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## **Dietary outcomes of community-based cardiovascular disease preventive interventions: a systematic review and meta-analysis**

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**Short title:** Dietary outcomes of community-based interventions

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**Authorship** HYH, HB, and SA conceived the review. HYH and RN was responsible for conducting the electronic searches and abstract screening. HYH and BGS independently screened full-texts, made final decisions on included papers, and extracted data. HB, SA and JV worked closely with HYH to plan the data analysis. HYH and BGS performed the analysis and HYH wrote the original draft of the manuscript. HB, SA, JV, DL, and GM have provided supervision throughout the review. All other authors reviewed and edited the manuscript for intellectual content. All authors read and approved the final version of the manuscript.

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## Abstract

**Objective:** We aimed to synthesize available evidence on the effects of community-based interventions in improving various dietary outcome measures.

**Design:** Systematic review and meta-analysis

**Setting:** We searched databases including Medline, EMBASE, PSYCINFO, CINAHL, and the Cochrane registry for studies reported between January 2000 and June 2022. The methodological quality of the included studies was evaluated using the Cochrane risk of bias tools for each study type. For some of the outcomes, we pooled the effect size using a random-effects meta-analysis.

**Participants:** A total of 51 studies, 33 randomized and 18 non-randomized, involving 100 746 participants were included.

**Results:** Overall, 37 studies found a statistically significant difference in at least one dietary outcome measure favoring the intervention group, whereas 14 studies found no statistically significant difference. Our meta-analyses indicated that, compared to controls, interventions were effective in decreasing daily energy intake (MJ/day) (MD: -0.25; 95% CI: -0.37, -0.14), fat % of energy (MD: -1.01; 95% CI: -1.76, -0.25), and saturated fat % of energy (MD: -1.54; 95% CI: -2.01, -1.07). Furthermore, the interventions were effective in improving fiber intake (g/day) (MD: 1.08; 95% CI: 0.39, 1.77). Effective interventions use various strategies including tailored individual lifestyle coaching, health education, health promotion activities, community engagement activities and/or structural changes.

**Conclusion:** This review shows the potential of improving dietary patterns through community-based CVD preventive interventions. Thus, development and implementation of context-specific preventive interventions could help to minimize dietary risk factors, which in turn decrease morbidity and mortality due to CVDs and other non-communicable diseases.

**Key words:** Dietary pattern; Community-based intervention; Cardiovascular diseases; Systematic review; Meta-analysis

## Introduction

Non-communicable diseases (NCDs) mainly cardiovascular diseases (CVDs) are major causes of adult morbidity and mortality worldwide<sup>(1)</sup>. In 2019 alone, 18.6 million deaths were due to CVDs, predominantly ischemic heart disease and stroke<sup>(1)</sup>. The burden of CVDs largely varies across time and regions which could be due to demographic and socioeconomic changes, epidemiological transitions, and changes in lifestyle-related factors resulting from globalization and industrialization<sup>(2-4)</sup>.

Unhealthy dietary patterns, along with metabolic and anthropometric determinants, are among the most important behavioral risks of CVDs<sup>(1)</sup>. In 2019, diet-related risks were among the top five risk factors for mortality<sup>(1)</sup>. Lifestyle modification, particularly targeting dietary risks, is one strategy to prevent cardiovascular events<sup>(5, 6)</sup>. Reduction of excess calorie intake, processed food, and increased intake of fruit, vegetables, and whole grains have been shown to minimize CVD risk<sup>(5, 7)</sup>. Likewise, reduction of saturated fat intake or replacement with polyunsaturated fat and increased intake of fiber are among the dietary recommendations for better heart health<sup>(8)</sup>.

