Review Article

Effectiveness of community-based cardiovascular disease prevention interventions to improve physical activity: A systematic review and meta-regression

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ABSTRACT

Cardiovascular diseases (CVDs) remain a leading cause of morbidity and mortality globally. Despite preventive community-based interventions (CBIs) seem efficacious in reducing CVD risks, a comprehensive up-to-date synthesis on the effectiveness of such interventions in improving physical activity (PA) is lacking. We performed a systematic review and meta-analysis of community-based CVD preventive interventions aimed at improving PA level. MEDLINE, EMBASE, CINAHL, Cochrane register and PSYCINFO databases were searched in October 2019 for studies reported between January 2000 and June 2019. We assessed the methodological quality of included studies using the Cochrane risk of bias tools. We performed a random-effects meta-analysis and meta-regression to pool estimates of various effect measures. Results are reported in line with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guideline. Our study protocol was registered in the PROSPERO database (CRD42019119885). A total of 44 randomized and 20 non-randomized controlled studies involving 98,919 participants were included. Meta-analyses found that CBIs improved the odds of attaining the recommended PA level (at least 150 min of moderate and vigorous PA (MVPA)/week) at 12 month (OR: 1.62; 95%CI: 1.25–2.11) and 18 to 24 months of follow-up (OR: 1.46; 95%CI: 1.12–1.91). Furthermore, interventions were effective in improving metabolic equivalents of task at 12 month (standardized mean difference (SMD): 0.28; 95% CI: 0.03–0.53), MVPA time at 12 to 18 months (SMD: 0.34; 95%CI: 0.05–0.64), steps per day (SMD: 0.32; 95%CI: 0.08–0.55), and sitting time (SMD: −0.25; 95%CI: −0.34 to −0.17). Subgroup analyses found that interventions in low- and middle-income countries showed a greater positive effect on attainment of recommended PA level (OR: 1.40; 95%CI: 1.02–1.92) than those in high-income countries (OR: 1.31; 95%CI: 0.96–1.78). Moreover, interventions targeting high-risk groups showed greater effectiveness than those targeting the general population (OR: 1.76; 95%CI: 1.30–2.39 vs. 1.17; 95%CI: 0.89–1.55). In conclusion, community-based CVD preventive interventions have a positive impact on improving the PA level, albeit that relevant studies in lower-middle and low-income countries are limited. With the rising burden of CVDs, rolling out CBIs targeting the general population and high-risk groups are needed to control the growing CVD-burden.

1. Introduction

By the year 2030, non-communicable diseases (NCDs) may account for more than 75% of global deaths (WHO, 2013). With an estimated 523 million cases and 18.6 million deaths (accounting 32.8% of all

deaths), cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality worldwide (Roth Gregory et al., 2020). Ischemic heart disease and stroke are the first and second leading cause of CVD deaths respectively (Roth Gregory et al., 2020; World Health Organization, 2017). Between 1990 and 2019, the age standardized

CVD deaths declined in high-income countries (HICs) and some middle-income countries in contrast to most low- and middle-income countries (LMICs) where a steep rise contributed to 75% of all global CVD deaths (World Health Organization, 2017; Roth et al., 2017). The differences in CVD burden observed between countries and regions could be due to demographic changes but as observed after age standardization, the difference is enhanced by socioeconomic changes, epidemiological transition, acquisition of behavioral risks and the influence of globalization and industrialization (World Health Organization, 2017; Roth et al., 2017; Gaziano et al., 2010).

Unhealthy lifestyles including physical inactivity are known behavioral risks of CVD. Fortunately, with community-based interventions (CBIs), the CVD burden can be reduced by targeting behavioral and metabolic risk factors in the entire community (Parker and Assaf, 2005; Elder et al., 1993; Mensah et al., 2017; Bhalla et al., 2006; Veazie et al., 2005). Population level lifestyle interventions are likely to be more cost-effective than treatment-oriented programs in both LMICs and HICs (Cecchini et al., 2010; Townsend et al., 2016; Checkley et al., 2014).

Improving an individual's level of physical activity (PA) is the core target area of primary CVD prevention, besides other lifestyle- and treatment-based interventions. PA recommendations are thereof among the main components of healthy lifestyle guidelines in several countries. Nevertheless, the level of PA in the general population is still low, in which one in four adults worldwide currently do not meet the World Health Organization (WHO) recommendations (World Health, 2019). Multifactorial interventions, in the general population as well as for individuals with risk factors, can improve PA level and in turn impact the occurrence of CVDs. CBIs aimed at improving PA level and other behavioral risks have been shown to decrease morbidity and mortality from CVDs (Li and Siegrist, 2012; Alves et al., 2016). Such interventions have been implemented mostly in HICs and recently in LMICs using various strategies, in which improving the level of PA is considered to be feasible (Dunn, 2009).

A review of studies between 2001 and 2012 indicated that CBIs seem to be effective in improving PA (Bock et al., 2014). Wahlich and colleagues also conducted a review of 9 randomized controlled studies and found that CBIs are efficacious in improving PA (Wahlich et al., 2020). However, all included studies were conducted in HICs and the evidence is not generalizable to other contexts. Furthermore, being a review of RCTs only, the observed efficacy might not reflect the real-world evidence. There is a paucity of comprehensive recent pragmatic evidence on such interventions to inform prevention and control efforts in various contexts. Available reviews are not comprehensive and limited by region (Brown et al., 2015; Van de Vijver et al., 2012) or target population (Walton-Moss et al., 2014; Mohan et al., 2018; Amiri Farahani et al., 2015). Moreover, the effectiveness of interventions particularly on PA level is not well documented. Little is also known about which intervention strategy provides a larger effect on PA level. We synthesized the effectiveness of community-based CVD interventions aimed at increasing the PA level and compared the effectiveness in LMICs and HICs. This evidence is valuable for policy makers and the scientific community to design effective strategies for CVD prevention principally through improving the PA level.

2. Methods

This systematic review was conducted as part of the work of the SPICES project - Scaling-up Packages of Interventions for Cardiovascular diseases in selected sites in Europe and Sub-Saharan Africa (https://www.uantwerpen.be/en/projects/spices/). One of the aims is to review the available evidence on community-based CVD preventive interventions targeting PA, diet, smoking, alcohol intake, and CVD knowledge. This specific review focuses on studies having PA as an outcome. The review protocol was prepared in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analysis Protocols (PRISMA-P) 2015 statement (Moher et al., 2015), and

registered in the PROSPERO International prospective register of systematic reviews (Reg. Number: CRD42019119885).

