Effect of workplace physical activity interventions on the cardio-metabolic health of working adults: systematic review and meta-analysis

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Abstract

Background: Adults in urban areas spend almost 77% of their waking time being inactive at workplaces, which leaves little time for physical activity. The aim of this systematic review and meta-analysis was to synthesize evidence for the effect of workplace physical activity interventions on the cardio-metabolic health markers (body weight, waist circumference, body mass index (BMI), blood pressure, lipids and blood glucose) among working adults.

Methods: All experimental studies up to March 2018, reporting cardio-metabolic worksite intervention outcomes among adult employees were identified from PUBMED, EMBASE, COCHRANE CENTRAL, CINAHL and PsycINFO. The Cochrane Risk of Bias tool was used to assess bias in studies. All studies were assessed qualitatively and meta-analysis was done where possible. Forest plots were generated for pooled estimates of each study outcome.

Results: A total of 33 studies met the eligibility criteria and 24 were included in the meta-analysis. Multi-component workplace interventions significantly reduced body weight (16 studies; mean diff: −2.61 kg, 95% CI: −3.89 to −1.33) BMI (19 studies, mean diff: −0.42 kg/m², 95% CI: −0.69 to −0.15) and waist circumference (13 studies; mean diff: −1.92 cm, 95% CI: −2.35 to −1.60). Reduction in blood pressure, lipids and blood glucose was not statistically significant.

Conclusions: Workplace interventions significantly reduced body weight, BMI and waist circumference. Non-significant results for biochemical markers could be due to them being secondary outcomes in most studies. Intervention acceptability and adherence, follow-up duration and exploring non-RCT designs are factors that need attention in future research.

Prospero registration number: CRD42018094436.

Keywords: Physical activity, Worksite interventions, Cardiovascular disease
Background

Physical activity as a modifiable health behavior for cardiovascular disease (CVD) prevention

According to the INTERHEART study, physical inactivity is one of the 9 major modifiable risk factors responsible for CVDs in both sexes worldwide [1]. It is responsible for 10% of the premature mortality, 6% of coronary heart disease burden and 7% of the diabetes burden worldwide [2]. Approximately 3.2 million annual deaths are attributable to insufficient activity [3] and 25% reduction in inactivity can avert 1.3 million deaths annually [2]. Physical activity (PA) aids in better glycemic control and it is a vital component of diabetes prevention and management [4]. The World Health Organization (WHO) now recommends 150–300 min of moderate to vigorous aerobic physical activity (MVPA) for adults aged 18–64 [5]. Some of the most common reasons for inactivity among adults are an unsupportive social and physical environment [6, 7] and lack of time [8]. Adults in urban areas spend almost 77% of their waking time being inactive at work or otherwise, leaving little time for exercise [9, 10].

Worksite physical activity programs are specifically designed with the aim of enhancing employee physical activity levels and improving their dietary behavior at the workplace [11]. Worksite settings provide effective channels to reach defined populations, disseminate information, create an effective medium for program delivery and study the impact to maximize benefits [12, 13]. These can be suitable settings for advocating an active lifestyle, improving employee productivity and reducing healthcare costs [14, 15]. Contemporary workplaces are thus ideal for interventions that promote higher levels of physical activity amongst employees, to improve health and optimize performance [16].

Rationale for the current systematic review and meta-analysis

A number of narrative and systematic reviews have demonstrated the positive effect of various worksite physical activity interventions on physical activity, productivity and cost outcomes [17–25]. However, only a handful of them have comprehensively evaluated the effects of these interventions on the major measurable cardiovascular disease markers. The last comprehensive review on the topic was done in 2010, included only randomized controlled trials (RCTs) and did not meta-analyze the effects [26]. Worksite PA interventions can provide an effective lever to address the CVD burden. However, the effectiveness of these interventions needs to be quantified. Given the availability of numerous primary studies in the area, it becomes imperative to present not only an overview but also obtain an overall quantitative estimate of intervention effects from different studies, both randomized and non-randomized. Therefore, we aimed to undertake a comprehensive and systematic synthesis of literature and meta-analysis of available evidence, to obtain a holistic view, of the potential of worksite PA interventions in improving the cardio-metabolic health of working adults.

Objective

To summarize evidence for the effect of worksite physical activity interventions on CVD risk markers (body weight, waist circumference, body mass index, blood pressure, lipids and blood glucose) among working adults and describe the intervention approaches used in the different studies.

Research question

Do worksite physical activity interventions lower the cardio-metabolic disease risk of adults?

Methods

The review methodology was registered with PROSPERO (registration ID: CRD42018094436) and has been described in detail in the protocol [27].

Search strategy and inclusion of studies

We searched Cochrane Central, PUBMED, CINAHL, PSYCINFO and EMBASE to identify relevant studies on workplace physical activity interventions published till March 2018 using keywords like “workplace”, “workers”, “physical activity”, “exercise”, “wellness”, “counseling”, “RCTs”, “trials” etc. A comprehensive strategy was prepared by one researcher (RM) and reviewed by the second (CS) researcher. The PUBMED search strategy is illustrated in the Additional File 1. It was then modified as per the indexing system of other databases.