Several countries and international organizations have established healthy dietary guidelines to prevent NCDs, including CVDs. Nevertheless, passive dissemination of dietary recommendations alone is generally considered ineffective in changing the intended behavior<sup>(9)</sup>. Multicomponent interventions through active community engagement can improve an individual's dietary patterns and reduce CVD burden at the population level<sup>(10, 11)</sup>. Community-based CVD preventive interventions aimed at improving dietary patterns and physical activity have been implemented using various strategies. However, comprehensive evidence on the impact of such interventions in improving dietary patterns is limited. Few reviews have highlighted the effectiveness of interventions on dietary outcome measures; however, such studies are limited to specific regions, contexts<sup>(12-14)</sup> or target populations<sup>(15, 16)</sup>. In those reviews, details of the intervention components, implementation strategy, and their impact on improving specific dietary patterns were not provided. Thus, we systematically reviewed the types and implementation of community-based preventive interventions for CVD and their effectiveness in improving dietary patterns. The evidence from this review is important for practitioners and researchers to design and implement preventive interventions through improvement of dietary patterns.

## Methods

This work is part of a systematic review under 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/>), which aimed to synthesize available evidence on the effect of community-based interventions (CBI) in improving behavioral risks and CVD knowledge. This paper specifically summarizes the evidence on the effects of such interventions on various measures of dietary patterns. The protocol for this review is registered in the PROSPERO International prospective register of systematic reviews (Reg. Number: CRD42019119885) and the result is presented in line with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) 2009 guideline<sup>(17)</sup>. The methodological details are available elsewhere<sup>(18)</sup> and those relevant to this study are briefly summarized here.

### Information sources and search strategy

Initially, MEDLINE, EMBASE, Cochrane Register of Controlled Studies, CINAHL, and PSYCINFO were used as the main databases to identify all studies published from 2000 to 2019. Then, the search was updated until June 2022 to include recent results. Other sources, including thesis online, OpenGrey, ProQuest, CHW Central, Google Scholar, ClinicalTrials.gov, and the WHO International Clinical Trials Registry were also searched for more similar articles. After a preliminary keyword search, we developed a systematic search strategy using terms related to population, intervention, and outcomes. The details of the search strategy are available elsewhere<sup>(18)</sup>. In addition, more eligible studies were included from reference lists of the included articles.

### Study screening

Studies were eligible to be included in this review if they aimed at prevention of CVDs and have dietary patterns as one of the outcomes. Studies were eligible if they were individual/cluster randomized controlled trials or controlled quasi-experimental or interrupted time series studies that tested interventions aimed at primordial or primary prevention of CVDs. Moreover, studies were included if they involved adult participants aged 18 years or above; and the interventions were based in community and/or primary healthcare settings. Studies were excluded if participants had diagnosed CVD; interventions included clinical and/or pharmacologic components; with sample size below 150, retention rate below 60% and a follow-up period

shorter than 9 months. Studies that were reported in the English language were considered with no limitation on study location.

Endnote files from all databases were checked for duplication and deduplication was performed using Bramer's method<sup>(19)</sup>. The deduplicated articles were exported into rayyan.QCRI.org<sup>(20)</sup> for further deduplication and screening purposes. We performed double screening (HYH and RN/BGS) on all retrieved titles/abstracts using defined criteria. Then, articles included in full-text review were read thoroughly by two independent reviewers (HYH and BGS) and a final decision for inclusion was made. Disagreements between two reviewers were solved through discussion. The article selection process is outlined in the PRISMA flow chart (see Figure 1).

### **Risk of bias assessment and data extraction**

For RCTs, the revised Cochrane tool for Risk of Bias (RoB2)<sup>(21)</sup>, while for NRC studies the Risk of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tool<sup>(22)</sup> were used to assess risk of bias of included studies. Double risk of bias assessment (HYH and BGS/RN) was performed independently and differences were resolved through consensus.

Relevant information was extracted from included articles by two reviewers (HYH and BGS) independently and disagreements were resolved through consensus. Data on year and country of study, intervention characteristics (description, setting, approach, duration, etc.), study design, participant characteristics, control group, sample size, attrition rate, outcome measures and summary findings was also captured. Furthermore, the outcome measures, summary measures and effect estimates were extracted. Whenever necessary, authors of included studies were contacted for further information. Results that were presented only graphically were extracted using WebPlotDigitizer<sup>(23)</sup>.