2.1. Search strategy

We searched electronic databases including MEDLINE, EMBASE, CINAHL, Cochrane register of controlled studies, and PSYCINFO in October 2019. Other databases including thesis online, OpenGrey, ProQuest, CHW Central, Google Scholar, ClinicalTrials.gov and the WHO International Clinical trials registry platform were also consulted. Using search terms related to the population, intervention, and outcomes, a comprehensive search strategy was developed through discussion with the team and information on intervention terminology from a prior preliminary search of literature. The full search strategy is available in the supplementary material (Box S1–5). In addition, reference lists of included articles and references of references were searched for potential eligible studies.

2.2. Study selection and screening

We included articles aimed at preventing CVDs and that have PA level as an outcome. Studies aimed to prevent cancer, falls, mental illnesses and other health issues were excluded irrespective of having PA level as an outcome. Furthermore, studies were included if they met the criteria below:

- Study population: We included studies that involved adult participants aged 18 years and above, with no restrictions on gender. Studies of individuals who had a formal diagnosis of any type of CVD were excluded.
- Intervention: We included studies that reported interventions carried out within the community for either primordial or primary prevention of CVD, which aimed at avoiding development of risk factors or controlling them. Interventions with clinical procedures or drug components were excluded. In this review, CBIs were defined as various primordial and primary prevention activities that use the community as setting, community as target, community as agent, and/or community as resource (McLeroy et al., 2003). Community includes households, workplaces, schools, religious centers, sport centres, pharmacies, primary health care units, community health workers among others, but not secondary and tertiary healthcare facilities. Interventions that started at health facilities and were linked to the community were also included provided that the study populations are those without CVD. We excluded studies based only in clinical settings.
- Comparator: Usual care, standard general practitioner (GP) referral, enhanced usual care (EUC) or waiting-list controls.
- Outcome: Studies that have any PA measure (both objective and self-reported) were included.
- Study designs: Individual or clustered randomized controlled trials or controlled quasi-experimental or interrupted time series studies were eligible.
- Other considerations: Studies with a total sample size below 150, attrition rate above 40% and a follow-up (FU) period shorter than 9 months were excluded. We restricted our attention to studies reported from January 1, 2000 to June 30, 2019. This review was limited to studies reported in the English language. However, no restriction was placed on study location.

Articles were exported as EndNote files into a single library. Duplicate articles from the searches were verified and removed. The remaining articles were imported into rayyan.QCRI.org (Ouzzani et al., 2016), a web-based tool that facilitates screening and collaboration among researchers. Two reviewers (HYH and RN) independently screened all retrieved articles assessing their titles and abstracts for inclusion using defined criteria. Articles designated for full text review

were read and final inclusion decisions were made. In case the reviewers were in doubt regarding inclusion of an article, discussions were held with other reviewers (HB and GM). Studies with multiple publications were considered as a single study. In case of any key missing information in the articles, author(s) were contacted twice via email. All reasons for exclusion of articles were noted and the review process is presented in the PRISMA flow chart (see Fig. 1).

2.3. Risk of bias assessment

The risk of bias of included randomized studies was assessed for each outcome using the revised Cochrane tool for Risk of Bias (RoB2) for individual randomized studies and with additional considerations (the timing of participant recruitment) for the cluster randomized studies (Sterne et al., 2019), which categorize studies into 'low', 'some concerns', and 'high' risk of bias. Whereas for non-randomized controlled (NRC) studies, we used the Risk of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tool (Sterne et al., 2016), which categorizes studies into 'low', 'moderate', 'serious', and 'critical' risk of bias. The risk of bias assessment was conducted independently by two reviewers (HYH and RN) who resolved any differences through consensus, and where necessary, consultation with a third reviewer (HB) was made.

2.4. Data extraction

Two reviewers (HYH and RN) independently extracted all relevant information from eligible full text articles. Any disagreements between reviewers were solved through consensus. Data were extracted on study design, participant characteristics, intervention characteristics, comparator group(s), FU duration, sample size and attrition rate, outcome measures, results, and funding sources. Data were also extracted on intervention components such as its description, length, setting, approach and intensity. For the outcomes, the measuring tool, effect estimates, and observed changes in PA level were recorded for each group. The team contacted author(s) of included studies via email to request for clarification of relevant information and extended results where necessary. Whenever the results were presented only graphically and we were unable to get the results from the corresponding author(s) after a reminder email, we extracted the relevant information using WebPlotDigitizer, which is evidenced to be valid and reliable (Cramond et al., 2019).