Eligibility criteria for inclusion of studies

- Study designs- Experimental study designs with a comparator group including randomized controlled trials, controlled trials, cluster RCTs, quasi-experimental studies; a comparator could be no intervention, minimal intervention, usual care, waitlisted control.
- Study populations- Studies involving individuals aged 18 and above; healthy populations as well as populations at risk of CVD were included
- Study outcomes- Studies reporting any of the CVD outcomes (body weight, body fat, waist circumference, BMI, blood pressure, plasma glucose, lipids and triglycerides)
- Study interventions- Workplace studies implementing physical activity based interventions targeting inactivity to improve the cardio-metabolic disease markers (anthropometric and biochemical) in adult employees
Exclusion criteria: Studies not published in the English language, those with a follow-up period of less than 6 months, observational studies and experimental studies without a comparator.

Referencing software Zotero was used to import the search results and remove the duplicates. Titles and abstracts of all the retrieved articles were screened independently by RM; CS independently screened 10% of the citations. The reference list of relevant studies obtained was further hand searched. Full texts of eligible studies were screened by RM and reviewed by CS. Wherever data for meta-analysis was unavailable in the public domain, the study authors were electronically contacted.

Data extraction, quality assessment and analysis
Data extraction was performed independently by the two researchers. Disagreements were resolved within the team. Items in the data extraction form were prepared by RM using the Cochrane Handbook recommendations and were verified by CS. Outcomes were appropriately converted to the International System of Units for studies that reported them in other units. Findings from all the studies were included in the narrative synthesis. Review Manager (RevMan version 5.3) was used for the meta-analysis. The inverse-variance method was used to combine effect sizes using the random effects models (REMs) [28]. The treatment effect was reported as mean difference (MD) with 95% confidence intervals (CIs) wherein CIs excluding 0 were considered to be statistically significant. Forest plots were generated using RevMan to compare each of the proposed outcome measures in the intervention vs the control groups in the included studies. Studies that did not provide this data were excluded from the meta-analysis. REMs were used to report the overall mean difference with 95% CIs. The confidence intervals for each study in the meta-analysis were observed for their level of overlap, for a visual assessment of heterogeneity. I² values, defined as ‘the percentage of variability in effect estimates that is due to heterogeneity rather than sampling error’, were used to determine the magnitude of variation beyond chance. It is calculated as \( [(Q-df)/Q] \times 100 \) where Q is the chi-square statistic and df is its degrees of freedom. A chi-square \( p \)-value of less than 0.05 was considered statistically significant for the presence of heterogeneity. Degree of heterogeneity was ascertained based on the cut-offs mentioned in the Cochrane handbook (0–40%: not important, 30–60%: moderate, 50–90%: substantial, 75–100%: considerable heterogeneity) [29].

The intervention effects on various CVD markers were also assessed under the sub-groups of study design (RCTs vs cRCTs), duration (6–12 months vs >12 months), intervention type (predominantly educational vs predominantly behavioral change vs predominantly environmental change based) and employee health status (all employees vs those at risk of CVD). The chi-square test \( p \)-value for sub-group differences was assessed for significant sub-group effects (a \( p < 0.05 \) indicates significant sub-group effect).

We classified the various intervention approaches used in the included studies based on a 2012 review by Heath et al. [30]. The interventions were broadly categorized as follows:

- Campaigns and informational approaches: This involves information dissemination through different mediums like text messages, emails, newspapers, television, radio, to raise awareness and encourage a change in health behaviors mainly increasing activity and improving diet.

- Behavioral and social approaches: This involves a change in individual behavior to incorporate more physical activity in their regular routine through goal setting, peer support and self-rewards. It can be implemented in groups (through technological means) as well as on an individual level with the help of a health provider/trainer and personalized activity plans.

- Environmental and policy approaches: This involves making the office infrastructure and physical environment more activity friendly through construction of walking paths, changes to the vending machines, introduction of ergonomic workstations, break rooms, fitness facilities etc.

The Cochrane risk of bias tool [31] was used to assess the bias in included studies. The assessment was independently performed by RM and CS and disagreements were resolved by consensus. Possible publication bias among the studies was visually assessed using funnel plots.

Results
Literature search and characteristics of included studies
Our search identified a total of 3774 records (Fig. 1). Out of these, 1873 were retrieved through Pubmed via MEDLINE, 696 through EMBASE, 922 through CENTRAL and 283 through CINAHL and PsychInfo. An additional 10 records were identified through other sources (identified by manually searching the reference list of included studies). After removal of duplicates, we screened 2517 records and identified 101 full text articles for eligibility assessment. Of these, 33 studies were included in the narrative synthesis. Studies reported various outcomes: weight \( n = 16 \) [32–47], BMI \( n = 19 \) [32–37, 39–44, 46, 48–53], waist circumference \( n = 13 \) [32–36, 39, 42, 43, 45–47, 51, 54], lipids \( n = 15 \) [32, 34–37, 39, 42, 44–47, 49, 51, 52, 55], triglycerides \( n = 8 \) [37, 39, 44–47, 49, 52], blood pressure \( n = 16 \) [32–37, 39, 42–47, 49, 51, 52] and glucose \( n = 10 \) [32, 34, 37, 39, 44–47, 49, 52]. A total of 24 studies were included in the meta-analysis. Data from other studies was not available.