### **Data analysis**

Findings are descriptively presented and discussed by study design, risk of bias, country and income per capita, intervention approach, and outcome measurements. Whenever needed, tables were used to present data comparing country, year of study, intervention duration, context and outcomes.

We used both narrative and quantitative synthesis to summarize evidence in this review. Studies were evaluated for eligibility to be included in the meta-analysis assessing the homogeneity of intervention and outcome measurements. Studies reported several measures of dietary patterns

and we performed a meta-analysis for any measure with at least two studies. As a result, meta-analysis was performed for intake of energy (MJ/day), fat (% of energy), saturated fat (% of energy), fiber (g/day), and fruit and vegetable (servings/day). Findings from studies without sufficient information on the above mentioned outcome measures or those with other measures of dietary pattern were summarized narratively.

## Meta-analysis

Due to heterogeneity observed in study populations and intervention duration, we expected between study heterogeneity and we performed a random-effects meta-analysis<sup>(24)</sup> for most of the outcome measures. Mean differences (MDs) with 95% confidence intervals (95% CIs) were used to summarize continuous outcomes. Whenever needed, SDs and/or standard errors (SEs) for mean differences were calculated from other reported parameters based on the Cochrane guideline<sup>(25)</sup>. We used the  $I^2$  statistic to quantify heterogeneity and we tested the significance thereof using Cochran's Q statistic<sup>(26)</sup>. We explored the variation in effectiveness across time using subgroup analysis based on FU time (9 to 12 months, 18 to 24 months and 36 months and above) and study design for each outcome measure included in the meta-analysis.

We constructed funnel plots to evaluate publication bias graphically and the significance of symmetry was tested using Egger's regression test<sup>(27)</sup>. We used the **meta** package in the free statistical software package R version 4.0.2 for all the analyses<sup>(28)</sup>. The review results are reported in accordance with the PRISMA 2009 statement<sup>(29)</sup> and a completed PRISMA checklist is available in the supplementary material (Table S3).

## Results

From all databases a total of 16 078 titles/abstracts were retrieved (15 885 from initial search and 193 recently updated). 766 articles were retained based on abstract screening and 73 more studies were identified through manual reference searching. Based on the full-text review, 51 studies involving 100 746 (56 689 in intervention and 44 057 in control group) reported at least one measure of dietary patterns and were eligible to be included in the narrative synthesis. Of these studies, 19 were eligible for a meta-analysis with regard to at least one dietary outcome measure. The article screening process is summarized using the PRISMA flow chart (Figure 1).



## Study characteristics

Detailed characteristics of included studies are available in the supplementary material (Table S1). Of 51 studies included in this review, 28 focused on high-income countries (HICs), specifically 12 in the USA<sup>(30-41)</sup>, four in the Netherlands<sup>(42-45)</sup>, two each in the UK<sup>(46, 47)</sup>, Spain<sup>(48, 49)</sup>, and Australia<sup>(50, 51)</sup>, one each in Japan<sup>(52)</sup>, Italy<sup>(53)</sup>, Denmark<sup>(54)</sup>, Germany<sup>(55)</sup>, Sweden<sup>(56)</sup> and Finland<sup>(57)</sup>. In contrast, 23 were in low and middle income countries (LMICs), particularly five in China<sup>(58-62)</sup>, four in India<sup>(63-66)</sup>, three in Iran<sup>(67-69)</sup>, two each in Sri Lanka<sup>(70, 71)</sup> and Kenya<sup>(72, 73)</sup>, one each in Bangladesh<sup>(74)</sup>, Nepal<sup>(75)</sup>, Malaysia<sup>(76)</sup>, Pakistan<sup>(77)</sup>, Thailand<sup>(78)</sup>, and Vietnam<sup>(79)</sup>, and one study recruited participants living in China, India and Mexico<sup>(80)</sup>.