2.5. Data analysis

Descriptive statistics were used to summarize the main study characteristics including study design, risk of bias, intervention approach and setting, and measurement of PA. Data are presented in tabular form for comparison purposes highlighting countries with income per capita
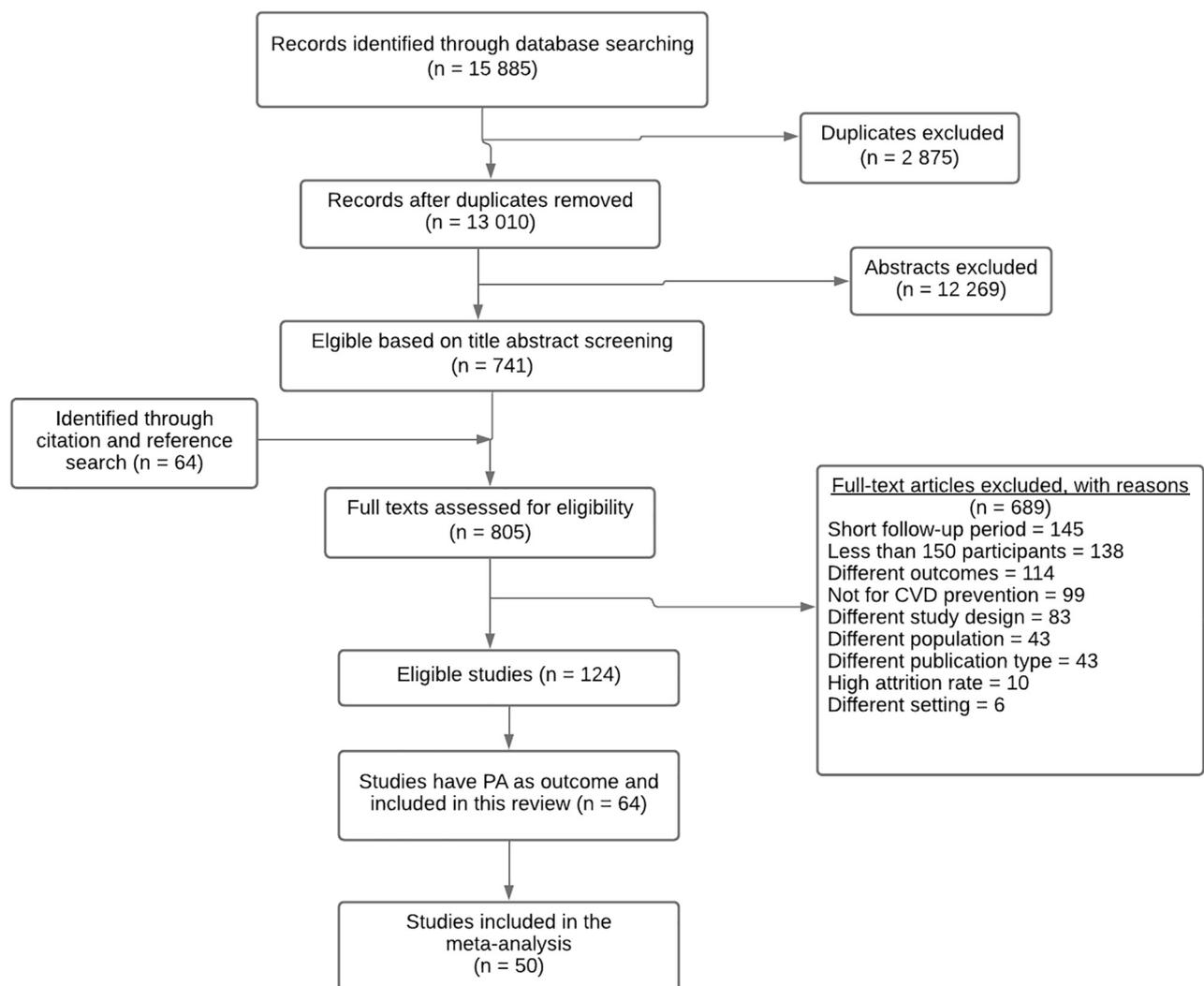

Fig 1. PRISMA flow chart illustrating the article search and selection process.

category, year of study, intervention duration, target population and outcomes among others.

We evaluated the eligibility of studies for meta-analysis and meta-regression based on the outcome measurement and intervention similarity. For any outcome measurement with at least three studies, we performed a meta-analysis. Hence, the results of seven outcome measures: attainment of recommended PA level (regular PA - at least 30 min of MVPA for at least 5 days a week, or 150 min of MVPA per a week), metabolic equivalents of task (METs-min/wk), moderate and vigorous PA (MVPA) time (min/wk), total PA (TPA) time (min/wk), step count (per day), walking time (min/wk), and sitting time (min/day) were synthesized using a meta-analysis. Findings from studies that did not report any of these outcome measures and/or interventions that employed exceptionally different strategies were summarized narratively. Furthermore, studies that did not report sufficient information and of which extended results were unavailable from the authors were also synthesized narratively.

2.6. Meta-analysis

Due to the variation in the FU duration and the frequency of measurement of the outcome across studies, we performed separate analyses at different time points. We categorized the FU time from baseline to outcome assessment into subgroups of 9 to 12, 18 to 24, and 36 months and above. We performed a random-effects meta-analysis of studies on each outcome measure separately. Random-effects meta-analysis models were selected over fixed-effect ones because we assumed a greater study-level variability in terms of study populations and intervention approach (Riley et al., 2011; Borenstein et al., 2010). For continuous outcomes, the standardized mean differences (SMDs) with 95% confidence intervals (95%CIs) were used to summarize the pooled effect. SMDs were calculated as the difference in mean of outcome measures between groups divided by the pooled standard deviations (SD) in all participants. For some studies, the sample mean and SD were not reported and could not be found from authors, hence, we estimated these quantities from other parameters reported in the study as suggested by Wan et al. (Wan et al., 2014). Similarly, when the SDs or standard errors (SEs) for differences were not available, we imputed them using other reported parameters based on the Cochrane guideline (Higgins et al., 2019). For categorical outcomes, odds ratios (ORs) with 95%CIs were pooled. We assessed heterogeneity for each outcome measure independently using the I^2 statistic and the significance of heterogeneity was tested with Cochran's Q statistics (Higgins and Thompson, 2002).

2.7. Subgroup analysis and meta-regression

An exploratory subgroup analysis was done considering the following potential effect-moderating factors: i) Income category of the country as defined by World Bank (HIC or LMIC); ii) Gender (women only, men only, or both); iii) Target group (general population or high-risk groups such as overweight/obese, elders, pre−/diabetes, pre/hypertension, metabolic syndrome, etc. but not CVD); iv) Main intervention setting (community, primary healthcare, or home-based); and v) Intervention approach (individual, group, or both). Intervention effects were estimated within subgroups and compared across subgroups to identify components that mainly modify the intervention effects. To identify the effects of covariates on the effect size, we performed a univariate and multiple meta-regression (Thompson and Higgins, 2002), considering the aforementioned study level covariates and intervention duration.

We assessed publication bias graphically with contour-enhanced funnel plots and Egger's regression test (Egger et al., 1997) for the statistical significance. We analyzed data using the **meta** package of the free statistical software R version 4.0.2 (Schwarzer, 2007). This review is reported in accordance with the PRISMA 2009 statement (Moher et al., 2009) with a flow chart highlighting the articles screening process (see Fig. 1). A completed PRISMA checklist is available in the supplementary material (table S2). The quality of evidence from this review was evaluated using GRADE (Guyatt et al., 2011) and the summary thereof is available in the supplement (table S4).

3. Results

The database search resulted in the retrieval of 15,885 abstracts. Title and abstract screening resulted in 741 articles and additional 64 articles were identified through reference search resulting in a total of 805 articles. Then, after reading the full article, 124 studies met the eligibility criteria. Of these, 64 studies had PA as an outcome and were therefore included in this review and analysis. Out of the 64 studies, 50 were included in the meta-analysis in at least one outcome measure, whereas the remaining 14 studies were summarized narratively (Fig. 1).

