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Occupational Health Promotion Programs on Cardiometabolic risk factors: A Systematic Review and Three-Level Meta-Analysis

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Abstract

Background: *This study aimed to evaluate the effectiveness of workplace-based health promotion programs targeting cardiometabolic risk factors.* **Methods:** *We conducted a systematic review and three-level random-effects meta-analysis following PRISMA guidelines, covering studies published from January 2019 to September 2024. Eligible studies included randomized controlled trials (RCTs) and quasi-experimental (QE) designs assessing workplace interventions to reduce cardiometabolic risks in adult workers. Twelve outcomes were considered. Subgroup analyses and meta-regressions were performed to explore sources of heterogeneity. Certainty of evidence was evaluated using GRADE assessment tool.* **Results:** *Forty-four studies (30 RCTs, 14 QE) involving 49,813 participants were included. Significant improvements were found in nine of twelve outcomes. These included reductions in BMI (–0.61kg/m*^{2}*; [–0.93; –0.29]), body weight (–2.43kg; [–3.48; –1.38]), waist circumference (–3.46cm; [–5.21; –1.71]), body fat (–1.58%; [–2.40; –0.76]), systolic (–3.75mmHg: [–5.67; –1.82]) and diastolic (mmHg; [-3.58; -1.29]) blood pressure, LDL cholesterol (–5.9 mg/dL; [–11.6; –0.12]), and an increase in HDL cholesterol (2.76 mg/dL; [0.42; 5.09]). All significant outcomes were supported by moderate-to-high certainty evidence except LDL cholesterol, which was rated very low. Non-significant results were observed for total cholesterol, triglycerides and FBG. High heterogeneity was observed. Pre-existing health conditions, author and duration of intervention partially explained between-study heterogeneity.* **Conclusions:** *Workplace health promotion programs were associated with improvements in various cardiometabolic health indicators. Greater effectiveness was observed in interventions targeting high-risk populations, delivered by physicians or qualified health professionals, and implemented over shorter durations. Findings support the integration of such programs into occupational health policies and broader public health strategies. Future research should optimize intervention designs, extend follow-up, and consider integrated approaches to maximize long-term benefits.*

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1. Introduction

The World Health Organization (WHO) defined health in 1946 as a "state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [1].

This holistic concept was further developed forty years later with the Ottawa Charter which described health promotion as "the process of enabling people to increase control over, and to improve, their health" [2]. Therefore, achieving a state of complete physical, mental and social well-being requires the ability to fulfil aspirations, satisfy needs, and change or cope with the environment, emphasizing health as a positive resource encompassing personal, social, and physical capacities [2].

Health determinants extend beyond medical factors including economic, political, social, cultural, environmental, and behavioral influences [3]. Accordingly, health promotion transcends the healthcare sector, requiring coordinated effort across all policy domains to address the broad range of health determinants and foster overall well-being. Within this framework, the workplace stands out as a strategic setting with the unique potential to simultaneously address multiple health factors and as a pivotal environment for such initiatives. This role was already emphasized at the Alma Ata Conference [4] held in 1978 which called for a joint effort among various sectors relevant to enhancing primary health care, "in particular agriculture, animal husbandry, food, industry, education, housing, public works, communications […]". To date, the importance of workplaces is even more evident. According to World Bank data estimates, the total labor force worldwide is approximately 3.65 billion [5] with a global 57.8% employment-to-population ratio in 2025 [6]. These data emphasize the importance of creating "healthier, safer, and more resilient workplaces" where individuals can perform their jobs without experiencing illness or injury due to work-related factors, while also having opportunities to improve their physical and mental health, and their social well-being [7]. In this context, the Total Worker Health (TWH) approach, advocated by the US National Institute for Occupational Safety and Health (NIOSH), integrates all aspects of work into cohesive interventions that address worker safety, health, and well-being. It is defined as policies, programs, and practices that combine protection from work-related safety and health hazards with the promotion of injury and illness prevention efforts to advance worker well-being [8]. This integrated approach emphasizes how the workplace environment can eliminate or reduce risks while enhancing worker health. It extends beyond traditional safety and health concerns by recognizing the interplay between work-related and non-work-related conditions. The TWH model acknowledges that workplace risk factors may contribute to health issues previously considered unrelated to work, such as obesity, sleep disorders, cardiovascular diseases, and depression [8].

Specifically, the prevention of cardiometabolic diseases represents one of the most significant focus areas for health promotion due to their high prevalence, often dire health consequences, and large socio-economic impact [9]. To date, only a few systematic reviews and meta-analyses [10–12] have been conducted to objectively measure the effectiveness of workplace health promotions interventions on cardiometabolic risk factors. Moreover, these previous studies focused exclusively on targeted populations, specific interventions, or single-component outcomes. Notably, Peñalvo et al. [13] investigated the effects of multicomponent workplace wellness programs on cardiometabolic health through a comprehensive meta-analysis of more than 30 years of studies published until June 2020. Their results displayed improvements in specific dietary, anthropometric, and cardiometabolic risk indicators while no definite drivers for in-between study heterogeneity such as socio-demographic, work-related or intervention characteristics were found.

Through a systematic review and meta-analysis of studies on workplace interventions targeting cardiometabolic risk factors published during the last five years, we aim to update the extant body of knowledge on this rapidly evolving field and extend previous insights by analyzing potential sources of heterogeneity and evaluating study quality with standardized assessment methods. Moreover, the results are expected to provide evidence-based recommendations for the development of future workplace health promotion programs, and to guide the integration of cardiometabolic health promotion into broader TWH frameworks.

2. Methods

This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-statement [14] and the Conducting Systematic Reviews and Meta-Analysis for Observational Studies of Etiology (COSMOS-E) [15] guide. The review protocol was registered on the international prospective register of systematic reviews (PROSPERO; Registration NO CRD42024617116).

2.1 Data Sources and Search Strategies

A systematic literature search was conducted in MEDLINE (PubMed), Web of Science and Embase-Ovid to identify studies published between January 1, 2019, and September 9, 2024, that evaluated the effectiveness of workplace health promotion programs targeting cardiometabolic health. A preliminary string was developed in August 2024 and initially launched on PubMed, before being adapted for the other databases. The search strings included terms such as "Health Promotion", "Health Education", "Health Campaign", "Well-being Program", and "Health Incentive Program." These were combined with workplace-related terms like "Work", "Workplace", "Occupations", "Occupational Groups", "Worker," and other terms related to cardiovascular risk factors such as "Blood Pressure", "Waist Circumference", "Body Mass Index", "Smoking Cessation", "Cholesterol", "Body Weight", "Triglycerides", "Waist-Hip Ratio", and "Blood Glucose." The complete search strings can be found in Supplementary Table 1. A research librarian was involved in the database searches to ensure methodological rigor, completeness, and accuracy.