Regarding the study design, 33 studies were randomized, of which 21 and 12, respectively, were individual- and cluster-randomized. Whereas, 18 studies were non-randomized controlled studies. Out of 33 randomized studies, 8 have low, 22 some concerns, and 3 high-risk of bias based on the Cochrane RoB2 tool. Of 18 non-randomized studies, 2 has low, 13 moderate, and 3 serious risk of bias. The risk of bias summary tables and figures are presented in the supplementary material (Table S4 and Figure S1).

Several continuous dietary outcome measures were reported including energy intake (MJ/d), sodium intake, salt intake, fat (% of energy), saturated fat (% of energy), fiber (g/day), carbohydrate (% of energy or g/day), protein (% of energy or g/day), frequency of sugary beverages, salty diet, fast and/or fried food, fruit and vegetable (servings per day), number of days eat fruit and/or vegetable, healthy eating index, plant-based diet index (PDI) and diet score. Categorical measures were also reported such as attainment of the required daily fruit and vegetable intake, recommended level of salt, adherence to dietary advice, vegetable procurement, recommended level of sugar, high salt intake, Mediterranean diet, snacks  $\geq$  twice/day, etc. Details of the outcome measurement for individual studies are presented in the supplementary material (Table S1).

## Interventions

Various strategies were employed to deliver the intervention package to target participants and/or populations. Most of them used various health education and awareness creation activities including seminars, lectures, and workshops as the main components of intervention<sup>(30, 34, 35, 37, 39, 41, 46-48, 50, 52, 53, 55, 56, 58-62, 65, 67-69, 72-78, 80)</sup>. Furthermore, other strategies were also considered including individual-tailored coaching interventions through face-to-face, mHealth or web-based<sup>(31, 33, 40, 45, 46, 52, 54, 56, 60, 64-66, 69, 74-76, 78, 79)</sup>, motivational interviewing<sup>(33, 45, 48)</sup>, group interactive sessions and/or activities<sup>(30, 38, 40, 42, 46, 49, 51, 53, 54, 63, 65, 69, 71, 74, 76, 78)</sup>, print or electronic materials<sup>(31, 39, 43, 44, 55, 60, 62, 69)</sup>, peer support<sup>(32, 39, 50, 63)</sup>, campaigns and mass media<sup>(44, 50, 66, 72, 77, 79)</sup>, and posters, brochures and pamphlets<sup>(43, 44, 66, 67, 69)</sup>. Likewise, health promotion activities through community mobilization, community networks, structural changes, and policy measures<sup>(34, 35, 47, 51, 56, 59, 68, 69, 80)</sup> were employed. Details of intervention strategies used by each included studies is available in the supplementary material (Table S2).

Eight studies had an intervention duration ranging from 6 to 9 months<sup>(37, 39, 41, 43, 49, 55, 65, 72)</sup>, 18 studies for 12 months<sup>(30-33, 38, 45, 47, 48, 51-53, 63, 70, 71, 75-78)</sup>, 5 studies for 14 to 18 months<sup>(35, 40, 60, 73, 74)</sup>, 10 studies for 24 months<sup>(34, 36, 42, 46, 58, 59, 62, 64, 66, 80)</sup>, 6 studies for 36 to 42 months<sup>(50, 57, 61, 67, 69, 79)</sup>, 4 for five years or above<sup>(44, 54, 56, 68)</sup>. The majority of studies followed up participants for outcome measures at 12, 24 and 36 months post-intervention. Most interventions were based in the community targeting groups of individuals, followed by home-based strategies either face to face or electronically, schools and workplaces or a combination of two or more settings. Trained volunteers, community health workers, peers, healthcare practitioners, nutritionists and other professionals were involved in facilitating the intervention.

Studies employed various dietary outcome measures including total energy intake (per day), fruit and vegetable servings, fat and/or carbohydrate % of energy, fiber intake, soda/sugary beverage consumption, cholesterol, saturated/unsaturated fat intake, salt intake, Mediterranean diet, healthy eating index, diet score, and frequency of fast food and/or snacks.