3.1. Study characteristics

The characteristics of the included studies are summarized in the supplementary material (table S1). Of 64 studies included in this review, 44 were from high-income countries. More specifically, 17 were based in the USA (Brownson et al., 2004; Campbell et al., 2002; Carrasquillo et al., 2017; The Writing Group for the Activity Counseling Trial Research Group, 2001; Dirige et al., 2013; Dubbert et al., 2002; Greaney et al., 2008; Ayala et al., 2015; Hays et al., 2016; Laska et al., 2016; Marcus et al., 2007; Napolitano et al., 2006; Resnicow et al., 2005; Stewart et al., 2001; Toobert et al., 2010; Østbye et al., 2009; Kegler et al., 2016), five each in the UK (Khunti et al., 2012; Isaacs et al., 2007; Iliffe et al., 2014; Davies et al., 2016; Bhopal et al., 2014), and Australia (Burke et al., 2003; Wendy et al., 2006; Freene et al., 2015; Lombard et al., 2010; Mitchell et al., 2019), four in Japan (Saito et al., 2011; Kubota et al., 2019; Saito et al., 2018; Zhu et al., 2013), three in the Netherlands (Kloek et al., 2006; Luten et al., 2016; Wendel-Vos et al., 2009), two each in New Zealand (Lawton et al., 2008; Elley et al., 2003), Belgium (De Cocker et al., 2008; Opdenacker et al., 2008), Finland (Aittasalo et al., 2004; Lindström et al., 2003) and Spain (Arija et al., 2017; Bóveda-Fontán et al., 2015), and one each in Denmark (Baumann et al., 2015) and Italy (Bo et al., 2007). In contrast, 20 studies were conducted in LMICs, i.e. five in China (Zhang et al., 2018; Lv et al., 2014; Lu et al., 2015; Huang et al., 2011; Chao et al., 2012), three in India (Thankappan et al., 2018; Ramachandran et al., 2013; Joshi et al., 2012), two each in Iran (Sarrafzadegan et al., 2009; Azizi et al., 2013), Pakistan (Nishtar et al., 2007; Jafar et al., 2009) and Sri Lanka (Chandraratne et al., 2019; Gunawardena et al., 2016), one each in Bangladesh (Fottrell et al., 2019), Malaysia (Ibrahim et al., 2016), Nepal (Neupane et al., 2018), Vietnam (Nguyen et al., 2012), and Kenya (Van de Vijver et al., 2016), and one multi-country study including participants living in China, India and Mexico (Anthony et al., 2015). In total, studies recruited 98,919 participants, 54,721 in the intervention and 44,198 in the control group.

Of the total studies, 28 were individual randomized trials, 16 cluster randomized, and 20 were NRC studies. Out of the 44 randomized studies, 16 have low, 24 some concerns, and four high-risk of bias based on the Cochrane RoB 2 assessment. Out of the 20 NRC studies, one has low, 15 moderate, and four serious risk of bias according to the Cochrane ROBINS-I tool. Details of the risk of bias for individual studies and each domain is available in the supplementary material (table S3).

Reported dichotomous outcome measures include the proportion of participants who attained the recommended PA level, increase in self-reported walking, or any PA. Various types of continuous outcome measures have also been used such as TPA time, MVPA time, METs-min, total energy expenditure (kcal/wk), walking time, step counts, sitting time, frequency and duration of any sports, transport activities, workplace activities, bicycling, and frequency of vigorous and moderate activities. Few studies used the PA activity score as an outcome measure.

Further details of outcome measures for each study is available in the supplementary material (table S1).

3.2. Interventions

Interventions involved several primordial and primary prevention strategies including health education and awareness creation either individually or in group through training, academic courses, lectures and workshops (The Writing Group for the Activity Counseling Trial Research Group, 2001; Laska et al., 2016; Østbye et al., 2009; Khunti et al., 2012; Wendel-Vos et al., 2009; Lv et al., 2014; Lu et al., 2015; Huang et al., 2011; Sarrafzadegan et al., 2009; Jafar et al., 2009; Gunawardena et al., 2016); community mobilization activities through group sessions, group activities, peer support programs, social networking and campaign (Brownson et al., 2004; Carrasquillo et al., 2017; Dirige et al., 2013; Ayala et al., 2015; Laska et al., 2016; Stewart et al., 2001; Toobert et al., 2010; Isaacs et al., 2007; Iliffe et al., 2014; Davies et al., 2016; Burke et al., 2003; Wendy et al., 2006; Freene et al., 2015; Lombard et al., 2010; Saito et al., 2018; Zhu et al., 2013; Kloek et al., 2006; Luten et al., 2016; De Cocker et al., 2008; Opdenacker et al., 2008; Arija et al., 2017; Baumann et al., 2015; Lv et al., 2014; Thankappan et al., 2018; Joshi et al., 2012; Azizi et al., 2013; Nishtar et al., 2007; Chandraratne et al., 2019; Fottrell et al., 2019; Ibrahim et al., 2016; Neupane et al., 2018; Nguyen et al., 2012; Van de Vijver et al., 2016); individual-based lifestyle counseling, coaching and motivational interviewing face-to-face or via phone calls (Carrasquillo et al., 2017; The Writing Group for the Activity Counseling Trial Research Group, 2001; Dubbert et al., 2002; Greaney et al., 2008; Hays et al., 2016; Resnicow et al., 2005; Østbye et al., 2009; Kegler et al., 2016; Davies et al., 2016; Bhopal et al., 2014; Mitchell et al., 2019; Saito et al., 2011; Zhu et al., 2013; Lawton et al., 2008; Elley et al., 2003; Aittasalo et al., 2004; Lindström et al., 2003; Bóveda-Fontán et al., 2015; Baumann et al., 2015; Bo et al., 2007; Zhang et al., 2018; Ibrahim et al., 2016; Neupane et al., 2018); motivational education materials and messages through electronically and/or print mails (Brownson et al., 2004; Campbell et al., 2002; The Writing Group for the Activity Counseling Trial Research Group, 2001; Greaney et al., 2008; Laska et al., 2016; Marcus et al., 2007; Napolitano et al., 2006; Resnicow et al., 2005; Kegler et al., 2016; Burke et al., 2003; Mitchell et al., 2019; Ramachandran et al., 2013; Fottrell et al., 2019); environmental and structural changes such as building PA facilities or workplace activities (Kubota et al., 2019; Luten et al., 2016; Lv et al., 2014; Anthony et al., 2015); and organizational such as increasing screening and coaching (Chao et al., 2012; Van de Vijver et al., 2016).