2.2 Eligibility Criteria

Two reviewers (EP, MVP) independently screened the list of titles, abstracts and full text articles, using the Rayyan intelligent tool for systematic reviews [16]. Studies selected for full-text review were independently assessed for inclusion, with any discrepancies resolved through consensus.

The inclusion criteria were the following:

- Population: adult population at the workplace
- Intervention: single or multicomponent health promotion intervention at the workplace that targets the reduction of cardiovascular risk factors.
- Design: interventional controlled trials, including randomized controlled trials (RCTs) or quasi-experimental studies (QE).
- Publication: articles published in the last five years (between January 1, 2019, to September 9, 2024).
- Outcome: objective parameters (such as anthropometric, hematological measures, and smoking cessation) related to cardiovascular risk factors
- Effect measure: estimates of the difference in the specified outcome and a measure of uncertainty (e.g. confidence interval or standard error), or sufficient data to compute them.
- Language: studies written in English or Italian.
- A detailed summary based on the PICOS framework is presented in Supplementary Table 2.

2.3 Data Extraction

Two reviewers (EP and MVP) independently extracted relevant data from the selected papers. Extracted data was organized into five main categories: publication details, workplace characteristics, workers details, intervention characteristics and outcome measures.

Publication details included: author, publication year, geographical region, study design, use of randomization and its type (cluster or individual).

Among the workplace characteristics we extracted: work sector, number of sites involved, company size (small: <50 employees, medium: 50-249 employees, large: ≥250 employees).

Workers' details included type of control sample, job title, ISCO-08 code from the International

Labour Organization (ILO), classification as white collar and/or blue collar, mean age, predominant ethnicity, mean work seniority, education level, number of smokers and alcohol consumers, physical activity (number of sedentary and active individuals, following WHO 2020 guidelines [17] with sedentary being less than 150 minutes of moderate to intense physical activity per week), type of contract, type of work shift (day and/or night), monthly salary, health status of participants (healthy and/or affected by specific diseases/cardiovascular risk factors).

Intervention characteristics included: area of interest (single or multiple, between dietary habits, physical activity, smoking cessation, stress management, sleep hygiene, health screening, alcohol consumption reduction), and type of intervention (1. Individual communication: mobile-based/smartphone app, online lesson, interactive website, newsletter, nutritional program to follow, coach support, booklet/paper, phone call, postal letter, recurrent computer messages, sleep hygiene program, scheduled health check-ups, nicotine replacement treatment, text messages; 2. Group communication: in-person lessons, social media communication, gamification; 3. Physical activity: physical exercises; 4. Self-awareness: relaxation techniques, workplace quit smoking program, quit smoking program, stress management techniques, quit drinking program), duration of the intervention, number of interventions (total number and monthly), modality of intervention (in-person and/or online), professional figure involved (physicians: if at least one physician was involved; other healthcare professional: if at least one among nurses, nutritionists, physiotherapists, psychologists was involved; other: if the intervention was conducted by non-medical staff (e.g., sports instructors, teachers, social services, colleagues, cooking experts)), involvement of the management in the planning phase, financial incentives, and re-engagement.

Finally, the following *outcome measures*, extracted as continuous effect sizes (ES), were selected: Body Mass Index (BMI) (kg/m^2), body weight (kg), total cholesterol (mg/dL), HDL cholesterol (mg/dL), LDL cholesterol (mg/dL), triglycerides (mg/dL), systolic blood pressure (SBP) (mmHg), diastolic blood pressure (DBP) (mmHg), body fat percentage, waist circumference (cm), fasting blood glucose (FBG) (mmol/L), smoking cessation.

If possible, missing data was resolved by assumptions agreed upon by two investigators (AG and II). The full list of assumptions is available in Supplementary Table 3.

2.4 Quality of Study Assessment

The quality of the studies was independently assessed by two reviewers (EP and MVP) using a previously established scoring system [13, 18–20], which has been applied for similar works. It is based on five criteria: study design, assessment of exposure, assessment of outcome, control for confounding, and evidence of selection bias. A binary score can be attributed to each criterion (0-1). The overall score results from the sum of individual scores with 0–3 scores considered as low-quality and 4–5 considered high-quality. The detailed list of the bias assessment criteria is available in Supplementary Table 4.

2.5 Quality of Evidence Assessment

The GRADE (Grading of Recommendations Assessment, Development and Evaluation) framework was employed to evaluate the overall certainty of evidence across studies for each outcome [21]. This framework classifies the quality of evidence in systematic reviews into four levels: "high," "moderate," "low," and "very low." The initial certainty level was set high, given that most of the studies included were RCTs. The certainty of evidence was subsequently assessed for potential downgrading. Decisions regarding upgrading or downgrading are based on the criteria and considerations outlined in the GRADE handbook [22]. Reasons for downgrading include: studies' limitations, indirectness of evidence, inconsistencies across findings, imprecision, and potential publication bias. The evaluations of these criteria were primarily informed by results from the study quality assessment, measures of heterogeneity, points estimates and confidence intervals and publication bias. Criteria for upgrading are large magnitude of effect size, presence of a dose-response gradient and plausible confounding factors that reduce the effect size. The assessment of evidence quality was conducted independently by two reviewers (MVP and EP), and discrepancies were resolved through discussion with a third reviewer (AG) to achieve consensus.

2.6 Statistical Analysis

Multiple inverse-variance random effects multilevel meta-analyses were conducted to account for dependencies between study-specific effect sizes. The multilevel approach allows for the consideration of both the variance in effect sizes within the same study (level 2) and the variance between different studies (level 3). The restricted maximum likelihood (REML) estimator was used to calculate between study heterogeneity $\tau2$. Statistical heterogeneity was assessed using Cochran's Q test and I^2 statistics. To determine whether the more complex three-level models provided a significantly better fit to the data compared to simpler two-level models, we employed likelihood ratio (LR) tests and compared Akaike Information Criterion (AIC) values across models.

Subgroup meta-analyses were performed for outcomes with more than 10 effect sizes to explore potential sources of heterogeneity related to study design, geographic location, workplace setting, enterprise size, type of worker, presence of pre-existing health risks, intervention modality, main provider of the intervention, economic incentives, involvement of management in intervention planning and study quality. We used Knapp-Hartung adjustment [23] to reduce the risk of false significant effects. We also conducted a series of meta-regressions to investigate the association of included outcomes with participant mean age, study size, number of interventions per month, prevalence of male participants, and overall intervention duration. Multiple meta-regressions were not conducted due to an insufficient number of studies to provide reliable estimates and ensure adequate statistical power. Potential publication bias and small study effect were assessed through an adaptation of Egger's Test for multilevel meta-analysis using the standard errors as moderators and the visual inspections of funnel plots. Finally, a leave-one-out sensitivity analysis was conducted to assess the robustness of the findings by iteratively removing one study at a time and examining the impact on the overall effect estimates. All analyses were performed using RStudio (version 4.4.3) [24].