## Meta-analysis

The pooled effects of CBIs with respect to selected dietary outcome measures are summarized in Table 1. In total, 19 studies were included at least once for one of the five dietary outcome measures that were synthesized. Studies that reported a change in total energy intake (MJ/day),

fruit and vegetable intake (servings/day), fiber intake (g/day), fat (% of energy) and saturated fat (% of energy) were considered. Based on 10 studies, interventions led to a decrease in daily energy intake compared to controls (MD: -0.25; 95% CI: -0.37, -0.14; number of studies (n)=10;  $I^2=0\%$ ), which is equivalent to 59.8 kilo calories lower intake of energy per day. The pooled results of seven studies showed a 1.1 grams of higher fiber intake per day in the intervention groups compared with controls (MD: 1.08; 95% CI: 0.39, 1.77; n= 6;  $I^2=68\%$ ). A pooled analysis of 5 studies (all RCTs) indicate that the decrease in fat % (MD: -1.01; 95% CI: -1.76, -0.25; n=5;  $I^2=66\%$ ) and saturated fat % (MD: -1.54; 95% CI: -2.01, -1.07; n=2;  $I^2=0\%$ ) of daily energy was higher in the intervention group as compared to controls. The increase in fruit and vegetable servings per day was higher in the intervention group compared to control, but the difference was not statistically significant (MD: 0.26; 95% CI: -0.03, 0.54). Forest plots of all synthesized dietary outcome measures are presented in Figure 2a-2e.

**Table 1.** Pooled effects of community-based interventions on dietary outcome measures

Outcome measure	No. of studies	MD (95% CI)	Heterogeneity statistic ( $I^2$ )
Energy intake (MJ/day)	10	-0.25 (-0.37, -0.14)***	0 (0–62)
Fiber intake (g/day)	7	1.08 (0.39, 1.77)**	68 (30–86)
Fruit and Vegetable (serving/day)	11	0.26 (-0.03, 0.54)	82 (68–89)
Fat (% energy)	5	-1.01 (-1.76, -0.25)**	41 (10–87)
Saturated fat (% energy)	2	-1.54 (-2.01, -1.07)***	0 (0–0)

\*  $p<0.05$ ; \*\*  $p<0.01$ ; \*\*\*  $p<0.001$

MJ: Mega Jul; MD: Mean Difference; CI: Confidence Interval; FU: Follow up

The subgroup analysis indicated that higher intervention effect in increasing fiber intake at 9-12 months (MD: 1.29; 95%CI: 0.71, 1.88) and 18-24 months (MD: 2.08; 95%CI: 0.81, 3.35) of FU compared to  $\geq 36$  months (MD: 0.08; 95%CI: -0.52, 0.68), with statistically significant subgroup difference ( $p < 0.01$ ). The decrease in fat percent of energy was higher at 9-12 months (MD: -1.16; 95%CI: -2.20, -0.12) than at 18-24 months (MD: -0.60; 95%CI: -1.16, -0.04), but the subgroup difference is not statistically significant ( $p = 0.36$ ). No time trend was observed in the remaining outcome measures. Forest plots of subgroup analysis are available in the supplementary material (Figure S2 – S5). Further subgroup analysis by study design showed that RCTs showed a larger decrease in energy intake (MD: -0.28; 95%CI: -0.42, -0.14) than NRC studies (MD: -0.21; 95%CI: -0.42, 0.00), but the subgroup difference is not statistically significant ( $p = 0.61$ ). The increase in fiber intake was slightly higher for RCTs (MD: 1.28; 95%CI: 0.63, 1.93) than NRC studies (MD: 0.10; 95%CI: -0.56, 0.76), with significant subgroup difference ( $p = 0.01$ ). Likewise, the increase in fruit and vegetable intake was higher in RCTs (MD: 0.41; 95%CI: -0.00, 0.82) than NRC studies (MD: 0.04; 95%CI: -0.32, 0.41), with no statistically difference between subgroups ( $p = 0.19$ ) (Figure S6 – S8).