The majority (62.5%) of the studies had an intervention duration of 12 to 24 months. Twenty-one studies had an intervention for 12 months (Carrasquillo et al., 2017; Greaney et al., 2008; Ayala et al., 2015; Marcus et al., 2007; Napolitano et al., 2006; Resnicow et al., 2005; Stewart et al., 2001; Lombard et al., 2010; Elley et al., 2003; De Cocker et al., 2008; Aittasalo et al., 2004; Lindström et al., 2003; Bóveda-Fontán et al., 2015; Bo et al., 2007; Thankappan et al., 2018; Joshi et al., 2012; Nishtar et al., 2007; Chandraratne et al., 2019; Gunawardena et al., 2016; Ibrahim et al., 2016; Neupane et al., 2018), 14 studies a period of 24 months (Brownson et al., 2004; The Writing Group for the Activity Counseling Trial Research Group, 2001; Laska et al., 2016; Toobert et al., 2010; Davies et al., 2016; Kubota et al., 2019; Saito et al., 2018; Kloek et al., 2006; Zhang et al., 2018; Lv et al., 2014; Lu et al., 2015; Ramachandran et al., 2013; Jafar et al., 2009; Anthony et al., 2015), five studies of 18 months (Campbell et al., 2002; Dirige et al., 2013; Wendy et al., 2006; Chao et al., 2012; Fottrell et al., 2019), six studies of 9 to 11 months (Dubbert et al., 2002; Østbye et al., 2009; Luten et al., 2016; Lawton et al., 2008; Opdenacker et al., 2008; Arija et al., 2017), five studies of 6 months (Isaacs et al., 2007; Iliffe et al., 2014; Freene et al., 2015; Zhu et al., 2013; Van de Vijver et al., 2016), and four studies for a period of three to five months (Hays et al., 2016; Kegler et al., 2016; Burke et al., 2003; Mitchell et al., 2019). Five studies considered a longer intervention duration lasting for three to four years (Bhopal et al., 2014; Saito et al., 2011; Huang et al., 2011; Azizi et al., 2013; Nguyen et al., 2012), two studies considered a period of five years (Wendel-Vos et al., 2009; Sarrafzadegan et al., 2009), with the longest period spanning 10 years (Baumann et al., 2015). Most of the studies performed FU measurements at 12 and/or 24 months after initiation of the intervention.

The most common intervention settings entailed community-based (54.7%), followed by home-based (29.7%), combined primary care settings and home-based (17.2%), eHealth using either phone call, message or internet (21.9%), and workplace and schools (6.3%). More than half (56.1%) of the interventions utilized a multi-component strategy in various settings. Community organizations, community health workers, volunteers, primary care providers (GPs and/or nurses), and peers were frequently used to provide or facilitate the intervention.

3.3. Meta-analysis

Table 1 summarizes the pooled effects of the intervention on binary and continuous measures of PA at different FU points. CBIs were effective compared to controls in improving the odds of participants who attained the recommended PA level at 12 month (OR: 1.62; 95% CI: 1.25, 2.11; number of studies (n) = 13; I^2 = 90%) and 18 to 24 months of FU (OR: 1.46; 95% CI: 1.12, 1.91; n = 18; I^2 = 92%). However, the effect at 36 months and above was not statistically significant (OR: 0.98; 95% CI: 0.64, 1.49; n = 6; I^2 = 93%) (Fig. 2a-c). The increase in METs was higher in the intervention group compared to controls at 12 months (SMD = 0.28; 95% CI: 0.03, 0.53; n = 8; I^2 = 96%) and 18 to 24 months of FU (SMD = 0.12; 95% CI: 0.00, 0.25; n = 10; I^2 = 92%), in which 0.1 SMD is approximately equivalent to 80 METs-min/week. Likewise, the improvement in MVPA time was significantly higher in the intervention group at 12 to 18 months as compared to controls (SMD = 0.34; 95% CI: 0.05, 0.64; n = 8; I^2 = 94%), which is roughly equivalent to a mean difference of 39 min of MVPA per week. Furthermore, the intervention was effective in increasing step counts (SMD = 0.32; 95% CI: 0.08, 0.55;

Table 1

Pooled effects of community-based interventions on binary and continuous physical activity measures.

Dichotomous outcome measure	FU time point (months)	No. of studies	OR (95%CI)	I^2 (%)
Recommended PA level	12	13	1.62 (1.25–2.11) **	90%
	18–24	18	1.46 (1.12–1.91) **	92%
	≥ 36	6	0.98 (0.64–1.49)	93%
Continuous outcome measures	**FU time point (months)**	**No. of studies**	**SMD (95% CI)**	**I^2 (%)**
METs/min/week	12	8	0.28 (0.03–0.53)*	96%
	18–24	10	0.12 (0.00–0.25)*	92%
	≥ 36	3	0.25 (−0.17–0.45)	62%
MVPA min/week	12–18	8	0.34 (0.05–0.64)*	94%
	24–36	3	0.16 (−0.71–1.04)	87%
TPA min/week	12	8	0.23 (−0.10–0.56)	96%
	24	3	0.04 (−0.74–0.81)	92%
	36	3	0.11 (0.07–0.15) ***	18%
Steps per day	12	5	0.32 (0.08–0.55)*	44%
Walking (min/day)	12–36	4	0.59 (−0.49–1.66)	92%
Sitting (min/day)	12	5	−0.25 (−0.34 to −0.17)***	87%