Common reasons for excluding studies from the review are reported in the PRISMA diagram. Twelve RCTs
[32–39, 49, 54, 56, 57], 15 cluster RCTs [40, 41, 43, 44, 46–48, 50, 53, 58–63], 3 quasi experimental trials [42, 52, 64], and 3 controlled trials [45, 51, 55] were included in the review. A total of 36,188 men and women aged 32 to 55 years participated in these studies with the study sample sizes ranging from 45 to 10,281.

The descriptive characteristics of the included studies are presented in Table 1. The studies had a varied population which included school and university personnel, employees of public and private sectors, blue collar workers (carpenters, bricklayers, road workers, crane operators, locomotive maintenance workers, gardeners, drivers, transportation workers, garage staff and factory workers), professional and technical, salaried and hourly workers, hospital staff, security guards, healthcare workers, casino employees and industry workers.

Out of the 33 studies reviewed, 13 studies [32–34, 36, 38–40, 43, 46, 49, 51, 56, 60] (8 RCTs, 4 cluster RCTs and 1 controlled trial) included only employees who had at least one raised CVD risk factor while the other 20 studies [35, 37, 41, 42, 44, 45, 47, 48, 50, 52–55, 57–59, 61–64] included all employees irrespective of their health status.

**Narrative analysis**

**Study interventions**

The studies used different types of interventions like campaigns, workshops and education; individual level behavioral change; and changes to the office environment and policies. Out of the 33 studies reviewed, 28 studies [32, 36, 37, 39–47, 49–64] used a mix of the three approaches whereas the other 5 studies [33–35, 38, 48] implemented any one of these three approaches. The intervention duration in all the studies ranged from 6 months to 5 years. Campaign approach included lifestyle coaches to educate on physical activity, workshops on cardiac risk factors, wellness fairs, point of choice prompts and information dissemination through...
| Author            | Year of Publication | Country  | Study Design | Study Duration | Study Setting                                      | Study Population                                      | Sample Size | Age | Gender | Study Outcomes                                                                 |
|-------------------|---------------------|----------|--------------|----------------|---------------------------------------------------|-------------------------------------------------------|-------------|-----|--------|--------------------------------------------------------------------------------|
| Almeida et al     | 2015                | USA      | cluster RCT  | 18 months      | Worksites in Virginia                             | Worksite employees with a BMI ≥ 25                    | 1790        | 46.9 (3.2) | Females (73.8%) | Body weight (kg), BMI (kg/m²); measured at 6 months                        |
| Atlantis et al    | 2006                | Australia| RCT          | 1 year         | Australian Casino                                  | Healthy but sedentary casino subjects                 | 73          | 32 (8) | Males (48%) | Waist circ (cm); measured at 6 months                                      |
| Barham et al      | 2011                | USA      | RCT          | 19 months      | Onondaga county NY                                 | Pre-diabetic or diabetic employees at the county     | 45          | 51.2 (8.0) | Males (16%) | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 6 and 12 months |
| Brehm et al       | 2009                | US       | cluster RCT  | –              | 8 manufacturing companies                          | manufacturing company employees                      | 341         | 43.8 (10.0) | Males (60%) | Body weight (kg), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 12 months |
| Chockalingam et al| 2008                | Canada   | RCT          | –              | Employees in the Halifax area, Nova Scotia         | Employees with at least 2 modifiable coronary risk factors | 397         | 44 (8) | Males (51%) | BMI (kg/m²), lipids (mg/dl), blood pressure (mm Hg); measured at 3 and 6 months |
| Christensen et al | 2012                | Denmark  | cluster RCT  | 14 months      | Danish Municipality in central Jutland             | Female overweight health care workers                | 98          | –        | Females (100%) | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg); measured at 12 months |
| Engbers et al     | 2007                | Netherlands | controlled trial | 1 year         | 2 government companies                            | overweight office employees with a BMI > 23         | 540         | 45.3 (9.6), 45.5 (8.7) | Females (37.4, 41.7%) | BMI (kg/m²), waist circ (cm), lipids (mg/dl), blood pressure (mm Hg); measured at 12 months |
| Fernandez et al   | 2015                | USA      | cluster RCT  | 5 years        | nonunionized manufacturing, R&D company with multiple sites in the northeastern United States | Worksite employees                                   | 3799        | 47.7 (7.4), 47.4 (7.8) | Males (68.1, 55.6) | BMI (kg/m²); measured at 36 months                                       |
| French et al      | 2010                | Minneapolis | cluster RCT  | 2 years        | 4 garages; 2 urban, 2 suburban                      | garage workers                                       | 832         | 49       | Males (79%) | BMI (kg/m²); measured at 18 months                                       |
| Goetz et al       | 2009                | USA      | quasi experimental | 1 year         | 12 sites of Dow science and technology company     | All employees in the manufacturing, r&d and administration departments at all sites | 10,281      | 443 (44.1) | Males (26.7, 25%) | Body weight (kg), BMI (kg/m²), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 12 months |