We explored the potential of publication bias using Egger's test of symmetry and funnel plots. Based on Egger's test, the null hypothesis of symmetry was not rejected at 5% significance level for energy intake ( $p=0.392$ ), fiber intake ( $p=0.332$ ), fruit and vegetable intake ( $p=0.485$ ) and fat percentage of energy ( $p=0.855$ ), indicating that no substantial publication bias was observed. Due to a small number of studies included in the meta-analysis, the statistical power of Egger's test might not be sufficient to detect considerable bias. However, visual inspection of funnel plots of standard errors against observed effect sizes showed no large deviation from symmetry. Funnel plots of all outcome measures are available in the supplementary material (Fig S2a – S2e).

### **Narrative synthesis**

Besides meta-analyses, a narrative synthesis was also employed to incorporate studies not included therein due to different outcome measures. Overall, out of 51 studies, 37 studies (21 from HICs and 16 from LMICs) found statistically significant differences in at least one dietary outcome measure favoring the intervention group. Whereas 14 studies (9 from HICs and 5 from LMICs) found no statistically significant difference in various dietary outcome measures across

intervention and control groups<sup>(32, 33, 37, 38, 42, 43, 47, 49, 51, 59)</sup>. Of 30 studies that measured fruit and vegetable consumption, 10 (33.3%) found no significant difference across intervention groups. One study<sup>(43)</sup> found a significant increase in vegetable consumption but not fruit intake. A study by Baumann et al<sup>(54)</sup> indicated that the improvement in fruit and vegetable intake in the intervention group compared to the control group was greatest at five years of follow up but at 10 years the difference across groups was not significant. A study in Sweden<sup>(56)</sup> found no significant difference across intervention groups in most dietary measures including percentage of energy from fat, carbohydrates, and protein, intake of fruits, vegetables, whole grain, fish, sweetened beverages or fried potatoes, and overall diet quality (assessed by Healthy Diet Score). However, men in the intervention county decreased intake of sweets to a greater extent than those in control<sup>(56)</sup>.

Studies that showed a significant improvement in dietary outcomes involved various intervention components including tailored individual lifestyle coaching and interactive sessions by trained professionals mainly dietitians, health education individually or in group, health promotion activities, community engagement activities and/or structural and system changes such as improving access to healthy food. More specifically, effective interventions consisted of one or more of the following intervention components: individual lifestyle coaching based on risk level and using motivational change tools; counseling by trained professionals besides primary care physicians either in practice or home; customized advice, motivational interview and feedback; and visual demonstrations on food portions. In contrast, interventions through mobile text messages alone, written health pamphlets, brochures and booklets, and postal healthy lifestyle guides were relatively less or not effective. At group level, interventions involving regular interactive group sessions and community lifestyle activities were effective. Furthermore, structural changes such as ensuring healthy foods during organizational meetings/events and increasing availability of affordable fresh fruits and vegetables in corner stores were also effective in improving healthy eating among participants. However, healthy cooking interventions in restaurants and cafeterias were not effective. Further details of intervention strategies and direction of effects for included studies are available in the supplementary material (Table S2).

## Discussion

This review summarizes the available evidence on the approach, strategies, and effectiveness of community-based CVD preventive interventions in improving healthy dietary patterns, which would contribute to halting the burden of CVDs and associated premature mortality. We reviewed 51 eligible studies, 33 RCTs and 18 NRC studies, exploring the intervention components, duration, outcome measures, and their effect on dietary patterns. We also conducted meta-analyses for studies with similar dietary outcome measures. Overall, the findings support that energy intake and fat percentage of energy, particularly saturated, could potentially be reduced through CBIs targeting both general and high-risk populations. The mean daily fiber intake was also significantly improved in the intervention group compared with the controls. Intervention strategies involving lifestyle coaching, health education, health promotion activities, community engagement activities, and/or structural and systemic changes demonstrated more pronounced effects. Furthermore, the subgroup analysis showed that relatively higher effects on fiber intake were observed at 12 and 24 months than at 36 months and longer, with significant subgroup differences across time.

