. Non-English studies, even if they held valuable information, were excluded on account of the challenges in translation and ensuring correct interpretation. Failure to address these challenges properly could lead to biases in the research outcomes.

2.4. Literature Screening and Data Extraction

The predefined search strategy was applied to retrieve studies from the databases, and the resulting literature was imported into EndNote X9 software for duplicate removal. The titles of the retrieved studies were screened to exclude the irrelevant literature. Subsequently, the abstracts or full texts were evaluated against the inclusion and exclusion criteria to exclude studies that did not meet the eligibility criteria.

The primary data extracted from the included studies comprised the following: first author, publication year, experimental groups, age and gender of participants, sample

size, inclusion criteria (BMI), oxygen concentration/altitude, intervention protocol, load intensity, training duration, training frequency, and outcome measures. In studies in which the standard error (SEM) was reported, the standard deviation (SD) was calculated using the equation $SD = SEM \times \sqrt{N}$, where SD represents the standard deviation, SEM denotes the standard error of the mean, and N refers to the sample size. Two authors (HC and PL) extracted the data using a specific sheet, and any disagreements were resolved through discussion with a third author (XJ).

2.5. Risk-of-Bias Assessment for Included Studies

The Cochrane Collaboration's tool for assessing the risk of bias in randomized controlled trials (RCTs) was used to evaluate the following domains: (1) random sequence generation; (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of outcome assessment; (5) incomplete outcome data; (6) selective reporting; and (7) other potential sources of bias. The assessment of the risk of bias was carried out independently by two authors (PL and YD), and any discrepancies were resolved through discussion.

2.6. Certainty of Evidence

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) method was employed to assess the quality of evidence [45]. GRADE assesses the certainty of evidence falling into the categories of very low, low, moderate, or high.

2.7. Statistical Analysis

Meta-analysis, sensitivity analysis, subgroup analysis, and publication bias assessment were conducted on the outcome measures of the included studies using Stata 18 and RevMan 5.4 software. The outcome measures in the included studies were continuous variables. When the units of the outcome measures were consistent, the mean difference (MD) was used as the effect measure, assuming unequal variances between groups. When the units of the outcome measures were inconsistent, Hedges' g was used as the effect measure, with the exact calculation method applied to compute the bias correction factor and the Hedges and Olkin correction used to calculate the standard error of the effect size. The magnitude of the effect size was interpreted as follows: negligible (<0.2), small ($0.2-0.5$), medium ($0.5-0.8$), and large (>0.8). The heterogeneity of the outcome measures was evaluated using the I^2 statistic and p -value. If $I^2 < 50\%$ and $p > 0.1$, indicating low heterogeneity among the studies, a fixed-effects model with inverse variance was applied. Otherwise, a random-effects model using the DerSimonian-Laird method was employed. A p -value < 0.05 was considered statistically significant. If substantial heterogeneity was observed, the stability of the results was assessed using the Leave-One-Out method. Publication bias was evaluated using funnel plots or Egger's test. If the funnel plot exhibits asymmetry or the Egger's test yields a p -value < 0.05 , it is considered indicative of significant publication bias. Conversely, the absence of these findings suggests no significant publication bias.

3. Results

3.1. Subsection

A total of 5309 articles were initially retrieved from the databases. After excluding 2541 duplicate studies and 2664 irrelevant studies, a comprehensive evaluation was conducted on the remaining 104 articles. Ultimately, 17 studies met the inclusion criteria and were included in the final analysis. The flowchart of the literature screening process is presented in Figure 1.