| Healy et al       | 2017                | Australia| Cluster RCT  | 4 years        | Worksites from a large public service organization | Worksite employees                                   | 231         | 45.6 (9.4) | Males (32%) | Body weight (kg), waist (cm), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 12 months |
| Jamal et al       | 2016                | Malaysia | RCT          | 2 years        | Melbourne                                          | Overweight/obese                                    | 194         | 405      | Women | Body weight (kg), BMI (kg/m²), waist |
| Author    | Year of Publication | Country | Study Design | Study Duration | Study Setting                                                                 | Study Population                                                                 | Sample Size | Age | Gender | Study Outcomes                                                                 |
|-----------|---------------------|---------|--------------|----------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------|-----|--------|--------------------------------------------------------------------------------|
| Kim et al | 2015                | Korea   | RCT          | 6 months       | 3 Korean worksites                                                           | Employees from the Korean gas corporation, district heating corporation and expressway corporation with a BMI > 25 kg/m² | 196         | 41.02 (6.82), 41.5 (6.98) | Males (100%) | Body weight (kg); measured at 6 months                                    |
| Kramer et al | 2015            | USA     | RCT          | 18 months      | Bayer corporation in Pittsburgh                                             | Pre diabetic employees both professional and technical, salaried and hourly workers with BMI >=24 | 89          | 52.3 (7.2) | Males (45%) | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 6 months |
| Lemon et al | 2010              | USA     | cluster RCT  | 3 years        | 6 hospitals in massachussets                                               | Hospital employees                                                                | 806         | –              | Males (19%) | BMI (kg/m²); measured at 12 and 24 months                                  |
| Lemon et al | 2014              | USA     | cluster RCT  | 3 years        | 12 central Massachusetts public high schools                                 | School employees                                                                  | 782         | –              | Males (33%) | Body weight (kg), BMI (kg/m²); measured at 12 and 24 months               |
| Limaye et al | 2016              | India   | RCT          | 3 years        | two multinational IT industries in Pune                                       | Employees with ≥3 risk factors (family history of CVD, obesity, highblood pressure, impaired glucose, impaired lipids) | 265         | 368 (7.2), 357 (8.1) | Males (74, 71%) | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 12 months |
| Linde et al | 2012              | USA     | cluster RCT  | 3 years        | Six worksites in the Twin cities area Minnesota                              | Worksite employees                                                                | 1672        | –              | Males (39%) | BMI (kg/m²); measured at 24 months                                      |
| Milani et al | 2009              | USA     | cluster RCT  | 1 year         | 2 geographically disparate work locations of a single employer               | Worksite employees                                                                | 339         | 40 (8), 43 (10) | Males (52, 53%) | Body weight (kg), lipids (mg/dl), blood pressure (mm Hg), glucose (mg/dl); measured at 6 months |
| Morgan et al | 2011              | Australia | RCT          | 14 weeks       | Tomago Aluminium company                                                      | Over-weight/obese male shift workers                                               | 110         | 44.4 (8.6) | Males (100%) | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg); measured at 14 months |
| Moy et al | 2006                | Malaysia | quasi experimental | 2 years public health university and teaching hospital in KL | Security guards                                                                   |                                                                                  | 186         | 45.6 (7.2), 48 (4.7) | Males (100%) | BMI (kg/m²), lipids (mg/dl), blood pressure (mm Hg), glucose (mg/dl); measured at 24 months |
| Muto et al | 2001                | Japan    | RCT          | 18 months      | building maintenance company in Japan                                        | Building maintenance company workers with at least one abnormal CVD risk factor  | 352         | 423 (4.5), 427 (2.7) | Males (100%) | Body weight (kg), BMI (kg/m²), lipids (mg/dl), blood pressure (mm Hg), glucose (mg/dl); measured at 18 months |
| Naito et al | 2008                | Japan    | controlled trial | 5 years Factories in Japan | Factory employees                                                            |                                                                                  | 2929        | 442.2 (8), 395 (7.6) | –          | HDL (mg/dl); measured at 60 months                                       |
| Nilsson et al | 2001              | Sweden   | RCT          | 18             | 4 branches of helsing                                                        | Nurses, cleaners, gardeners                                                       | 89          | 49.7          | –          | BMI (kg/m²), lipids (mg/dl), blood                                        |
Table 1 Descriptive characteristics of the included studies (Continued)