Where necessary, ESs were standardized by converting measurement units. The difference between intervention and control group changes at follow-up was either directly extracted or computed from the available data. Standard errors (SE) of the ESs were extracted or computed from available estimates whenever possible. If no relevant statistics were available, SEs were computed on the following assumptions: for paired observations without reported covariance (within-group changes at follow-up) we applied a correlation coefficient of 0.9 when loss to follow-up was below 10%, and 0.5 when loss exceeded 10%. For independent samples (between-group change at follow-up) we used a correlation coefficient of 0.

3. Results

The literature search returned 6069 articles. After removing duplicates (n = 641), 5,428 articles remained. After screening the titles and abstracts, 110 were found to be relevant for retention. Then, the full texts were examined and assessed against exclusion and inclusion criteria. Sixty-six articles did not meet the eligibility criteria. Finally, a total of 44 publications (25–68) were included, comprising 30 RCTs and 14 QE studies. Details of the search process and selection of studies are provided in Figure 1.

The full list of included articles together with their main characteristics is reported in Table 1. Most studies were conducted in Europe (n=14), and Asia (n=14), followed by North America (n=8), Middle East (n=4), South America (n = 3) and New Zealand (n=1). The occupational sectors in which the effectiveness of health promotion interventions was assessed included the tertiary sector (n=16), healthcare (n=9), industry (n=9), mixed sectors (n=6), and unspecified sectors (n=4). Concerning the number of worksites adhering to the interventions, 33 studies reported engaging between 1 and 60 sites, while 11 articles did not provide this information. The reported dimension of the enterprise involved was large for 24 studies and medium for 6 studies. Fourteen articles did not specify the company

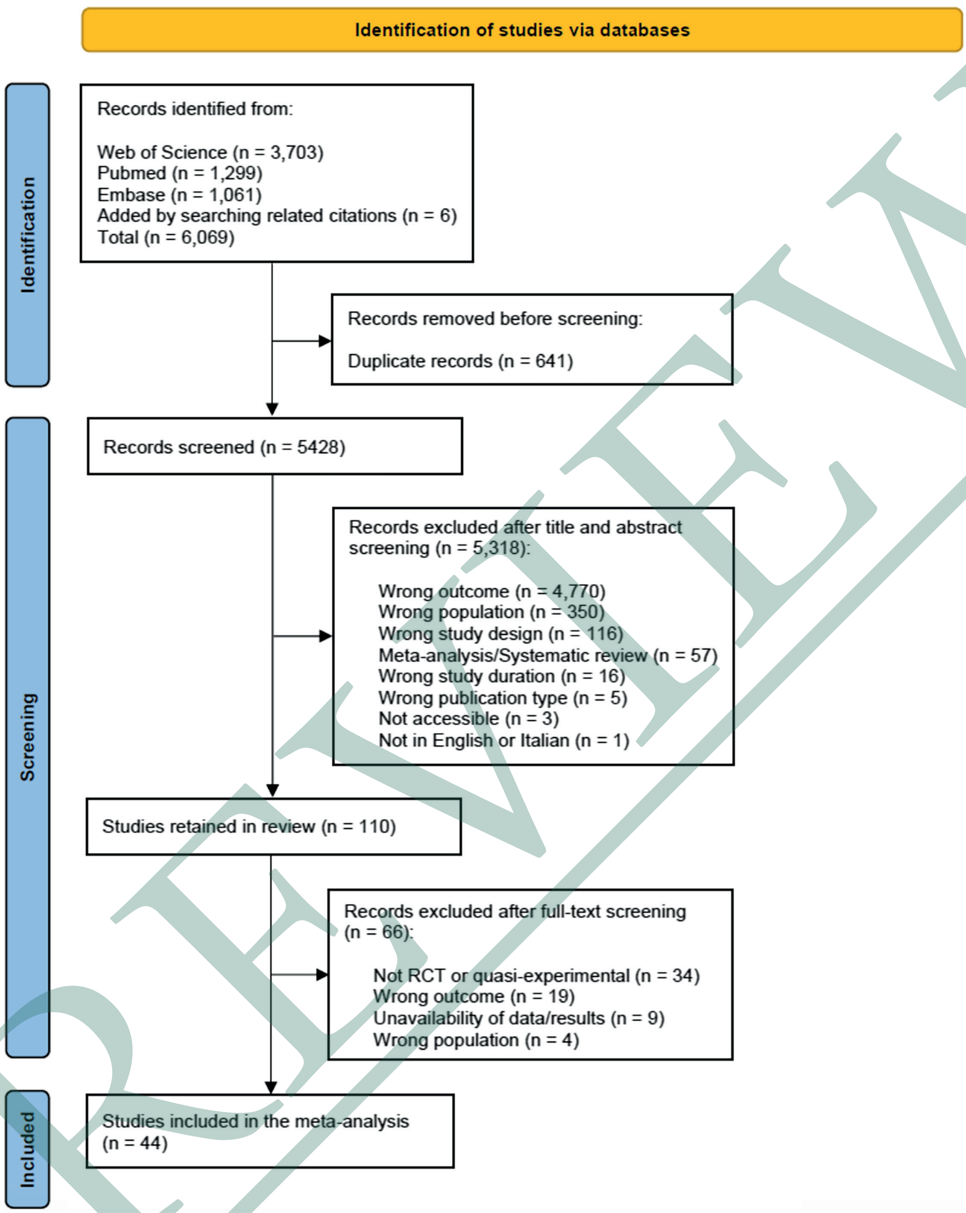

Figure 1. Study selection according to the PRISMA-flow diagram.

size. Numbers of participating employees varied considerably between studies (median 110, range 16-24396) with an overall number of participants of 49,813 (cases: 32,457, controls: 17356). The average duration of the intervention was 9.28 months (range: 1-60). Most represented areas of intervention targeted physical activity (86%, 38/44), dietary habits (48%, 21/44), followed by smoking cessation (18%, 8/44), stress management (14%, 6/44), alcohol drinking behavior (5%, 2/44) sleep hygiene (2%, 1/44), with 19 studies (43%) having more than one target. Concerning the modality of intervention, 21 (48%) adopted both web-based and in-person interventions. The most represented outcomes were BMI (n=30), body weight (n=19) and systolic blood pressure (n=20). (Supplementary Table 5). The mean quality score assessment was 4.0 (± SD 1.1) with 32 high-quality studies and 12 low-quality studies

Table 1. Main characteristics of the included studies.