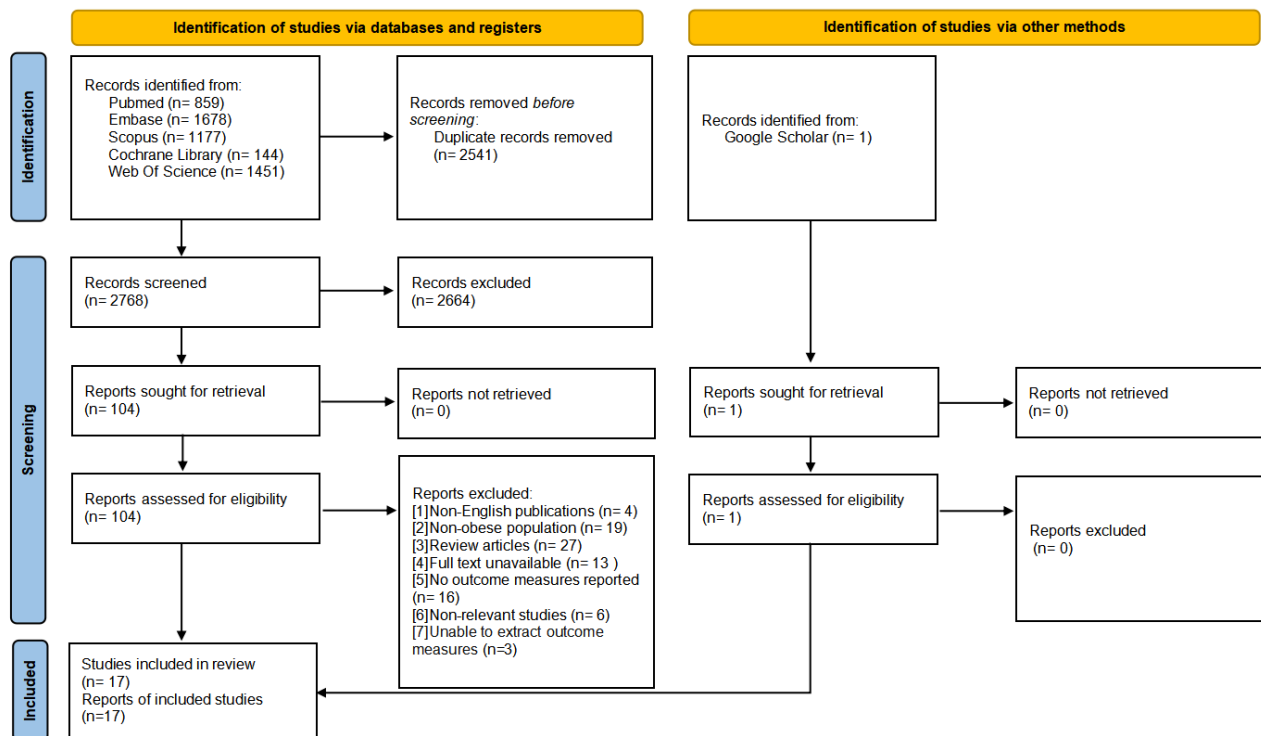


Figure 1. PRISMA flowchart of study selection.

3.2. Study Characteristics

The basic characteristics of the included studies are summarized in Table S2. A total of 517 overweight or obese adults were included in the analysis HT: 267, NT: 250. Two studies involved male participants; six studies involved female participants; eight studies included both male and female participants; and one study did not report the gender of the participants. The hypoxic conditions in the included studies ranged from 17.2% to 12% FiO₂. The interventions in the studies included walking ($n = 2$), aerobic exercise ($n = 7$), high-intensity interval training or high-intensity full sprint ($n = 4$), combined aerobic and resistance training ($n = 2$), combined training ($n = 1$), and Pilates ($n = 1$). Twelve studies reported CRF and fourteen studies reported SBP and DBP.

3.3. Risk-of-Bias Assessment Results

The risk-of-bias assessment for the included studies is presented in Figure 2. Three studies explicitly described allocation concealment. Regarding blinding, seven studies employed a single-blind design, and three studies utilized a double-blind design. Six studies reported issues with participant dropout during the intervention period. Two studies had small sample sizes, with fewer than 10 participants in the intervention and control groups. One long-term intervention study exhibited discrepancies between the actual tested sample size and the reported sample size.

3.4. Certainty of Evidence

The overall certainty of evidence underwent assessment with the application of the GRADE tool, and the findings are presented in Table S3. H-post represents the measured value after HT; H-pre represents the measured value before HT; and N-post indicates the measured value after NT. The GRADE method shows that the certainty level of DBP (H-post, H-pre) was moderate, and the certainty level of CRF and SBP was low. The level of certainty for DBP (H-post, N-post) was very low.

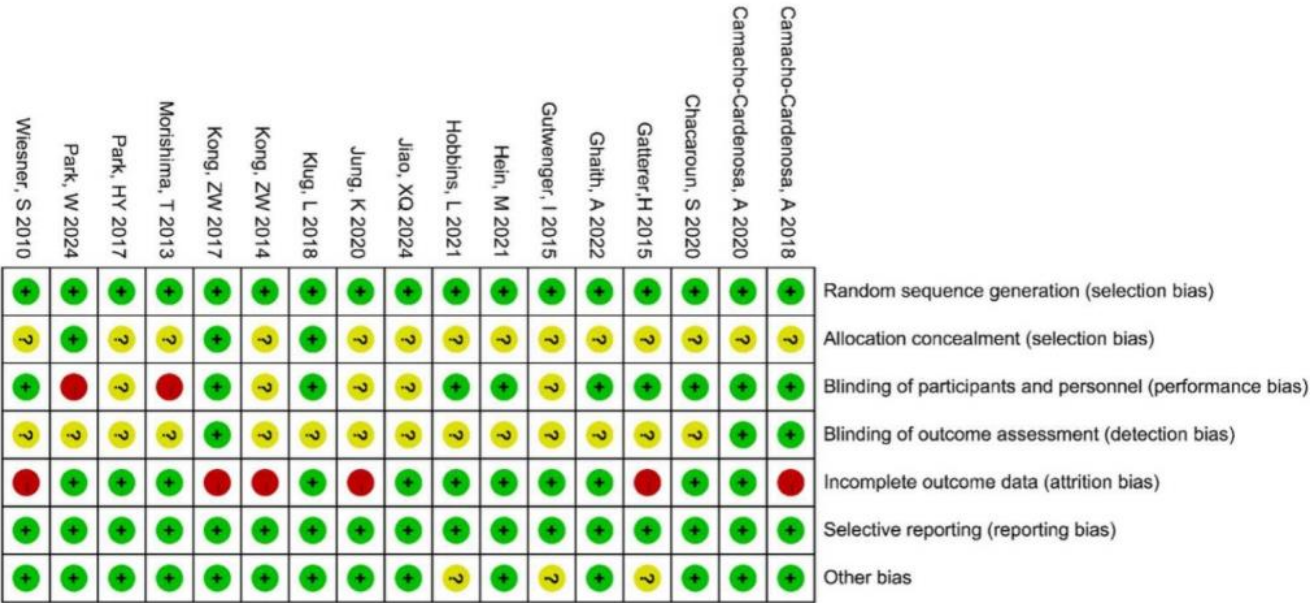


Figure 2. The risk assessment of bias [5,27,43,46–59].