| Author            | Year of Publication | Country | Study Design | Study Duration | Study Setting | Study Population                                      | Sample Size | Age | Gender | Study Outcomes                                      |
|-------------------|---------------------|---------|--------------|----------------|---------------|--------------------------------------------------------|-------------|------|--------|-----------------------------------------------------|
| Prabhakaran et al | 2009                | India   | controlled   | 4 years        | Industrial sites in India                              | industry employees                     | 6889        | 40.8 | (10.8), 386 (11.7) | Body weight (kg), waist circ (cm), blood pressure (mm Hg), glucose (mg/dl); measured at 48 months |
| Racette et al     | 2009                | USA     | cluster RCT  | 1 year         | Worksites within a large medical center in Missouri    | Medical centre employees aged 18 and above | 123         | 45 (9) | Males (11.25) | Body weight (kg), BMI (kg/m²), blood pressure (mm Hg), glucose (mg/dl); measured at 12 months |
| Siegel et al      | 2010                | USA     | cluster RCT  | 2 years        | 16 elementary schools in 2 areas of LA                | All school employees                    | 413         | 40 (0.80) | Males (17%) | BMI (kg/m²); measured at 2 years                   |
| Shrivastava et al | 2017                | India   | cluster RCT  | 6 months       | 4 worksites from Delhi-NCR                             | overweight employees                    | 267         | 35.8 | (7.6), 39 (8.7) | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg), lipids (mg/dl), glucose (mg/dl); measured at 6 months |
| Viester et al     | 2017                | Netherlands | RCT        | 12 months      | Construction company in Netherlands                    | Blue collar workers (carpenters, road workers, crane operators, and factory workers) | 314         | 47 (9.5) | –       | Body weight (kg), BMI (kg/m²), waist circ (cm), blood pressure (mm Hg), lipids (mg/dl); measured at 12 months |
| Weinhold et al    | 2015                | USA     | RCT          | 2 years        | University in US                                        | Worksite pre-diabetic employees with a BMI more than 25 | 69          | 51.6 | (9.5), 51.0 (8.1) | Body weight (kg), BMI (kg/m²), waist circ (cm) blood pressure (mm Hg), measured at 7 months |
| Williams et al    | 2014                | USA     | cluster RCT  | 2 years        | 30 Hotels in Hawaii                                     | Hotel employees with a BMI >=25         | 1207        | 46 (9.6), 46.1 (10.2) | BMI (kg/m²); measured at 12 and 24 months |
| Wilson et al      | 2016                | USA     | cluster RCT  | 12 months      | Railroad maintenance facilities of Union Pacific Railroad | Locomotive maintenance employees at the company | 362         | 47, 44 | Males (93.7, 94.6%) | Body weight (kg), BMI (kg/m²); measured at 12 months |

Note: CVD = Cardiovascular Disease; borg = Borg Public Sector; RCT = Randomized Controlled Trial; BMI = Body Mass Index; LA = Los Angeles; NCR = National Capital Region; mm Hg = Millimeters of Mercury; mg/dl = Milligrams per Deciliter; Males: Females.
newsletters, brochures, internet etc. Behavioral change included incentivized group activities or tailored-for-individual weight loss regimes through physical activity, goal setting and rewards. Organizational changes included making stairs and walls more aesthetic, mapping of walking routes and more. Detailed description of the intervention and control groups is presented in Additional File 2.

Risk of bias in included studies
Risk of bias among the included studies was assessed using the Cochrane risk of bias assessment tool as shown in Fig. 2. The risk of bias summary for individual studies has been presented in Additional File 4.

The highest risk of bias emanated from performance bias due to unblinded participants and study personnel. There was also a high unclear risk of selection bias and detection bias due to lack of adequate data reported on randomization, allocation concealment and blinding of study outcome assessors.

Meta-analysis
Intervention effects on cardio-metabolic risk markers
We undertook exploratory meta-analyses to pool the effect estimates for body weight, body mass index, waist circumference, systolic and diastolic blood pressure, total cholesterol, low density lipoprotein (LDL-C) and high density lipoprotein (HDL-C) cholesterol, triglycerides and blood glucose. Review Manager Software (RevMan version 5.3) was used to generate forest plots. The random effects model was used to generate intervention effects.

Results from the meta-analyses showed an overall significant intervention effect for body weight (16 studies, Mean difference: -2.61, 95% CI -3.89, −1.33), body mass index (19 studies, Mean difference: -0.42, 95% CI -0.69, −0.15) and waist circumference (13 studies, Mean difference: -1.92, 95% CI -3.25, −0.60) but there was considerable heterogeneity among estimates ($I^2 = 94, 89 and 92\%$ respectively; $p$-value < 0.0001). The pooled estimates for lipids, blood pressure and blood glucose were not statistically significant.