First Author and year	Country	Design	Working sector	Number of employees	Number of sites	Modality of intervention	Duration (months)	Outcome	Quality Score
Arrogi et al, 2019(25)	Belgium	QE	Industry	300	4	Individual communication, Group communication, Physical exercise	9	BMI, body fat %, WC	3
Asfar et al, 2021(26)	USA	RCT	Industry	134 males	17	Individual communication, Group communication, Self-awareness	6	Smoking cessation	5
Barranco-Ruiz et al, 2019(27)	Ecuador	RCT	Tertiary	98	1	Physical exercise	4	BMI, body weight, SBP, DBP, body fat %,	4
Clemes et al, 2022(28)	UK	RCT	Tertiary	382	Unknown	Individual communication, Group communication, Physical exercise	18	BMI, weight, TOT-Chol, HDL, LDL, TG, body fat %, WC	5
Day et al, 2019(29)	USA	RCT	Tertiary	421	10	Individual communication, Group communication, Physical exercise	6	Weight	4
Diaz-Benito et al, 2021(30)	Spain	RCT	Unknown	72	Unknown	Individual communication, Group communication, Physical exercise	3	BMI, weight, WC	4
Fang et al, 2019(31)	Taiwan	RCT	Industry	75	Unknown	Group communication, Physical exercise	3	BMI, weight, TOT-Chol, HDL, LDL, TG, SBP, DBP, body fat %, WC	5
Garcia-Rojas et al, 2021(32)	Mexico	QE	Healthcare	2002	7	Individual communication, Group communication, Physical exercise	12	SBP, DBP	3
Gerodimos et al, 2021(33)	Greece	RCT	Healthcare	54	1	Group communication, Physical exercise	1,5	SBP, DBP, body fat %	5

(*continued*)

First Author and year	Country	Design	Working sector	Number of employees	Number of sites	Modality of intervention	Duration (months)	Outcome	Quality Score
Gimenez et al, 2024(34)	Brazil	RCT	Healthcare	28 females	1	Individual communication, Group communication, Physical exercise	2	BMI, weight, TOT-Chol, HDL, LDL, TG, WC, FBG	4
Guirado et al, 2024(35)	France	RCT	Tertiary	40 females	6	Group communication, Physical exercise	3	BMI, weight, TOT-Chol, HDL, LDL, TG, WC, FBG	4
Hassani et al, 2020(36)	Iran	RCT	Industry	92 males	1	Group communication, Individual communication	3	BMI, weight, body fat %, FBG	5
Hee Woo et al, 2019(37)	South Korea	RCT	Healthcare	68	Unknown	Individual communication, Group communication, Physical exercise	3	BMI, TOT-Chol, HDL, LDL, TG, SBP, DBP, WC, FBG	4
Hu et al, 2023(38)	China	RCT	Various	24396	60	Individual communication, Group communication, Physical exercise, Self-awareness, Environmental	24	SBP, DBP, smoking cessation	5
Iturriaga et al, 2019(39)	Spain	RCT	Unknown	63 females	Unknown	Group communication, Physical exercise	3	BMI, body fat %	4
Jorvand et al, 2020(40)	Iran	QE	Healthcare	114	8	Individual communication, Group communication, Physical exercise	6	TOT-Chol, HDL, LDL, TG, FBG	3
Karatrantou et al, 2020(41)	Greece	RCT	Tertiary	40	8	Group communication, Physical exercise	6	SBP, DBP, body fat %	4
Kim et al, 2023(42)	South Korea	QE	Unknown	296 males	Unknown	Group communication, Individual communication, Self-awareness	6	Smoking cessation	4
Kim et al, 2022(43)	South Korea	RCT	Various	50 females	Unknown	Individual communication, Physical exercise	6	TOT-Chol, HDL, LDL, TG, FBG	4

Koch et al, 2022(44)	Germany	RCT	Tertiary	120	1	Group communication, Physical exercise	6	SBP, DBP	5
Kong et al, 2022(45)	China	RCT	Unknown	388	2	Individual communication, Group communication, Physical exercise, Environmental	12	BMI, WC	5
Kotejoshyer et al, 2021(46)	USA	RCT	Tertiary	269	1	Individual communication, Group communication, Physical exercise	60	BMI, body fat %	5
Kugathasan et al, 2023(47)	Canada	QE	Tertiary	524	8	Individual communication, Group communication, Physical exercise	16	BMI, weight	3
Lennefer et al, 2020(48)	Germany	RCT	Industry	121	1	Individual communication, Group communication, Physical exercise	1	BMI	4
Ma et al, 2021(49)	Japan	RCT	Industry	75	1	Individual communication, Physical exercise, Environmental	3	BMI, body fat %	4
Mahdavi-Roshan et al, 2020(50)	Iran	QE	Healthcare	97 females	5	Individual communication, Group communication	2	BMI, weight, WC	4
Maphong et al, 2021(51)	Thailand	QE	Tertiary	78	2	Individual communication, Group communication, Physical exercise, Environmental	2	SBP, DBP, WC	2
Mat Azmi et al, 2022(52)	UK	QE	Tertiary	16	2	Group communication, Physical exercise, Environmental, Individual communication	2	TOT-Chol, HDL, LDL, TG, FBG	2
Moon et al, 2024(53)	South Korea	QE	Tertiary	68	2	Individual communication, Group communication, Physical exercise	3	BMI, TOT-Chol, HDL, SBP, DBP, WC, FBG	2

(continued)

First Author and year	Country	Design	Working sector	Number of employees	Number of sites	Modality of intervention	Duration (months)	Outcome	Quality Score
Nagata et al, 2022(54)	Japan	QE	Tertiary	3697	Unknown	Individual communication, Group communication, Environmental, Physical exercise	2	BMI, weight, LDL, SBP, DBP, WC	2
Nahm et al, 2020(55)	South Korea	RCT	Industry	40	1	Individual communication, Group communication, Physical exercise	3	BMI, weight, SBP, DBP, body fat %	4
Ozaki et al, 2019(56)	Japan	RCT	Various	80	Unknown	Individual communication, Group communication, Physical exercise	3	BMI, weight	5
Raymond et al, 2019(67)	USA	QE	Various	831	5	Individual communication, Group communication	60	BMI, TOT-Chol, HDL, LDL, TG, WC	2
Rigotti et al, 2020(68)	USA	RCT	Healthcare	106	7	Individual communication, Self-awareness	12	Smoking cessation	5
Röhling et al, 2020(57)	Germany	RCT	Healthcare	30	1	Individual communication, Group communication, Physical exercise	3	BMI, weight, TOT-Chol, HDL, LDL, TG, SBP, DBP, body fat %, WC, FBG	5
Ruettger et al, 2022(58)	UK	RCT	Tertiary	244	25	Individual communication, Group communication, Physical exercise	6	BMI, weight, TOT-Chol, HDL, LDL, TG, SBP, DBP, body fat %, WC	5