Excess energy intake is associated with weight gain, which may increase the risk of CVD incidence and mortality<sup>(81, 82)</sup>. By suppressing atherosclerosis and protecting heart cells against ischemic damage, energy restriction is associated with a lower rate of CVD events<sup>(83)</sup>. Thus, decreasing energy intake is one of the required outcomes of preventive interventions for CVDs. Most of the studies in this review measured energy intake to evaluate the effectiveness of the intervention, and the majority indicated that CBIs are effective in decreasing total daily energy intake, which is also supported by our meta-analysis. On average participants in the intervention group had 59.8 kcal (250.2KJ) lower energy intake per day compared with controls. The average recommended daily calorie intake of an adult ranges from 2000 to 2500 kcal<sup>(84)</sup>. Thus, CBIs decrease daily energy intake of participants by 2.5% to 3.0% as compared to controls, which is a significant percentage towards weight reduction provided that the intervention effect is sustained in the long run. Since calorie restriction favorably affects cardiac function<sup>(85)</sup>, CVD preventive interventions should incorporate strategies to limit an individual's total calorie intake to the required level that is sufficient for energy balance. Nevertheless, energy restriction interventions require self-monitoring of intake and loss through active weight and food measurements.

Training and demonstration of participants on self-monitoring of diet and body weight could be vital components of such interventions.

Healthy dietary guidelines recommend a reduction in dietary saturated fat and replacement with polyunsaturated and monounsaturated fat to lower the risk of CVD<sup>(86)</sup>. Our review and meta-analysis showed that interventions were effective in reducing percent of energy from fat, particularly saturated fat. Overall, interventions led to a 1.1% decrease in percent of daily energy from fat. Nevertheless, crude assessment of ‘fat percentage of energy’ might not be an appropriate measure of healthy dietary pattern, rather, qualitative identification of specific fat type is more informative. Findings on the association between saturated fat intake and heart disease are inconsistent, which would most probably be due to the variation in comparison groups<sup>(87)</sup>. Replacing saturated fats with polyunsaturated fats is strongly associated with a lower risk of coronary heart diseases<sup>(88)</sup>. However, replacing saturated fats with refined low quality carbohydrates results in cardiometabolic disorders, including obesity and diabetes, which increase the CVD risk<sup>(89, 90)</sup>. Thus, the superficial use of phrases such as ‘fat intake reduction’ as a dietary intervention might be practically misleading. A few studies included in this review measured percent of energy from saturated fat and the meta-analysis showed that interventions decreased percent of daily energy from saturated fat by 1.5%. Thus, rolling out such community-based interventions would decrease percent of energy from saturated fat. Interventions should explicitly describe the reduction of saturated fats and their replacement with healthier polyunsaturated fats rather than processed carbohydrates.

Increasing consumption of fiber is also recommended to minimize the risk of a range of diseases, including heart diseases and diabetes<sup>(91-93)</sup>. A few studies included in our review evaluated the effects of interventions on fiber intake. Overall, our meta-analysis showed that interventions were effective in increasing daily fiber intake by approximately 1.1g than controls. Compared with the recommended daily intake of 25 to 30 g of fiber, interventions led to a decrease by 3.3 to 4.0%. Including fiber intake improvement as a dietary intervention strategy could be helpful for the primary prevention of CVDs.

It is evident that fruit and vegetable intake is associated with reduced CVD risk, showing a clear dose-response relationship<sup>(1, 94)</sup>. Most of the studies included in our review measured fruit and vegetable intake as one of the outcomes. Our narrative synthesis indicated that most studies



found a significant improvement in fruit and vegetable consumption measured in various ways. Our meta-analysis specifically on daily fruit and vegetable servings indicated that there was an increase in the average servings per day by 0.26, but the difference was not statistically significant between intervention and control groups. A previous review also found a similar result, i.e., the effectiveness in improving fruit and vegetable servings is minimal<sup>(95)</sup>. A change in fruit and vegetable intake can be hampered by several factors, including the access and affordability of fruits and vegetables. Participants' socioeconomic status and environmental conditions, including access to healthier food, determine the effectiveness of lifestyle interventions<sup>(96)</sup>. However, inaccurate measurement of portion size might also be a reason for the insignificant association.