3.5. Meta-Analysis

3.5.1. CRF

The analysis of CRF included 14 RCTs. Analysis of the pre- and post-HT data (see Figure 3 for individual studies) demonstrated that HT significantly improved CRF (Hedges’ g 0.42, 95% CI 0.22 to 0.62; $p = 0.00$, $I^2 = 19.51\%$). Compared with NT (see Figure 4 for individual studies), HT was significantly superior (Hedges’ g 0.34, 95% CI 0.14 to 0.54; $p = 0.00$, $I^2 = 0.00\%$).

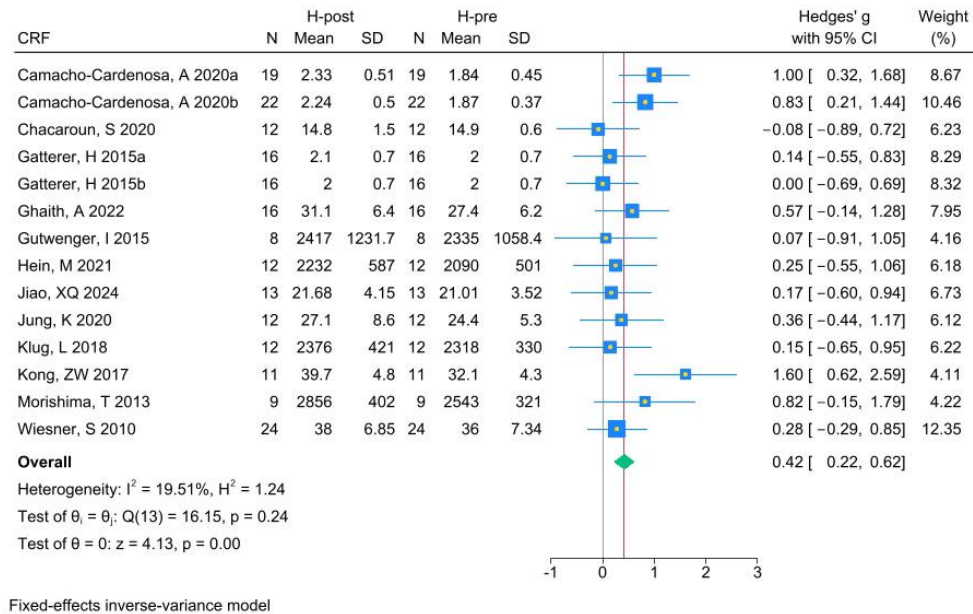


Figure 3. Forest plot of CRF (H-post, H-pre) meta-analysis [5,43,46–55].

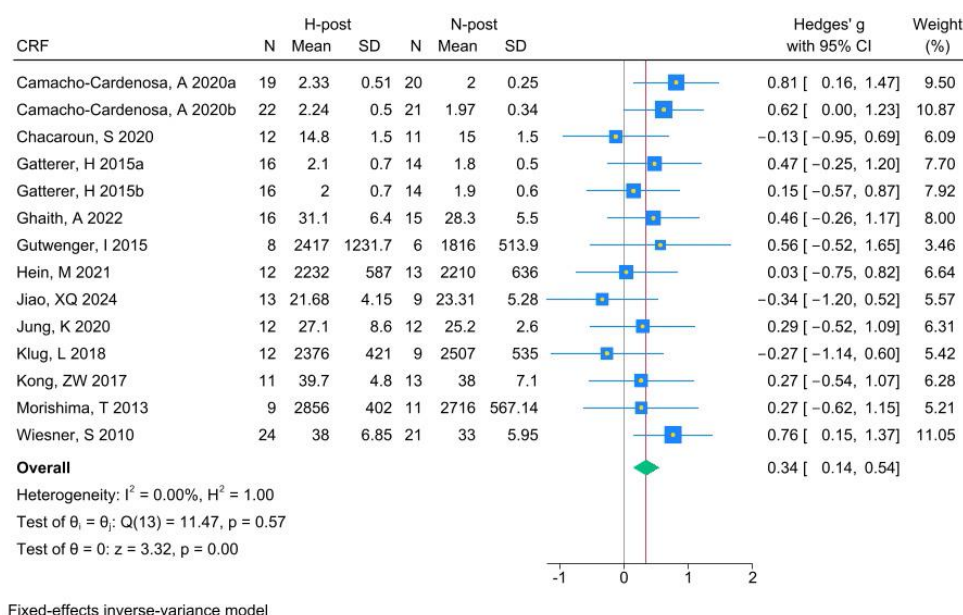


Figure 4. Forest plot of CRF (H-post, N-post) meta-analysis [5,43,46–55].

3.5.2. SBP

The analysis of SBP included 19 RCTs. Analysis of the pre- and post-HT data (individual studies are presented in Figure 5) demonstrated that HT significantly improved SBP (MD -5.19 , 95% CI -6.92 to -3.45 ; $p = 0.000$, $I^2 = 0.00\%$). Compared with NT (see Figure 6 for individual studies), there was no significant difference between HT and NT (MD -0.13 , 95% CI -2.75 to 2.49 ; $p = 0.93$, $I^2 = 42.96\%$).