Ryu et al, 2021(59)	South Korea	QE	Tertiary	52	2	Individual communication, Physical exercise	3	BMI, TOT-Chol, HDL, LDL, TG, SBP, DBP, body fat %, WC	4
Saavedra et al, 2020(60)	Iceland	QE	Tertiary	47	1	Group communication, Physical exercise	3	BMI, weight, TOT-Chol, HDL, LDL, TG, SBP, body fat %	2
Shakerian et al, 2023(61)	Iran	RCT	Industry	588	1	Individual communication, Group communication, Physical exercise	6	BMI, body fat %	4
Song et al, 2019(62)	USA	RCT	Industry	8143	40	Individual communication, Group communication, Self-awareness	18	BMI, TOT-Chol, HDL, SBP, DBP, FBG	5
Thorndike et al, 2021(63)	USA	RCT	Healthcare	602	1	Individual communication, Environmental	24	BMI, weight, TOT-Chol, HDL, LDL, TG, SBP, DBP, WC	5
Van de Ven et al, 2023(64)	Netherlands	RCT	Various	176	Unknown	Individual communication, Group communication, Physical exercise	6	BMI, weight	5
Wang et al, 2020(65)	China	RCT	Various	4548	60	Individual communication, Environmental, Self-awareness	24	SBP, DBP, smoking cessation	5
Wilson et al, 2022(66)	New Zealand	QE	Tertiary	148	Unknown	Individual communication, Group communication, Physical exercise	4	BMI, weight, SBP, DBP, body fat %, WC	2

(Supplementary Table 6). Aggregate study characteristics are listed in Supplementary Table 7.

Pooled estimates were derived for twelve outcomes, including eight cardiovascular risk factors and four anthropometric measurements. Among the cardiovascular risk factors, blood pressure was the most frequently analyzed outcome (24 estimates from 20 studies), whereas BMI was the most examined among anthropometric measurements (39 estimates from 30 studies).

Three-level meta-analysis pooled results revealed statistically significant improvements in nine out of twelve outcomes (Table 2). All anthropometric measures showed statistically significant reductions: BMI (-0.61 kg/m2, [–0.93; –0.29]; I^2level2=63.7%, I^2level3=31.8%, p.het<0.01; Figure 2), weight (-2.42 kg, [–3.48; –1.38]; I^2level2=20.7%, I^2level3=77.2%, p.het<0.01), body fat (-1.58%, [–2.37.; –0.79]; I^2level2=15.6%, I^2level3=69.9%, p.het<0.05), and waist circumference (-3.46 cm, [–5.15; –1.76]; I^2level2=59.9%, I^2level3=36.2%, p.het<0.05). Among cardiovascular risk factors, significant changes after health promotion programs were observed for LDL cholesterol (-5.9 mg/dL, [-11.54; -0.22]; I^2level2=71.7%, I^2level3=24.7%, p.het<0.05), HDL cholesterol [2.76mg/dL, (0.41; 5.10]; I^2level2=0%, I^2level3=96.3%, p.het<0.05), DBP (-2.34 mmHg, [-3.58; -1.13]; I^2level2=1.6%, I^2level3=94.2%, p.het<0.001) and SBP (-3.746 mmHg, [-5.67; -1.83]; I^2level2=9.6%, I^2level3=83.7%, p.het<0.001; Figure 3). Finally, smoking was significantly reduced (OR: 0.79, [0.63; 0.98], I^2 =77%, p.het=0.016). No significant changes were observed for total cholesterol (-5.96 mg/dL, [-12.08; -0.92]; I^2level2=76.4%, I^2level3=18.2%, p.het<0.001); FBG (-0.98 mg/dL, [-6.44; 4.50]; I^2level2=0%, I^2level3=97.0%, p.het<0.001), triglycerides (-11.78 mg/dL, [-28.34; 4.77]; I^2level2=0%, I^2level3=96.8%, p.het<0.001) and smoking cessation (OR: 1.43, [0.99; 2.07], I^2 =88%, p.het<0.001:). The complete representation of forest plots is available in Supplementary Figures 1-10.

High within-study heterogeneity was found for BMI, weight, waist circumference, total cholesterol, and LDL cholesterol. High between-study heterogeneity was observed in the remaining outcomes, including body fat, HDL cholesterol, DBP, SBP, FBG, triglycerides, and smoking cessation. Overall high levels of heterogeneity (I^2>60%) were observed across all outcomes.

Subgroup meta-analyses and univariate meta-regressions identified significant heterogeneity (p<0.05) across several variables. Among the anthropometric outcomes, the pooled BMI estimate showed significant heterogeneity in relation to the provider of intervention (p.het=0.049), with healthcare professionals (-1.60 kg/m2 [-2.55;-0.65]) and physicians (-0.74kg/m2 [-1.25;-0.53]) achieving a more significant BMI reduction compared to other professionals (-0.39kg/m2 [-0.76;-0.02]); intervention duration (p.het=0.047), with interventions lasting less than three months proving a more effective reduction than longer ones (-0.93kg/m2 [-1.33;-0.52]), and health status of participants (p.het=0.049), with studies considering individuals with cardiovascular risk factors (-1.45 kg/m2 [-2.00; -0.90]) showing greater effectiveness compared to studies with healthy/mixed individuals (-0.38 kg/m2 [-0.67; -0.08]). The pooled estimate for weight reduction showed significant heterogeneity based on the presence of economic incentives (p = 0.002), with a greater reduction observed in studies that did not provide economic incentives (–2.99 kg [–3.99; –2.00]). Body fat reduction exhibited significant heterogeneity by geographic region (p.het=0.001), with studies conducted in Asia (–1.47% [–1.48; –0.42[), Europe (–1.27% [–0.77; –0.04]), and other countries (–1.47% [–1.48; –0.42]) showing significantly greater reductions compared to those from North America (1.33% [–0.32; 2.99]). Significant heterogeneity was also observed for intervention duration (p.het=0.003), with shorter interventions proving more effective (-2.14% [-3.08; -1.00]). For waist circumference (WC), the only significant source of heterogeneity was the provider of the intervention (p.het=0.001). Interventions led by healthcare professionals, specifically physicians (–3.58cm [–4.85; –2.32] and other health workers (–10.85cm [–14.19; –7.50]), achieved significantly greater reductions compared to those delivered by other professionals (–2.04cm [–3.72; –0.36]). Among the cardiovascular risk factors, the pooled estimate for total cholesterol showed significant heterogeneity according to the health status of participants

Table 2. Results of the multilevel random effects meta-analysis for all the included outcomes.