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
MET: Metabolic Equivalent Task; MVPA: Moderate and Vigorous Physical Activity; TPA: Total Physical Activity; OR: Odds Ratio; SMD: Standardized Mean Difference; CI: Confidence Interval; FU: Follow-up.
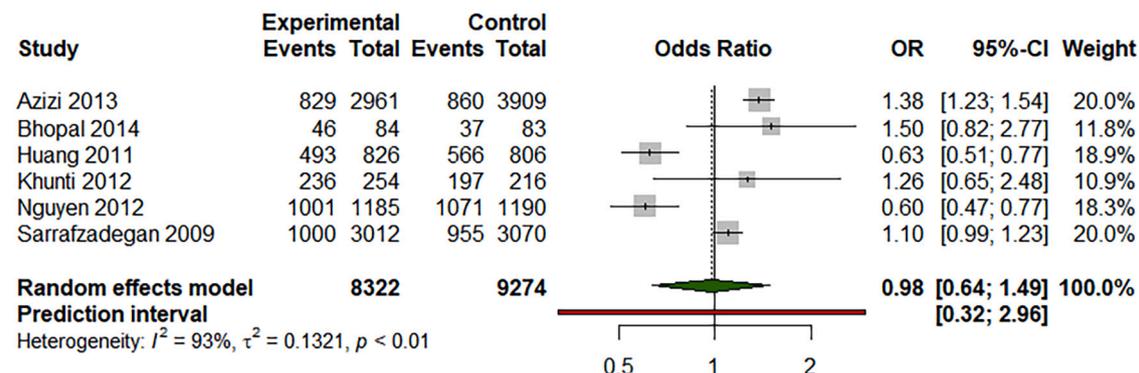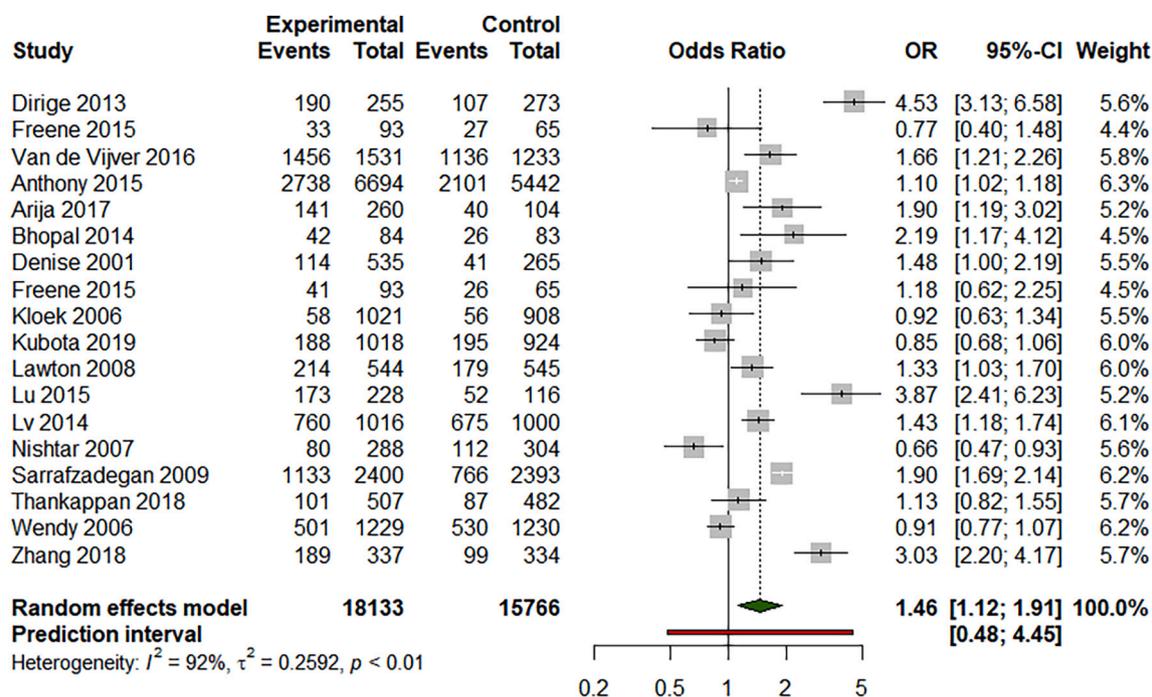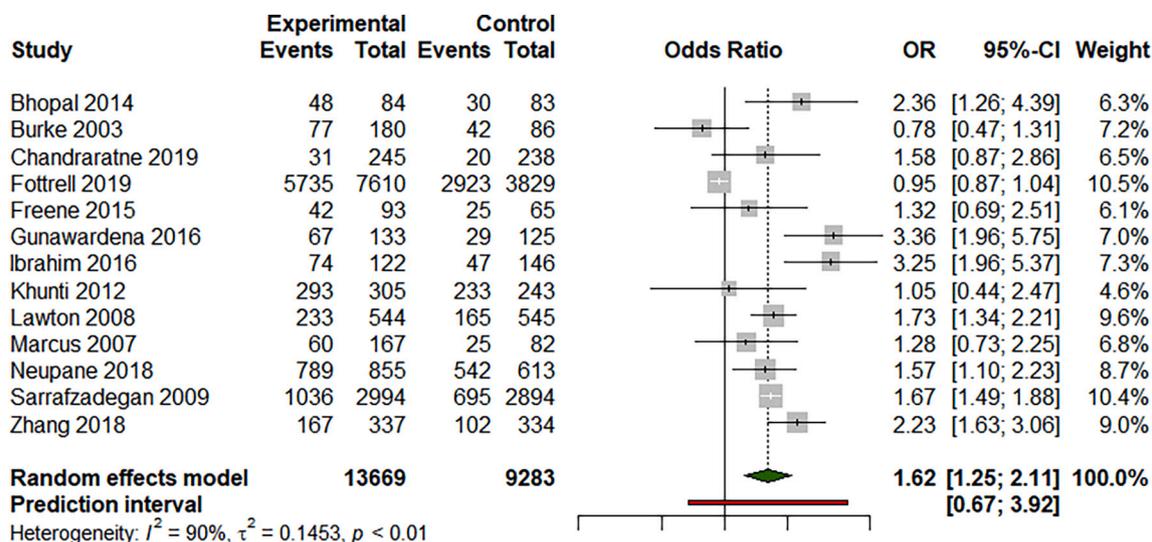
Fig 2. Forest plots indicating the effect of community-based cardiovascular disease preventive interventions on recommended physical activity level at: a) 12 month, b) 18 to 24 month, and c) 36 month of follow-up.

$n = 5$; $I^2 = 44\%$) and decreasing sitting time at 12 months of FU (SMD = −0.25; 95% CI: −0.34, −0.17; n = 5; $I^2 = 87\%$). Forest plots of all the outcome measures at each FU time are available in the supplementary material (fig. S2–S8).

3.4. Subgroup analysis and meta-regression

The majority of studies reported the proportion of participants who attained the recommended PA level, thus we used it for subgroup analysis and meta-regression. Overall, studies based in LMICs showed a significantly higher positive effect, taking all FU time points into consideration (OR: 1.40; 95% CI: 1.02,1.92; $I^2 = 93\%$) than HICs (OR: 1.31; 95% CI: 0.96, 1.78; $I^2 = 86\%$). However, the test for subgroup differences was not statistically significant ($p = 0.10$). Interventions targeting high-risk groups were more effective (OR: 1.76; 95% CI: 1.30, 2.39; $I^2 = 78\%$) than those targeting the general population (OR: 1.17; 95% CI: 0.89, 1.55; $I^2 = 92\%$) with significant subgroup difference ($p = 0.03$). RCTs showed a higher and significant intervention effect (OR: 1.72; 95% CI: 1.28, 2.30; $I^2 = 91\%$), whereas NRC studies found a non-significant effect (OR: 1.06; 95% CI: 0.81; 1.38; $I^2 = 90\%$) with significant subgroup variation ($p < 0.009$). Further subgroup analyses indicated that the subgroups did not significantly vary based on the intervention approach whether group, individual, or combined ($p = 0.47$), and main intervention settings ($p = 0.35$). The pooled intervention effects for the subgroups of each of the study level covariates and the forest plots are available in the supplementary material (fig. S9–S13).