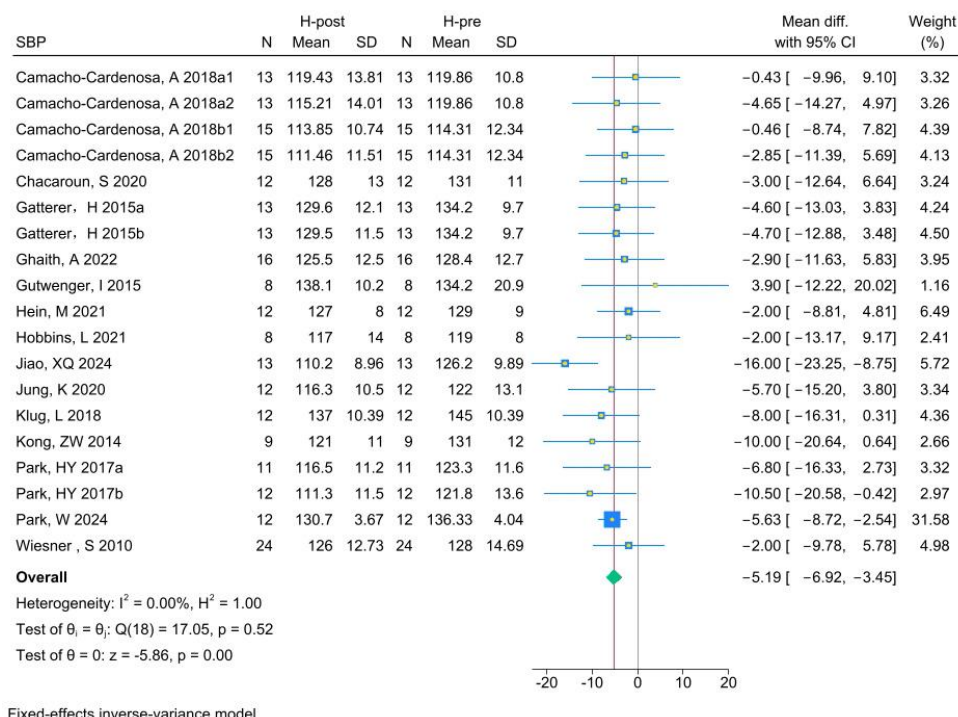


Figure 5. Forest plot of SBP (H-post, H-pre) meta-analysis [5,27,46,49–59].

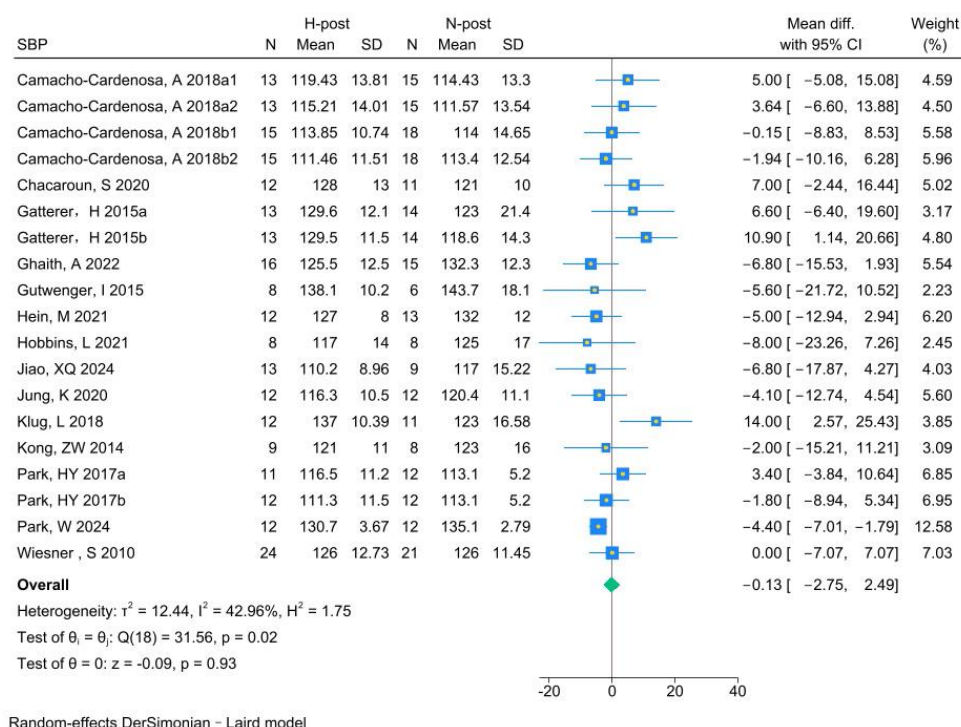


Figure 6. Forest plot of SBP (H-post, N-post) meta-analysis [5,27,46,49–59].

3.5.3. DBP

The analysis of DBP included 19 RCTs. Analysis of the pre- and post-HT data (see Figure 7 for individual studies) demonstrated that HT significantly improved DBP (MD -3.25 , 95% CI -4.59 to -1.92 ; $p = 0.00$, $I^2 = 0.00\%$). Compared with NT (see Figure 8 for individual studies), there was no significant difference between HT and NT (MD 0.05 , 95% CI -2.00 to 2.10 ; $p = 0.96$, $I^2 = 53.71\%$).