Outcome*			Overall estimate (95% CI)	p. Het	I^2 level 3	I^2 level 2	GRADE	
BMI (kg/m²)	39	30	-0.61 (-0.93; -0.29)	<0.001	31.8%	67.3%	Moderate ⊕⊕⊕○	Indirectedness
Weight (kg)	26	19	-2.42 (-3.48; -1.38)	<0.001	20.8%	77.2%	Moderate ⊕⊕⊕○	Indirectedness
Body Fat (%)	20	16	-1.58 (-2.37; -0.79)	<0.001	62.9%	15.6%	High ⊕⊕⊕⊕	
Waist Circumference (cm)	20	17	-3.46 (-5.15; -1.76)	<0.01	36.2%	59.9%	Moderate ⊕⊕⊕○	Indirectedness
Total Cholesterol (mg/dL)	19	16	-5.96 (-12.08; 0.92)	<0.001	18.2%	76.4%	Very low ⊕○○○	Indirectedness Inconsistency Imprecision
LDL Cholesterol (mg/dL)	18	15	-5.88 (-11.54; -0.22)	<0.001	24.7%	71.7%	Very low ⊕○○○	Indirectedness Inconsistency Imprecision
HDL Cholesterol (mg/dL)	19	16	2.75 (0.41; 5.10)	<0.001	96.3%	0%	Moderate ⊕⊕⊕○	Indirectedness
DBP (mm/Hg)	22	19	2.34 (-3.58; -1.13)	<0.001	94.2%	1.6%	High ⊕⊕⊕⊕	
SBP (mm/Hg)	24	20	-3.75 (-5.67; -1.83)	<0.001	83.7%	9.6%	High ⊕⊕⊕⊕	
FBG (mmol/L)	12	11	-0.98 (-6.44; 4.50)	<0.001	97.0%	0%	Low ⊕⊕○○	Inconsistency Imprecision
Triglycerides (mg/dL)	17	11	-11.79 (-27.34; 3.75)	<0.001	96.8%	0%	Very low ⊕○○○	Indirectedness Inconsistency Imprecision
Smoking (OR)	5	5	0.79 (0.63; 0.98)	0.016	77.0 %		Low ⊕⊕○○	Indirectedness Publication bias

Anthropometric outcomes include BMI, weight, body fat, and waist circumference (WC). Cardiovascular risk factors include total cholesterol (TOT-Chol), systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting blood glucose (FBG), and smoking reduction.GRADE level for certainty of evidence: 'high' indicates that we are very confident that the true effect lies close to that of the estimate of the effect; 'moderate' indicates that the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; 'low' indicates that the true effect may be substantially different from the estimate of the effect; and 'very low' indicates that the true effect is likely to be substantially different.*

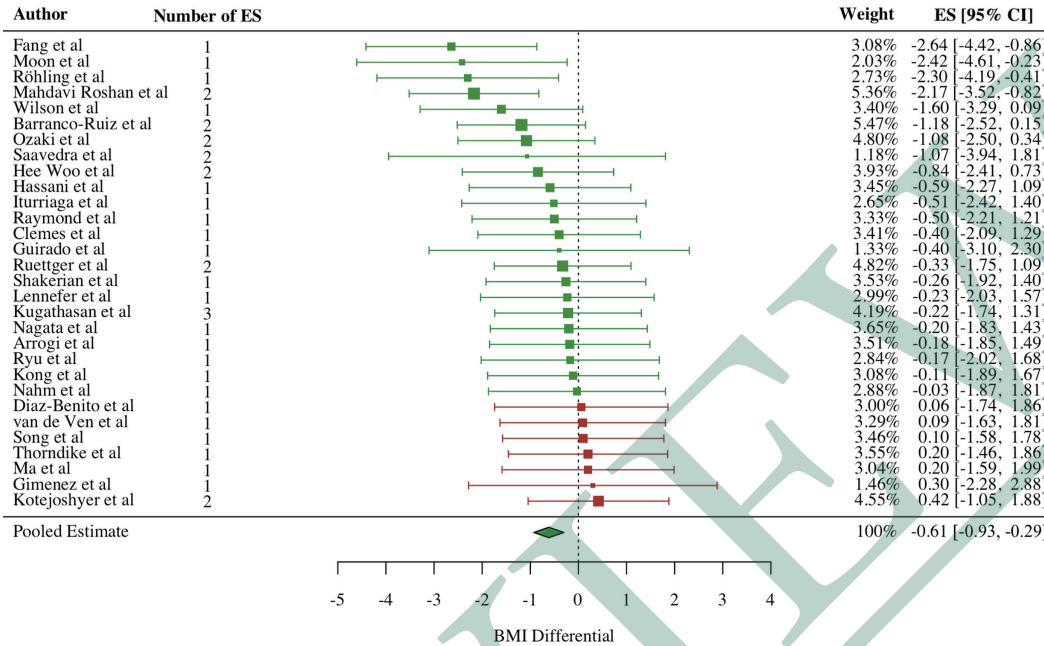

Figure 2. Forest plot of BMI (kg/m2).

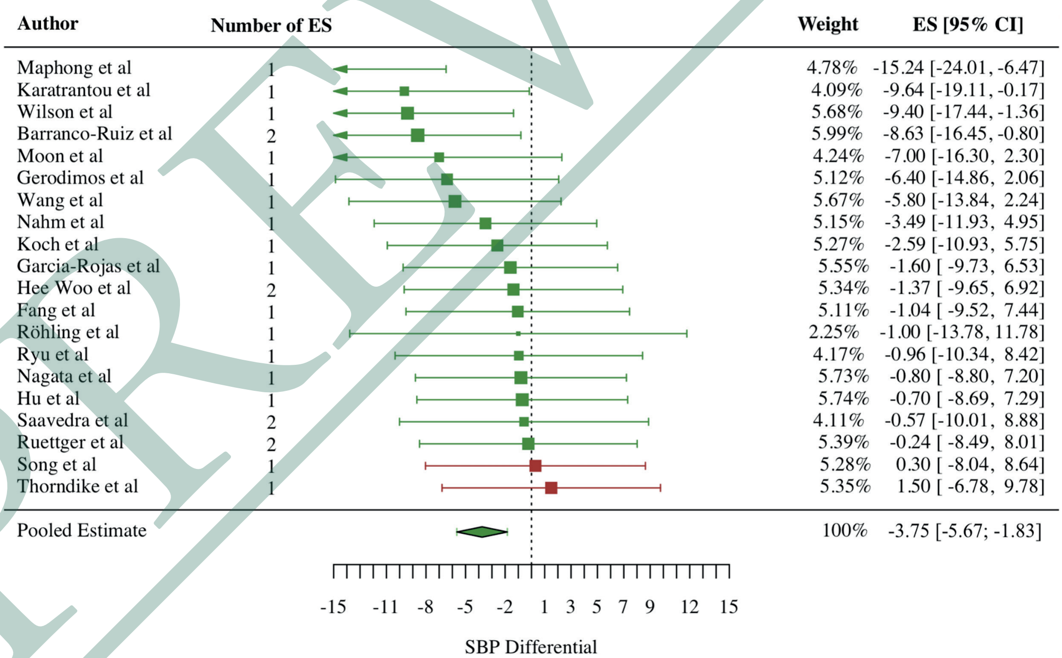

Figure 3. Forest plot of SBP (mm/Hg).