The results of meta-regression analysis are presented in Table 2. We used 28 study intervention effects (ORs) for attaining recommended PA level in the analysis of five study level covariates. For two of the covariates, risk of bias and target group, the degree of heterogeneity (I^2) differed considerably between subgroups, however, the remaining covariates did not vary significantly. The multiple meta-regression showed that considering the covariates simultaneously, the overall test of moderators was significant ($F_{5,23} = 2.798$; $p = 0.04$), explaining $R^2 = 42.6\%$ of the heterogeneity. After adjustment for the other covariates included, none of the covariates were independently significant.

3.5. Publication bias

Publication bias was explored using funnel plots and Egger's test of symmetry. For attainment of recommended PA, the null hypothesis of symmetry was not rejected at 12 ($p = 0.21$), 18 to 24 ($p = 0.99$), and 36 months ($p = 0.50$) of FU, which means that there is no substantial publication bias. For METs, publication bias was detected at 12 month ($p = 0.003$), but not at 18 to 24 ($p = 0.56$) and 36 months ($p = 0.48$). The Egger's test for MVPA was not statistically significant at 12 to 18 ($p = 0.30$) and 24 to 36 months of FU ($p = 0.65$), implying no deviation from symmetry. Furthermore, the funnel plot and Egger's test for TPA indicated no sign of publication bias at 12 ($p = 0.53$), 24 ($p = 0.77$) and 36 months ($p = 0.69$). Similarly, no sign of publication bias was found for steps count (p = 0.56), sitting (p = 0.83), and walking time (p = 0.11). Due to a small number of studies for some of the outcomes, the Egger's test may lack statistical power to detect bias. Nevertheless, inspection of

Table 2
Multiple meta-regression of study level covariates.

Covariates included in the model	Estimate (β)	SE	95%CI
Intercept	−0.47	0.35	(−1.20–0.25)
Risk of bias (*low or some concerns*)	0.55	0.32	(−0.12–1.21)
Target group (*high-risk*)	0.33	0.23	(−0.14–0.80)
Study design (*RCT*)	0.22	0.23	(−0.26–0.71)
Country income per capita (*LMIC*)	0.27	0.20	(−0.14–0.68)
Duration of the intervention	−0.01	0.01	(−0.02–0.01)

SE: Standard Error; CI: Confidence Interval; LMIC: Low- and middle-income countries; RCT: Randomized controlled trial.

the funnel plots showed no huge deviation from symmetry. Detailed results of publication bias assessment including the funnel plots are available in the supplementary material (fig. S14–S21).

3.6. Narrative synthesis

Out of 14 studies not included in the meta-analysis in any of the outcome measures, five studies found a statistically significant difference in PA level in favor of the intervention group (Dubbert et al., 2002; Stewart et al., 2001; Toobert et al., 2010; Elley et al., 2003; Bóveda-Fontán et al., 2015). One study found a higher increase in walking time for exercise in the intervention group than the controls (Dubbert et al., 2002). Two studies found a significantly higher increase in energy expenditure in leisure-time and MVPA time in the intervention group than controls (Stewart et al., 2001; Elley et al., 2003). Furthermore, the other two studies showed an increase in frequency of all activities and level of PA in the intervention group than controls (Toobert et al., 2010; Bóveda-Fontán et al., 2015). In contrast, nine studies found no significant difference in all PA measures across intervention groups (Brownson et al., 2004; Carrasquillo et al., 2017; Greaney et al., 2008; Ayala et al., 2015; Laska et al., 2016; Zhu et al., 2013; Aittasalo et al., 2004; Ramachandran et al., 2013; Joshi et al., 2012).

4. Discussion

4.1. Summary of evidence

In this review, we conducted a meta-analysis of dichotomous and continuous PA measures reported in 39 RCTs and 11 NRC studies to explore the type and effectiveness of community-based CVD preventive interventions in improving PA level. We also provided a narrative synthesis of additional 14 similar studies. Findings from several meta-analyses demonstrated that the effectiveness of CBIs varies along with PA measures at various points of FU time. Significant improvement was observed in the proportion of participants who attained the recommended PA level, METs, MVPA time, and step counts at one year from baseline. Similarly, the sitting time also significantly decreased among the intervention group than controls. Our analysis further showed that the intervention effects were more pronounced at first and second year of FU, while at third year and above the effect became diminished and non-significant.

Previous reviews investigated the effectiveness of lifestyle interventions in improving metabolic risk factors such as obesity, high blood glucose, hypertension, and metabolic syndrome (Alageel et al., 2017; Patil et al., 2018; Widmer et al., 2015). Whereas, our review focused on the impact of interventions on behavioral risks particularly PA level and we found a significant improvement in various measures of PA. A previous review also showed that personal contact and tailored CBIs are effective in improving population PA level (Bock et al., 2014). Other earlier reviews before 2007 also indicated community-wide interventions and face-to-face counseling are effective in improving PA (Kahn et al., 2002; Ogilvie et al., 2007). Likewise, a recent review of randomized controlled studies found that CBIs are efficacious in improving objectively measured PA (Wahlich et al., 2020). Our review was based on studies that measured PA objectively and/or self-report, indicating the effectiveness of CBIs is not limited to objective measures. Furthermore, the Cochrane review of articles until 2011 also reported minimal reductions in behavioral CVD risk factors including PA following multicomponent behavioral interventions (Ebrahim et al., 2011). Therefore, community-based lifestyle interventions should be incorporated as one of the core components of programs aimed at prevention and control of CVDs.

Our meta-analyses found that the effectiveness of interventions declined at longer FU time and that it even became non-significant. The non-significance of the pooled estimate could be explained by the small number of articles that measured the outcome at 36 months and beyond.