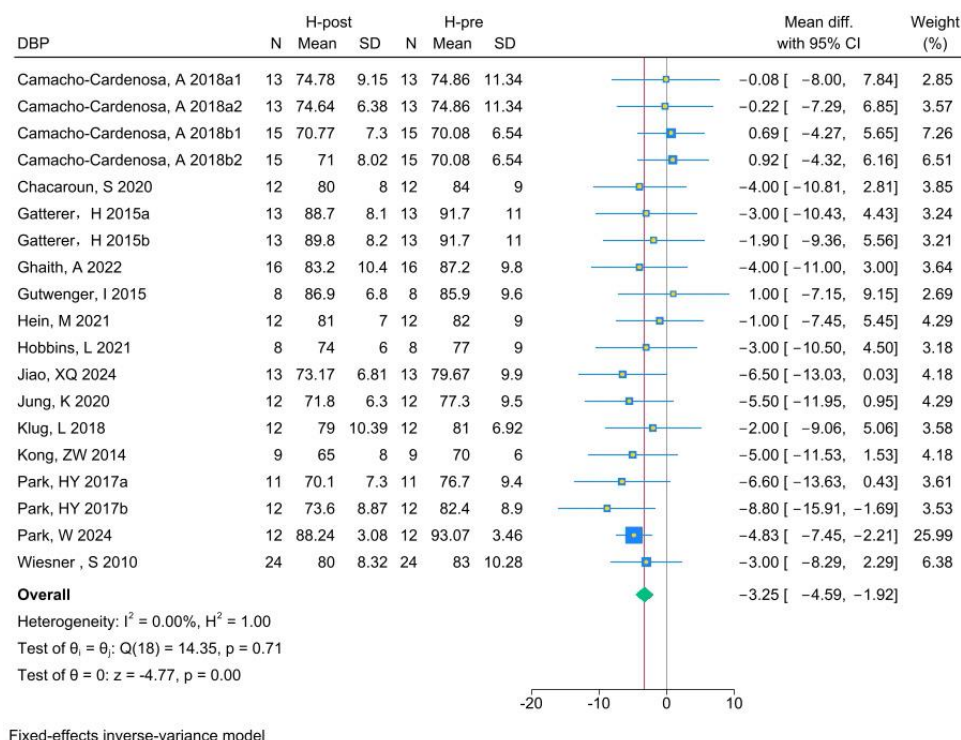


Figure 7. Forest plot of DBP (H-post, H-pre) meta-analysis [5,27,46,49–59].

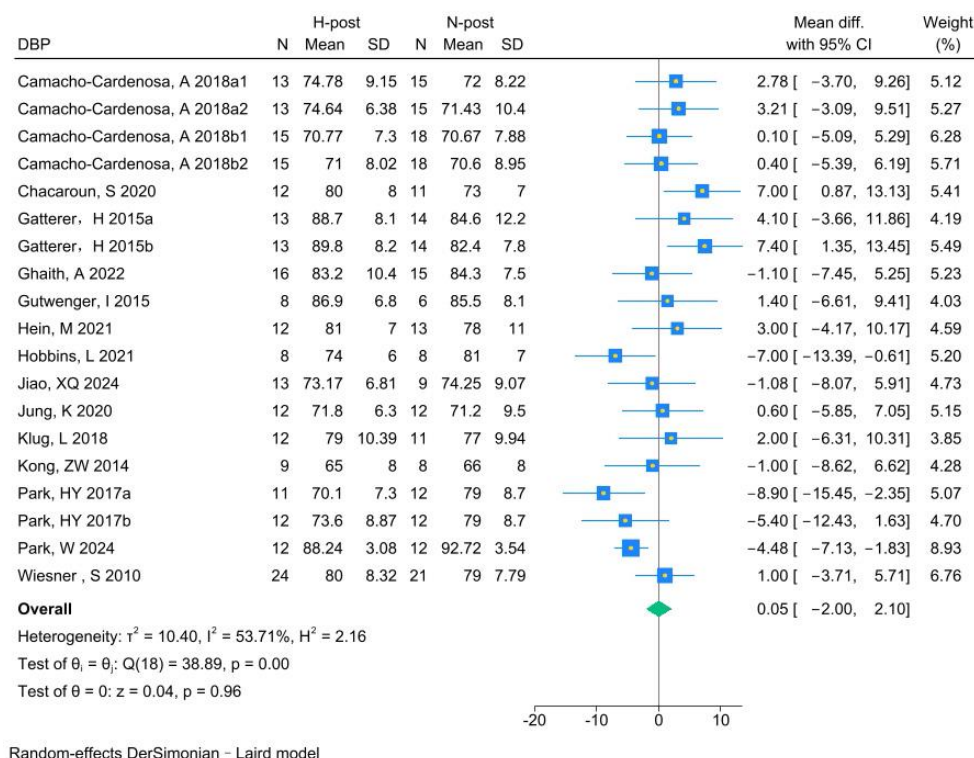


Figure 8. Forest plot of DBP (H-post, N-post) meta-analysis [5,27,46,49–59].