(p.het=0.014), with studies involving individuals with cardiovascular risk factors showing a greater reduction (–22.52mg/dL [–36.59; –8.63]) compared to those involving healthy individuals (–2.52mg/dL [–8.93; 3.80]). The same result was obtained for LDL cholesterol (p.het=0.001) with a reduction of (–24.17mg/dL [–33.09; –15.24]) for individuals with cardiovascular risk factors. The pooled results for HDL cholesterol showed significant heterogeneity based on enterprise size (p.het=0.001), with studies involving medium-sized enterprises reporting a significant increase in HDL cholesterol (13.83mg/dL [9.01; 18.66]). No significant sources of heterogeneity were identified for FBG and DBP. For SBP, heterogeneity was observed only in relation to the presence of economic incentives, with a significant reduction found in studies that did not offer such incentives (–4.76mmHg [–6.77; –2.76]). Finally, triglycerides pooled estimates showed significant heterogeneity according to enterprise size (p.het=0.015), with medium-sized enterprises again demonstrating a significant decrease (–42.29mg/dL [–70.98; –13.62]). Among the meta-regressions, we found a significant association between the number of interventions per month and LDL cholesterol (β=0.12, p=0.025). Another association was found between the mean age of participants and FBG (β = 0.46, p = 0.000). Full results of the subgroup meta-analyses and meta-regressions are available in Supplementary Table 8.

A visual inspection of funnel plots and an adaptation of Egger's regression tests was performed to evaluate potential small-study effects or publication bias (Supplementary Figures 11-22). Egger's test indicated potential small-study effects or publication bias for triglycerides (p=0.037), and smoking cessation (p=0.006), which was further supported by the asymmetry observed in the corresponding funnel plot. Visual inspection of the funnel plots suggested a potential asymmetry for LDL cholesterol, and FBG although Egger's test was not statistically significant. No asymmetry in the plots or significant results from Egger's tests were observed for several outcomes, including BMI, weight, body fat, total cholesterol, HDL, LDL, waist circumference, DBP, and SBP.

In the leave-one-out sensitivity analysis, similar pooled effects were observed across all anthropometric outcomes, indicating the robustness of these results. However, for cardiovascular risk factors, the exclusion of specific studies affected the statistical significance of some pooled estimates. The total cholesterol estimate became significant upon the removal of Ryu et al. [59], Raymond et al. [67], and Gimenez et al. [34]; FBG estimate became significant after excluding the study by Fang et al. [31]; and triglycerides reached significance after excluding the study by Kim et al. [42]. Conversely, the pooled estimate for LDL cholesterol lost its statistical significance when the study by Fang et al. [31] was removed.

The quality of evidence, as assessed using the GRADE system, is presented in Table 2, with a detailed justification for each rating available in Supplementary Table 9.

4. Discussion

This systematic review and meta-analysis synthesized the evidence from 44 studies assessing the effectiveness of workplace-based health promotion interventions on cardiometabolic health outcomes. The main finding of our analysis is that such interventions can lead to significant improvements across a wide range of anthropometric and cardiovascular risk parameters. Specifically, we observed significant improvements in nine out of twelve cardiometabolic outcomes. Although changes in individual parameters were generally modest, even small improvements can lead to meaningful health benefits at both the individual and population levels. Evidence shows that slight, but sustained changes in these parameters directly contribute to reducing cardiovascular and cerebrovascular events, decreasing the risk of chronic metabolic diseases, and reducing systemic inflammation [69,70]. Moreover, cardiometabolic risk is deeply intertwined with mental health, psychological well-being, and overall quality of life [71–73]. In addition to direct health benefits, these improvements can yield indirect advantages for employers and healthcare systems. Weight loss, improved blood pressure control, and better lipid profiles are associated with reduced absenteeism, greater productivity, and job satisfaction potentially contributing to preserved work capacity and extended working life [74–76]. Improved cardiometabolic health is linked to lower disease burden, treatment costs, and decreased resource utilization, leading to important implications for public health and healthcare systems [77].

These results support the growing body of evidence that the workplace is an effective setting for the implementation of multidimensional health promotion strategies. In this regard, a meta-analysis by Peñalvo et al. [20] evaluated the impact of multicomponent workplace interventions on dietary habits, overweight, and cardiometabolic health, by analyzing 121 studies conducted between 1990 and 2020. The authors highlighted a significant increase in fruit and vegetable consumption and HDL cholesterol, and significant reductions in BMI, body weight, SBP, DBP, LDL cholesterol, triglycerides, and FBG. Other previous meta-analyses [73, 78–80] with a lower number of included studies and mainly focused on lifestyle interventions and dietary habits yielded similar promising results.

Despite these positive findings, the observed between-study heterogeneity was consistently high across all outcomes, possibly due to variations in study design, sociodemographic characteristics, workers' details, and implementation contexts. Subgroup analyses and meta-regressions explained some of this heterogeneity. For instance, interventions led by healthcare professionals, especially physicians, were more effective in reducing BMI and waist circumference. This aligns with results presented by Zusman et al. [81], highlighting the impact of the provider of the intervention and the need to match their clinical expertise with the proposed intervention and the desired outcome. Additionally, shorter interventions [<3 months] were associated with greater improvements in BMI and body fat. Shorter lifestyle interventions tend to achieve higher adherence, as maintaining motivation and consistent behavioral change is easier over limited periods. This may also relate to a novelty effect, whereby enthusiasm and commitment are strongest early on. Another possible explanation is selection bias, as participants in longer programs could be more prone to drop out if early results are not achieved. Similar results were found in a recent systematic review and meta-analysis by Rotunda et al. [82] investigating the effectiveness of lifestyle interventions lasting 6 months or less on the body weight of adults with overweight or obesity, concluding that interventions lasting less than 13 weeks were at least as effective as longer ones [13-26 weeks]. Early phases of intervention often yield the greatest weight loss, and shorter multicomponent programs tend to have higher adherence and compliance resulting in a greater retention rate [83]. Moreover, early weight loss has been identified as a predictor of greater long-term weight reduction [84]. Baseline cardiometabolic profile also emerged as a possible moderator, with employees already at higher cardiovascular risk benefiting more from interventions targeting BMI, total cholesterol, and LDL cholesterol. This finding aligns with previous studies [85, 86] highlighting better results in high-risk populations. With regard to unexplained heterogeneity, inconsistent reporting of certain variables across studies limited our ability to explore key sources of variation. Most studies did not report baseline cardiovascular-related characteristics, such as dietary habits or physical activity, nor participants' socioeconomic status. Information on work schedules, including shift or night work, was also generally missing, along with other occupational risk factors such as workload and job stress. Few studies provided details on the engagement of workers in program planning, despite its potential impact on participation and motivation. Further sources of heterogeneity are likely contextual, with multiple layers potentially influencing the effectiveness of occupational health promotion programs, including factors such as country, culture, language, corporate culture, job roles, and organizational implementation. The awareness of the sources of heterogeneity is essential to drive future health promotion programs. Factors influencing effectiveness – such as the workforce's cardiometabolic profile, the intervention provider and the duration of the programs – should be carefully considered to optimize cardiometabolic outcomes. In this regard, occupational physicians play a crucial role, given their expertise in both the health impacts of work environments, exposures and organization and individual susceptibility factors. This comprehensive perspective allows them to support employers and policymakers to develop integrated, tailored health strategies that align with enterprise characteristics and workers' specific health and safety needs. The increasing availability of digital health technologies (e.g., mobile apps, telehealth, wearables) may further enhance the scalability of these programs, reducing barriers related to geographic and resource constraints. It's worth noting that most of the analyzed studies focused only on traditional workplace health promotion programs rather than adopting integrated and holistic approaches, such as the TWH model. Future preventive strategies should also tackle organizational and environmental factors to promote both healthier workplaces and healthier individual behaviors. TWH builds on the recognition that work is a social determinant of health and seeks to improve workers' health and well-being by targeting working conditions and individual factors, thereby reducing their possible additive effect [87].