The overall mean difference and 95% CIs for each outcome, along with the heterogeneity in individual studies have been presented in Table 2. Exploratory sub-group analysis showed a significant sub-group effect by study design for body weight ($p = 0.0008$) and BMI ($p < 0.00001$) and by intervention type for BMI ($p = 0.008$) and TC ($p = 0.0007$). However, there was no sub-group effect for the other outcomes (waist circumference and biochemical markers). (Additional File 3) In conclusion, sub-groups could not explain the high levels of heterogeneity responsible for the variability in study effect size estimates because the $I^2$-squared values were not reduced substantially.

Also, since these analyses usually involve multiple testing in case of many outcomes and would ideally require a much smaller $p$-value cut-off for significance, sub-group analysis estimates are observational and should be interpreted with caution.

The forest plots for all the individual outcomes have been shown in the figures below. Each forest plot shows the individual effect estimates for the intervention and control groups and the mean difference in each study, along with the overall pooled mean difference and corresponding CIs. (Figs. 3, 4, 5, 6, 7, 8, 9, 10, 11, 12).

(A visual assessment of the funnel plots for each outcome showed the presence of some asymmetry for a few biochemical outcomes but we did not conduct any formal statistical tests to assess the same.)

Discussion
Based on the 33 studies reviewed, we found that changes in diet and physical activity at worksites had a significant and positive effect on body weight, body mass index and waist circumference of working adults. It can be concluded that workplace based physical activity interventions can positively affect anthropometric outcomes and thus have the potential to alter the biochemical risk markers too. The results need to be interpreted with caution though, due to high heterogeneity among studies. The $p$-values for the chi-square test for heterogeneity were quite significant, suggesting a high degree of variability in effect estimates due to
actual differences in studies and not due to sampling error (chance). This may be due to variability in sample sizes (they ranged from 45 to 10,281 participants) as well as the different study designs used in different studies. The various intervention approaches used across studies might also have contributed to the heterogeneity, as indicated by the exploratory sub-group analyses.

There could be a few reasons for the lack of a stronger evidence for the effect on biochemical variables. Anthropometric outcomes were the primary outcomes in almost all the studies whereas biochemical outcomes in a third, and only as secondary outcomes in half of the studies included in the meta-analyses. Those studies were therefore not adequately powered to detect significant changes in blood pressure, lipids and glucose levels.

Some reviews done in the past have shown a similar pattern with most included studies focusing only on anthropometric outcomes, which underscores the need for more high quality trials studying the effect of physical activity interventions on blood pressure and biochemical measures as well [65][66].

A few previously done reviews such as the one by Fleming et al. [67], a 2010 review by Groeneveld et al. [26] and a brief overview of worksite health promotion programs and non-communicable disease prevention [68] have all suggested the possibility of greater intervention effectiveness among

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**Table 2** Pooled estimates from meta-analysis of studies for change in each CVD risk outcome

| Outcome                  | Number of studies | Mean difference | Confidence interval | Heterogeneity |
|--------------------------|-------------------|-----------------|---------------------|--------------|
| Body weight (kg)         | 16                | -2.61           | [-3.89, -1.33]      | 94%          |
| Body mass index (kg/m²)  | 19                | -0.42           | [-0.69, -0.15]      | 89%          |
| Waist circumference (cm) | 13                | -1.92           | [-3.25, -0.60]      | 92%          |
| Systolic blood pressure (mmHg) | 16 | -1.73           | [-4.25, 0.79]       | 93%          |
| Diastolic blood pressure (mmHg) | 15 | -1.73           | [-4.25, 0.79]       | 93%          |
| Total cholesterol (mg/dl) | 11               | -3.75           | [-9.84, 2.23]       | 86%          |
| HDL cholesterol (mg/dl)  | 12                | 0.54            | [-1.13, 2.20]       | 88%          |
| LDL cholesterol (mg/dl)  | 10                | -3.25           | [-8.00, 1.51]       | 75%          |
| Triglycerides (mg/dl)    | 8                 | 0.62            | [-4.82, 6.06]       | 55%          |
| Blood glucose (mg/dl)    | 10                | -3.14           | [-6.47, 0.20]       | 94%          |

Estimates highlighted in bold indicate the effect sizes that were statistically significant.

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**Fig. 3** Forest plot for change in body weight