3.6. Sensitivity Analysis

To assess the robustness of the meta-analysis results, a Leave-One-Out sensitivity analysis was conducted for outcomes with high heterogeneity: DBP (H-post vs. N-post). The results demonstrated that, after sequentially excluding individual studies [56], the heterogeneity significantly decreased (MD 0.50, 95% CI -1.49 to 2.48 ; $p = 0.62$, $I^2 = 40\%$), and the pooled results remained consistent with the original meta-analysis findings.

3.7. Subgroup Analysis

Subgroup analyses were performed for the outcome measure CRF (H-post vs. N-post) based on age, duration, frequency, time, oxygen concentration, and exercise intensity (Figure 9). The subgroup variables included age, duration, frequency, time, FiO_2 , and exercise intensity. The results demonstrated that HT was significantly superior to NT in six aspects: age < 45 years (Hedges' $g = 0.50$, $p = 0.001$); intervention duration of 8 weeks (Hedges' $g = 0.43$, $p = 0.008$); three sessions per week (Hedges' $g = 0.40$, $p = 0.001$); each session lasting < 45 min (Hedges' $g = 0.49$, $p = 0.006$); $FiO_2 > 15\%$ (Hedges' $g = 0.69$, $p = 0.001$); and high-load-intensity exercise (Hedges' $g = 0.57$, $p = 0.001$).

3.8. Publication Bias Analysis

The funnel plots for each outcome measure exhibited slight asymmetry (Figure 10). Egger's regression tests were conducted for each outcome measure. Specifically, the p -values were as follows: CRF (H-post, H-pre): $p = 0.673$; CRF (H-post, N-post): $p = 0.0367$; SBP (H-post, H-pre): $p = 0.5022$; SBP (H-post, N-post): $p = 0.2498$; DBP (H-post, H-pre): $p = 0.422$; and DBP (H-post, N-post): $p = 0.2991$.

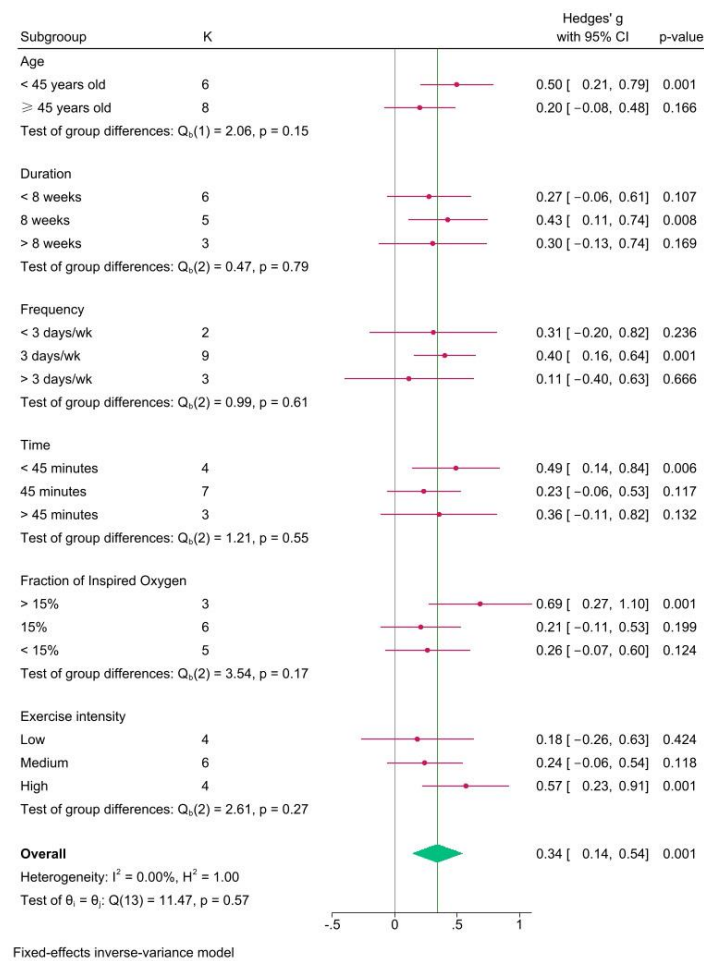


Figure 9. Results of subgroup analysis.

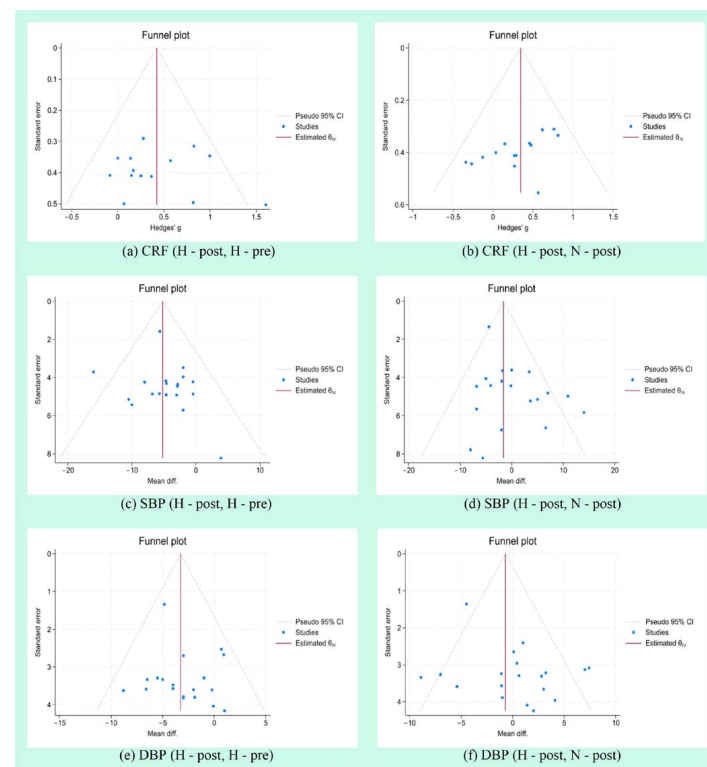


Figure 10. Publication bias analysis result.

4. Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis to comprehensively evaluate the effects of exercise training in hypobaric or normobaric hypoxic environments on cardiometabolic health in overweight or obese adults. This study aimed to assess the impact of hypoxic training on cardiometabolic health in overweight or obese adults through meta-analysis, while also elucidating its advantages compared with normoxic training. Through subgroup analysis, this study provides evidence-based hypoxic exercise prescriptions for overweight or obese adults, thereby contributing to the improvement of cardiometabolic health in this population. The primary finding of this meta-analysis is that HT significantly improved CRF, SBP, and DBP in overweight or obese adults. Compared with NT, HT demonstrated a significant advantage in improving CRF. The subgroup analysis demonstrated that HT was significantly superior to NT in the following six aspects: age < 45 years, an intervention duration of 8 weeks, three sessions per week, each session lasting < 45 min, $\text{FiO}_2 > 15\%$, and high-load-intensity exercise.

The results of this study demonstrate that HT significantly improved CRF in overweight or obese adults (Hedges' $g = 0.42$, $p = 0.00$) and demonstrated a significant advantage compared with NT (Hedges' $g = 0.34$, $p = 0.00$). Previous studies have primarily focused on the effects of various exercise modalities on cardiometabolic health in overweight or obese adults [30]. Currently, only one meta-analysis on normobaric hypoxic training has investigated its effects on cardiometabolic health in overweight or obese individuals [23]; however, that study did not include any content related to CRF. The results of a network meta-analysis indicated that various hypoxic training paradigms can effectively improve $\text{VO}_{2\text{max}}$ in healthy adults [60], which is consistent with the results of the present study.

A meta-analysis of the effects of altitude training on the aerobic capacity of athletes demonstrated that HT did not significantly affect $\text{VO}_{2\text{max}}$ but could significantly increase hemoglobin levels in athletes [61]. $\text{VO}_{2\text{max}}$ is one of the most important markers of CRF [5]. The mechanisms underlying hypoxia-induced improvements in $\text{VO}_{2\text{max}}$ are not yet fully understood [62]. A potential mechanism is that the body increases erythropoietin (EPO) production in hypoxic environments, promoting an increase in red blood cell count in the bloodstream [63]. This leads to an increase in hemoglobin levels, enabling the transport of more oxygen to various tissues in the body, thereby enhancing the body's maximal aerobic metabolic capacity [64]. Compared with hypoxia stimulation alone, exercise combined with a hypoxic environment appears to be more effective in promoting CRF in humans [65], primarily reflected in greater improvements in $\text{VO}_{2\text{max}}$. The primary reason is that HT enhances the body's physiological responses and adaptive capacity to hypoxia, thereby improving $\text{VO}_{2\text{max}}$ [62]. This anti-hypoxic physiological response and adaptive capacity can be more effectively mobilized in younger individuals [43], which corroborates the findings of the subgroup analysis in this study, in which, compared with NT, individuals aged < 45 years showed a significant improvement in CRF after HT (Hedges' $g = 0.50$). Our analysis found that when $\text{FiO}_2 > 15\%$, HT had a better effect on CRF in overweight or obese individuals (Hedges' $g = 0.69$, $p = 0.001$).

Although current studies have confirmed that moderate- or high-intensity training in hypoxic environments is safe and feasible [48,66], exercising in hypoxic environments also induces greater metabolic responses and increases the level of fatigue in the body [67]. However, studies have demonstrated that the effects of exercise on subjective perceived fatigue are similar in hypoxic and normoxic environments, and there is no gender disparity [68]. When the oxygen concentration is too low, it may also cause harm to the cardiovascular system. Some studies have demonstrated that combining hypoxic stimulation with low- or moderate-intensity training does not lead to significant improvements in CRF [69,70]. When hypoxia is combined with high-intensity training (e.g., $>60\%$ HRR, $>77\%$ HRmax,

>64% VO_2max), it increases the stimulation of the cardiovascular system, thereby enhancing the body's adaptive capacity [48]. Simultaneously, under conditions of reduced cellular oxygen supply, lower blood oxygen saturation can trigger the transactivation of hypoxia-inducible factors (HIFs) [71]. High-intensity training can significantly improve brachial artery flow-mediated vasodilation, thereby increasing VO_2max to a greater extent [72]. Therefore, combining hypoxic stimulation with high-intensity training may lead to greater improvements in CRF.

Current studies have found that the duration of high-intensity hypoxic training for overweight or obese adults is maintained between 16 and 42 min [28,43,48,59,73], and the intervention period is mostly 12 weeks [28,43,59,73], the frequency of interventions is mostly three times per week [5,28,43,59,73]. This is consistent with the subgroup analysis in this study, in which high-intensity exercise (Hedges' $g = 0.57$, $p = 0.001$), each session lasting < 45 min (Hedges' $g = 0.49$, $p = 0.006$), and three sessions per week (Hedges' $g = 0.66$, $p = 0.040$) significantly improved CRF. Unlike previous findings, the intervention period no longer requires 12 weeks; an 8-week intervention (Hedges' $g = 0.43$, $p = 0.008$) can significantly impact CRF in overweight or obese adults.