We believe that the results of our meta-analysis may have important implications for public and occupational health practices and policymaking. The workplace represents a unique, yet underutilized, setting for the implementation of preventive strategies, reaching a large proportion of the adult population during their most productive year. Integrating structured health promotion interventions into occupational health policies could contribute to the reduction of the non-communicable disease burden.

Our study has several strengths. Multiple cardiometabolic outcomes were considered, along with their drivers, through a methodologically sound approach enabling a comprehensive analysis of the factors associated with cardiometabolic health outcomes. Additionally, it offers a pragmatic contribution to cardiovascular health promotion by focusing on practical aspects of the initiatives that can inform the development of future effective strategies. Furthermore, the study includes articles published after 2020, a period marked by the transformative impact of the COVID-19 pandemic, which significantly affected work patterns, efficiency, and productivity, and cardiometabolic health [90]. The long-term consequences on worker well-being and cardiometabolic profile are still unknown and unfolding, underscoring the importance of adapting health promotion interventions to the new post-pandemic work environments. Finally, unlike previous published meta-analyses, we adopted a validated tool (GRADE) to assess the certainty of evidence.

Several limitations should also be acknowledged. The study revealed significant between-study heterogeneity for most of the outcomes, which was only partially explained by subgroup meta-analyses. Some variables were not consistently reported across studies, reducing our ability to examine potentially important sources of variation. As a result, conclusions should be considered carefully, recognizing that the unexplained variability may influence the magnitude of the pooled effects. Furthermore, the certainty of evidence for several outcomes, including total cholesterol, LDL cholesterol, FBG, triglycerides and smoking cessation, was rated as "low" or "very low" according to the GRADE framework, indicating high uncertainty regarding the true effect estimates. These results did not remain consistent in sensitivity analyses and should be therefore interpreted with caution, in contrast to other cardiometabolic parameters supported by moderate or high-certainty evidence. Additionally, publication bias or small study effects were detected for triglycerides and smoking cessation. Consequently, the generalizability and reliability of these findings should be cautious. Moreover, a wide range of modalities of interventions was considered, both single-component and multi-component, making it difficult to isolate the effect of specific components of the health promotion programs. The follow-up duration was generally under 12 months and in most cases without re-engagement, limiting the assessment of long-term effectiveness and possibly overestimating short-term benefits. Therefore, it is important to interpret our results as evidence of short- to medium-term effectiveness, acknowledging that the long-term sustainability of these benefits remains unclear. Long-term data are needed to determine whether initial improvements are maintained beyond the intervention period. This represents a critical knowledge gap that future research should address through extended follow-up assessments and periodic re-engagement strategies. Finally, most of the studies were conducted in Europe and Asia, potentially affecting the generalizability of our findings.

Our findings support the inclusion of workplace-based health promotion programs within national and global public health strategies, such as the EU Healthier Together Initiative [88] and the WHO Global Action Plan for the Prevention and Control of Noncommunicable Diseases [89]. To this end, policymakers should consider some essential actions, including (i) encouraging cross-sector collaboration among stakeholders: healthcare providers, enterprises, public institutions and academia; (ii) supporting the implementation of the TWH model within occupational health and safety frameworks; (iii) assessing workers needs in terms of safety and health to define suitable preventive measures and health promotion strategies; (iv) offering fiscal or accreditation incentives to enterprises that implement evidence-based health promotion programs.

In this perspective, workplace health promotion should be recognized not only to enhance individual well-being, but also as a strategic tool to reduce health inequalities, strengthen workforce resilience, and support sustainable economic growth.

Further studies should prioritize longer follow-up durations and incorporate periodic employees' re-engagement to provide more insights into the durability of the effects. Future research should also explore the optimal frequency, intensity, and combination of intervention components to identify the most effective strategies for improving cardiometabolic health. Moreover, integrated approaches combining individual-level interventions with organizational and environmental changes in line with the TWH model are needed. Lastly, future studies should incorporate implementation science frameworks to assess barriers and facilitators influencing occupational health promotion program adoption, scalability, and long-term sustainability across diverse sectors, workplace settings, and employees' populations.

5. Conclusion

In conclusion, this systematic review and meta-analysis provides evidence that workplace-based health promotion interventions can lead to significant improvements in cardiometabolic health outcomes. Given the workplace's unique position to reach a large and diverse adult population, integrating structured health promotion into occupational health policies offers a promising strategy to improve occupational and public health, reduce healthcare costs, and support workforce productivity. Although the observed changes are generally modest, they have the potential to reduce the burden of cardiovascular and metabolic diseases at the population level. However, the short follow-up durations and partly unexplained heterogeneity across studies warrant caution in interpreting the findings and limit conclusions on long-term effectiveness. Future research should aim to optimize intervention designs, extend follow-up periods, and adopt integrated approaches in line with the TWH approach to maximize long-term benefits and sustainability.

Supplementary Materials: The following are available online: Figure S1-10: Forest plots, Figure S11-22: Funnel plots, Table S1: Search strings on different electronic databases: PubMed, Embase, Web of Science, Table S2: PICOS framework – inclusion and exclusion criteria, Table S3: Study assumptions for SEs and Ess calculation, Table S4: Quality assessment criteria, Table S5: Numbers of studies investigating different outcomes, Table S6: Quality assessment of included studies, Table S7: Aggregate characteristics of included studies, Table S8: Stratified meta-analyses and univariate meta-regressions results from three-levels random effects models, Table S9: Summary of GRADE ratings and justifications for downgrading, Table S10: PRISMA Checklist.

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