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| Study or Subgroup | Intervention | Control | Mean Difference | IV, Random, 95% CI | Mean Difference | IV, Random, 95% CI |
|-------------------|--------------|---------|-----------------|-------------------|-----------------|-------------------|
| Almeida 2015      | -1.02        | 4.95    | 872             | -0.58             | 7.17            | 631               | 8.1%             | -0.44 [-1.09, 0.21] |
| Chen 2014         | -1.22        | 2.05    | 56              | -0.3              | 1.95            | 43                | 8.0%             | -0.92 [-1.71, -0.13] |
| Christensen 2012  | -5.8         | 22.41   | 54              | -0.3              | 20.49           | 44                | 1.8%             | -5.50 [-14.01, 3.01] |
| Healy 2017        | 0.62         | 3.89    | 136             | 0.43              | 3.63            | 95                | 7.9%             | 0.19 [-0.79, 1.17]  |
| Jamal 2016        | -2.42        | 4.82    | 97              | -0.69             | 2.65            | 97                | 7.8%             | -1.73 [-2.82, -0.64] |
| Kim 2015          | -1.71        | 3.29    | 63              | -1.56             | 3.45            | 59                | 7.7%             | -0.15 [-1.35, 1.05] |
| Kramer 2015       | -4.71        | 3.94    | 56              | -1.04             | 4.12            | 28                | 7.1%             | -3.67 [-5.51, -1.83] |
| Limaye 2016       | -1           | 2.91    | 133             | 0.7               | 2.9             | 132               | 8.1%             | -1.70 [-2.40, -1.00] |
| Morgan 2011       | -4           | 4.43    | 65              | 0.3               | 4.65            | 45                | 7.2%             | -4.30 [-6.03, -2.57] |
| Muto 2001         | -1           | 3.2     | 70              | 0.5               | 2.2             | 68                | 7.9%             | -1.50 [-2.41, -0.59] |
| Prabhakaran 2009  | -8.6         | 41.66   | 4987            | 12.46            | 532             | 925               | 5.4%             | -20.80 [-23.81, -17.39] |
| Racette 2009      | -0.8         | 35.62   | 68              | 0.6               | 31.22           | 55                | 1.0%             | -1.40 [-13.22, 10.42] |
| Srivastava 2017   | 1.6          | 2.76    | 156             | 0.38              | 2.03            | 111               | 8.1%             | 1.22 [0.65, 1.79]  |
| Viester 2017      | 0.4          | 17.46   | 127             | 1.1               | 21.35           | 129               | 3.8%             | -0.70 [-5.47, 4.07] |
| Weinhold 2015     | -4.9         | 3.55    | 35              | -0.4              | 3.49            | 34                | 7.3%             | -4.50 [-6.16, -2.84] |
| Wilson 2016       | -0.73        | 29.25   | 237             | 1.4               | 29.16           | 135               | 7.8%             | -2.13 [-8.30, 4.04] |

Total (95% CI) 7212 2631 100.0% -2.61 [-3.89, -1.33]
### Fig. 4

Forest plot for change in body mass index

### Fig. 5

Forest plot for change in waist circumference
populations already at risk of CVDs compared to mixed populations. Hence, there is need for better quality studies to ascertain the role of employee health status in intervention effectiveness. A comparison of the effects of individual level behavior change on CVD risk reduction, compared to educational approaches and changes to the office environment is also an interesting facet that can be further explored.

Another aspect that needs consideration is participant compliance and barriers to intervention adherence.

**Fig. 6** Forest plot for change in systolic blood pressure

**Fig. 7** Forest plot for change in diastolic blood pressure
Unlike clinical or medical interventions which can be constantly monitored for acceptability, the effectiveness of lifestyle based interventions is difficult to evaluate since intervention uptake is a complex measure [69]. Some studies concluded lack of compliance, issues with intervention adherence, low participation and retention rates and inadequately motivated employees as some of the reasons which could have affected the study results. Non-adherence could also be one reason for very small effect sizes in studies with larger sample sizes [70].

Long-term participation and employee adherence thus seem to be major challenges in implementation of worksite physical activity interventions [70] [71]. It becomes paramount to devise innovative and practical ways to motivate the workforce and ensure sustained interest of the participants throughout the study [72]. Greater adherence and acceptability would ensure greater uptake that would in-turn result in more tangible health benefits to the employees.

**Limitations and strengths**

Our review has a few strengths. To the best of our knowledge, this is the first meta-analysis focused solely on the anthropometric and biochemical outcomes related to physical activity interventions at worksite. Secondly, the last review reporting the effects of worksite physical activity interventions was conducted over 10 years ago [73].