A growing body of research indicates that implementing HIIT is beneficial [74–76]. HIIT can be divided into high-volume, high-intensity interval training and low-volume, high-intensity interval training according to the cumulative duration of 15 min of high-intensity exercise [77]. Among them, for low-volume, high-intensity interval training, low-intensity recovery exercises are arranged between every two high-intensity exercise sessions. In contrast, for high-volume, high-intensity interval training, the total duration of high-intensity exercises is no more than 15 min, and this time scope does not include the durations of the warm-up phase, the intervals, and the recovery stage [78]. This form of exercise is currently favored by young people, as it does not require a long duration of physical activity [79], achieves significant fat loss results [80,81], and provides substantial benefits for cardiometabolic health [82,83]. Therefore, we recommend that overweight or obese young individuals (aged < 45 years) engage in HIIT under hypoxic conditions ($\text{FiO}_2 > 15\%$) for 8 weeks, with three sessions per week and each session lasting less than 45 min, to enhance CRF and improve cardiometabolic health.

Numerous studies have demonstrated that both individuals with hypertension and those with normal blood pressure can effectively reduce their blood pressure through exercise [49,84,85], and this effect is independent of weight loss [86]. This is also consistent with our analysis results. Compared with pre-intervention, HT significantly improved SBP ($\text{MD} = -5.19$, $p = 0.00$) and DBP ($\text{MD} = -3.25$, $p = 0.00$) in overweight or obese adults. Additionally, in our study, the baseline blood pressure values of these overweight or obese adults were all within the normal range. However, in the comparative analysis with NT, no significant advantage of HT was observed, which aligns with the findings of previous studies [23].

HT does not provide additional benefits in terms of improving blood pressure. The development of hypertension is closely related to excessive activity of the sympathetic nervous system [87]. For individuals with hypertension, the increased production of nitric oxide and enhanced bioavailability triggered by exercise may serve as the primary physiological mechanisms for lowering blood pressure [88,89]. Obesity exacerbates the risk of cardiometabolic diseases and is also a significant risk factor for hypertension [90]. Currently, in addition to long-term reliance on medication to control blood pressure, exercise has been recommended as an effective approach to prevent elevated blood pressure [91]. Research has shown that HIIT can significantly improve blood pressure in overweight or obese individuals by approximately 3–5 mmHg [91]. HIIT had the most beneficial effect on improving CRF in overweight and obese adults [74], which corresponds to one aspect of our

recommendation: encouraging overweight or obese adults to engage in HIIT to improve cardiometabolic health. The potential physiological mechanisms by which high-intensity exercise improves blood pressure may be related to the observed enhancements in vascular endothelial function and autonomic nervous system regulation during high-intensity exercise interventions [30]. Research has indicated that, compared with other types of exercise, combined and hybrid training can yield the most beneficial effects on cardiometabolic health indicators [30]. Although our study confirmed that HT can improve blood pressure in overweight or obese adults, the effects of hypoxic and normoxic environments on blood pressure improvement were similar. The impact of combining hypoxic stimulation with exercise on blood pressure remains unclear. Future research should focus on exploring the potential of combining different types of exercise with hypoxic training paradigms to determine the possible effects of HT on improving cardiometabolic health indicators. This will help continuously optimize the best exercise prescriptions for HT to enhance cardiometabolic health in overweight or obese adults.

Limitations: Among the 17 included studies, 6 reported varying degrees of participant attrition, and 2 studies had sample sizes of fewer than 10 participants. The types of exercise examined in the included studies were diverse; however, after further categorization, certain exercise types, such as combined training and Pilates, were represented by only one study each. This limitation hindered our ability to perform more detailed subgroup analyses across different exercise types. Among the included studies, the subjects in eight studies were analyzed as a combined group of males and females. Therefore, it was not possible to conduct a subgroup analysis by gender. In terms of age, in this study, 45 years old was taken as the benchmark, and the subjects were divided into young individuals and middle-aged and elderly individuals. Due to the limitation of the number of studies, there was no further distinction made between middle-aged and elderly individuals. The prescription of exercise intensity has always been a challenging task [92]. Owing to the limited number of studies, we were unable to explore the exercise intensity prescription for HIIT under hypoxic conditions in overweight or obese adults; instead, we only suggested that the intervention duration should be less than 45 min. Future research should prioritize determining the optimal exercise intensity prescription for HIIT under hypoxic conditions in overweight or obese adults.

5. Conclusions

HT demonstrates favorable effects in improving cardiometabolic health among overweight or obese adults. Compared with NT, this advantage is primarily reflected in CRF, while the effects on SBP and DBP are similar. It is recommended that young adults who are overweight or obese engage in HIIT under hypoxic conditions ($\text{FiO}_2 > 15\%$). The recommended intervention should span 8 weeks, with three sessions per week, and each session should not exceed 45 min.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/life15040566/s1>: Table S1: Search strategy; Table S2: Main characteristics of studies included in the meta-analysis; Table S3: Certainty of evidence for meta-analyzed outcomes.

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