Nevertheless, the effect size also diminished indicating the continuity of the intervention effect is questionable. Consistently, a review by Murray et al. found that CBIs have a larger effect at 6 to 9 months compared with 9 to 15 months, and no sufficient evidence was observed on maintenance beyond 15 months (Murray et al., 2017). Another review also found a decline of the intervention effect after six months of intervention (Sansano-Nadal et al., 2019). This implies that CBIs need to consider mechanisms to improve the sustainability of the impacts after cessation of the intervention package. The most popular RE-AIM planning and evaluation framework emphasizes the necessity of the component 'maintenance' after the intervention. Hence, intervention packages should explicitly report the framework utilized for implementation and evaluation guidance, steps followed, and the adaptations made to improve maintenance (Hailemariam et al., 2019). Community engagement should be a core component of such interventions to sustain the intended effect beyond the intervention period. Furthermore, a strong partnership between academia and public health institutes could help to facilitate collaboration among researchers, practitioners and policy makers to institutionalize an intervention into the routine public health practice. Funding agencies should also encourage researcher-practitioner-policy maker linkages and support such initiatives to sustain the impact of public health interventions beyond the intervention period.

Our subgroup analysis revealed that studies in LMICs showed a higher and significant effect on attainment of recommended PA level than those based in HICs. Although reviews seldom compare the effectiveness across contexts, independent systematic reviews in LMICs showed CBIs are effective in reducing diabetes and other CVD risk factors (Van de Vijver et al., 2012; Gyawali et al., 2019; Shirinzadeh et al., 2019). This could be due to the assumption that such interventions in LMICs are often needs-driven, leading to a higher likelihood of providing a positive impact and a greater potential for scale-up (Wu and Sullivan, 2009). This implies, in response to the emerging burden of CVDs in LMICs, community-based approaches could be cost-effective so that the country's income level need not be a major barrier for successful implementation.

Furthermore, in our subgroup analysis and meta-regression, interventions targeting high-risk groups (e.g. pre-diabetes, hypertensives, overweight/obese, metabolic syndrome, sedentary elders, and vulnerable population) showed a greater effectiveness than those interventions targeting the general population. In line with this, a Cochrane review found that interventions are more effective in high-risk hypertensive and diabetic populations than in the general population (Ebrahim et al., 2011). This could be due to a better adherence of high-risk groups to the intervention packages than the general population. These findings suggest that targeting of current CVD prevention activities to high-risk individuals might be of more value than the general population with poor adherence. Although targeting the general population is supposed to have a higher impact at population level risk reduction, the effectiveness is more pronounced by targeting high-risk groups. Hence, CBIs should give special attention to high-risk groups besides considering innovative strategies to improve the CVD risk at population level.

RCTs and studies with low risk or some concerns of bias showed a higher effectiveness than their respective counterparts. The multiple meta-regression also showed that the risk of bias of included articles highly determines the effect size. A review by Bock et al also found that the effect of the intervention was significantly higher for high-quality studies (Bock et al., 2014). This exemplifies that well designed intervention packages are most likely to provide a better effectiveness. Hence, interventions in real-life settings should put an effort to replicate the intervention effect observed in well-designed controlled studies.

We found that studies are disproportionately concentrated in high- and upper middle-income countries, whereas studies in low-income countries are scanty, particularly in sub-Saharan Africa. This shows a huge disease-burden and research-effort gap, where the burden is in LMICs, while the research effort is concentrated in HICs. Despite LMICs

sharing the higher proportion of social and economic burden of CVDs, studies evaluating the effectiveness of CBIs have been scarce, preventing the development of evidence-based public health policies to address the problem (Gómez-Olivé and Thorogood, 2018). LMICs share up to 80% of the global CVD burden, however, they only share below 10% of the research resources that are required to identify and evaluate sustainable solutions to address this escalating challenge (Vos et al., 2020; Owolabi et al., 2016). Hence, these issues need to be addressed through establishment of CVD and other NCDs research units in LMICs and taking lessons from HICs.

One of the strengths of this review is that it provides up-to-date evidence and pooled estimates on the effectiveness of CBIs aimed at CVD prevention in improving measures of PA at various points of FU time. Secondly, we performed a comprehensive subgroup analysis to highlight the impact of various study level covariates on the observed effectiveness. We also performed a multiple meta-regression, which allowed us to understand the reasons for disparity across studies and the impact on the effect measure. Thirdly, this review provided comparisons on the effectiveness across contexts in LMIC and HIC and highlights the research effort gap in LMICs.

4.2. Limitations

The results of this review should be interpreted in the context of the following limitations. First, this review considered only articles published in the English language, which could lead to language bias. Second, the observed effects were heterogeneous; therefore, pooled estimates might be questionable. Nevertheless, we used the Hartung-Knapp adjusted Sidik-Jonkman method to construct adjusted CIs for the true effect sizes which leads to a better approximation of the distribution of the pooled estimator as compared to a normal approximation, and which resulted in more conservative intervals in case of a small number of studies and large heterogeneity (Sidik and Jonkman, 2007). Furthermore, the level of uncertainty can be attributed to differences in target populations and cultural variations in how these interventions are perceived, hence, result in changes in PA. Therefore, this review provides an overall picture of the effect of such interventions, underlining that this is not necessarily the effect for the population at hand. Second, we did not perform subgroup analysis based on the outcome measurement technique (objective vs. self-report). Nevertheless, through qualitative observation, there is no variation in the effectiveness based on measurement technique. Last, for some of the outcomes only a small number of trials were included in the meta-analyses and subgroup analyses. Consequently, the confidence intervals for the effect size are often wide leading to less precise estimates.

5. Conclusions

Existing CBIs delivered in either individually or in groups appeared to be effective in improving PA level at 12 months. However, a remarkable decline in effectiveness was observed in longer FU periods. Therefore, intervention reports need to provide explicit explanation of the intervention theory, implementation fidelity and potential for maintenance to improve continuity of the intervention impact in the long run. Future interventional studies need to consider mechanisms to improve the sustainability of the intervention package through strong partnership with public health institutes and linkage with the routine general practices or community organizations. Despite studies of such type being concentrated in HICs, the effect of the intervention was higher in LMICs. The need for effective CBIs for CVD prevention remains a key in LMICs, which are disproportionately affected by the disease.

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HYH, HB, and SA conceived the review. HYH and RN was responsible for conducting the electronic searches, independently screened the identified references and made final decisions on included papers. HB, SA and JV worked closely with HYH to plan the data analysis. HYH performed the analysis and wrote the original draft of the manuscript. HB, SA, JV and GM have provided supervision throughout the review. All other authors reviewed and edited the manuscript. All authors read and approved the final version of the manuscript.

Declaration of Competing Interest

We declare no competing interests.

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Appendix A. Supplementary data

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