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**Table 1**

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | Mean Difference | IV, Random, 95% CI | Mean Difference | IV, Random, 95% CI |
|-------------------|------|----|-------|------|----|-------|--------|-----------------|-------------------|-----------------|-------------------|
| Chen 2014         | -7.25| 27.6| 56    | -9.44| 24  | 43    | 9.0%   | 2.19 [-7.99, 12.37] |                  |                 |
| Jamal 2016        | 1.54 | 26.68| 97    | -0.77| 22.81| 97    | 10.3%  | 2.31 [-4.66, 9.30]  |                  |                 |
| Kramer 2015       | -3.1 | 24.3 | 51    | -0.5 | 18.3 | 26    | 9.2%   | -2.60 [-12.29, 7.09] |                  |                 |
| Limaye 2016       | -6.57| 15.46| 133   | -1.16| 17.78| 132   | 11.4%  | -5.41 [-9.42, -1.40] |                  |                 |
| Moy 2006          | -8.12| 29  | 102   | 6.57 | 35.96| 84    | 9.3%   | -14.69 [-24.22, -5.16] |                  |                 |
| Muto 2001         | -6.4 | 24.3 | 73    | 4.5  | 22.7 | 56    | 9.9%   | -10.90 [-19.05, -2.75] |                  |                 |
| Nilsson 2001      | 3.86 | 47.95| 43    | 0    | 54.91| 46    | 4.8%   | 3.96 [-17.52, 25.24] |                  |                 |
| Prabhakaran 2009  | -10.7| 60.73| 4987  | 6.5  | 51.09| 925   | 11.5%  | -17.20 [-20.90, -13.50] |                  |                 |
| Racette 2009      | -8   | 45.18| 58    | -4   | 53.76| 55    | 5.9%   | -4.00 [-21.81, 13.81]  |                  |                 |
| Srivastava 2017   | 4.78 | 24.17| 148   | -2.77| 23.37| 102   | 10.7%  | 7.55 [1.57, 13.53]    |                  |                 |
| Vierst 2017       | -19.33| 49.88| 116   | -23.2| 45.24| 115   | 8.1%   | 3.87 [-6.41, 16.15]    |                  |                 |
| Total (95% CI)    | 5874 | 1681| 100.0% |  |     |       |        | -3.75 [-9.84, 2.33]    |                  |                 |

**Fig. 8** Forest plot for change in total cholesterol

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**Fig. 9** Forest plot for change in HDL-cholesterol
interventions on anthropometric and biochemical CVD risk markers was done in 2010 and our work provides updated literature on the topic. Thirdly, considering that we were dealing with multi-component PA interventions with multiple outcomes (and not a drug trial) we used a broad search strategy and covered 5 different databases to obtain a synthesis of all the relevant literature for practical understanding and future research. Fourthly, unlike a majority of previous reviews assessing the effect of worksite PA interventions primarily on physical activity, the proximal outcome, our review goes to the next level and summarizes the effects on the more distant anthropometric and biochemical outcomes.

A limitation of our study was that assessment of bias in individual studies was based on the data as reported in them. In some studies, relevant information on aspects of randomization and reporting of data was not presented which may have led to an underestimation of their quality. Another limitation was that we could not include data from nine studies in our meta-analyses since the estimates required for the analysis were not available. We wrote to the study authors but unfortunately only one of them provided data for our analyses. Additionally, it is possible that the interventions caused a change in other health behaviors like diet too, apart from physical activity, which in-turn could have led to an improvement in CVD outcomes.

Conclusions

Worksite physical activity interventions were effective in improving anthropometric measures, namely body weight, BMI and waist circumference. We were however unable to demonstrate a significant effect on biochemical variables. A possible reason could be that almost two-third of the studies were either not reporting the biochemical outcomes or not adequately powered to assess intervention effects on these
variables. The potential of such interventions to prevent CVD and overall non-communicable diseases (NCDs) needs attention by employers and policy makers for improving the health status of the population. This can significantly contribute to achieving the UN targets of a 25% relative reduction in premature deaths from NCDs by 2025 [73].

Implications for future research

Overall, the evidence on the wide-ranging benefits of physical activity interventions is robust for action, and the absence of statistically significant biochemical improvements should not act as a deterrent to adoption by workplaces. Ways to enhance uptake of worksite physical activity interventions by employers, employees and the environment need to be studied. A robust process evaluation framework along with assessment of factors like dietary changes, frequency of sickness, back pain, absenteeism etc., would provide greater insights into the relative effectiveness and complementarity of the different types of interventions. A design based on a theoretical framework like the Medical Research Council framework [74] for designing and evaluating complex intervention studies is an option. Also, future worksite PA intervention studies should adequately power for the biochemical outcomes and have longer follow-up durations. Hard-endpoints should be strived for wherever possible.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12966-019-0896-0.

Additional file 1. Search terms. This file provides the search strategy used to obtain relevant articles from PUBMED.

Additional file 2. Study interventions. This file includes a table that describes the purpose, characteristics, interventions and results of each study included in the review.

Additional file 3. Exploratory Sub-group analyses. This file includes the tables describing the effects of workplace interventions on outcomes, analyzed under sub-groups.

Additional file 4. Risk of bias summary for individual studies in the review.

Abbreviations

BMI: Body Mass Index; CI: Confidence Interval; CVD: Cardiovascular Disease; HDL-C: High Density Lipoprotein Cholesterol; LDL-C: Low Density Lipoprotein Cholesterol; MVPA: Moderate to Vigorous Physical Activity; PA: Physical Activity; RCT: Randomized Controlled Trial; WHO: World Health Organization

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Authors’ contributions

All authors contributed to the manuscript. RM and CS conducted the data screening and assessment of methodological quality. RM conducted the data extraction, analysis and the initial draft of the manuscript with the help of CS. SG and CS authors critically shaped and modified the manuscript as we moved through multiple drafts. All the other authors reviewed the manuscript, provided critical inputs along the way. All the authors have read and approved the manuscript.

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Fig. 12 Forest plot for change in blood glucose
Competing interests
The authors declare that they have no competing interests.

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