Overall, effective interventions mostly employed tailored individual lifestyle coaching, stage-matched strategies, and interactive sessions by professionals, such as dietitians, health education individually or in groups, community engagement activities, health promotion activities, and/or structural and system changes. One study<sup>(73)</sup> demonstrated the recommended portions to participants using diagrams of full platter and found significant improvements in all dietary measures in the intervention group compared to controls. Furthermore, interventions that involve multiple components are likely to be more effective than those that use one or two strategies. A review by Crane et al. also showed that individual-tailored interventions are the most effective behavioral interventions<sup>(97)</sup>. Thus, tailoring interventions to individual needs and readiness to change, involving professionals and practical demonstrations is vital, for improving effectiveness.

In general, CBIs delivered through various strategies have demonstrated effectiveness in improving various measures of dietary pattern; however, studies have focused on high-income countries. Despite measurement of dietary behavior being complex, consistent changes were observed following the interventions. Nevertheless, interventions need to emphasize practical demonstrations of dietary intake measurements, including portions of food and energy balance, to observe the intended behavioral change. Our review focused on interventions that measured effectiveness beyond 9 months to depict intermediate- and long-term effects and found significant differences between persons who were subject to CBIs and those who were not in most dietary outcome measures. Thus, integrating dietary components along with other lifestyle



interventions such as physical activity, cessation of smoking, and alcohol consumption could help to reduce the burden of CVD and risk factors at the population level <sup>(18, 98)</sup>.

### **Methodological considerations**

We assessed the risk of bias of studies using tools from the Cochrane Collaboration. However, this quality assessment was hampered by inadequate reporting of each component, particularly reporting of bias from the intended intervention and bias due to missing outcome data. For randomized studies, sequence generation, methods of allocation concealment, and blinding were not well described in some of the eligible studies. For non-randomized studies, an inadequate description of study participant selection and insufficient list of confounders and how they were adjusted were among the issues that affected the risk of bias assessment. We recommend the use of standard guidelines to accurately report methodological processes to ensure appropriate interpretation of results and to provide replicable methods for future similar studies.

Furthermore, we considered individual RCTs, cluster RCT and NRC studies in the analysis. The unit of randomization and sampling is different for these study designs and thus the CI for the effect size might be narrow because clustering would not be taken into account. Nevertheless, we used a Hartung-Knapp-adjusted Sidik-Jonkman method to estimate CIs, which is a conservative approach and the results are less likely to be biased.

### **Limitations**

By using a systematic approach and two independent reviewers throughout the process, our methodology was strengthened. Nevertheless, interpretation of findings from this review should consider the following limitations. First, restriction of articles to only the English language might have resulted in language bias. Second, owing to the heterogeneity in outcome measurement techniques and inconsistent reporting, we could not perform a meta-analysis for some of the outcomes. Nevertheless, these outcomes were summarized using narrative synthesis. Third, the observed effects of a few outcome measures seems heterogeneous. However, we constructed confidence intervals using the Hartung-Knapp-adjusted Sidik-Jonkman method, which resulted in more conservative intervals in case of a small number of studies and large heterogeneity<sup>(99)</sup>.

## Conclusions

This review shows that community-based CVD preventive interventions have the potential of improving dietary patterns and, in turn, CVD risk profiles among adults. Interventions appear to decrease individuals' daily energy intake, fat and saturated fat percentage of energy, and increase intake of fiber, fruits, and vegetables. A decline in effect size was observed at a longer follow-up, indicating low sustainability after the intervention duration. Intervention components with tailored lifestyle coaching, individual and/or group health education, community-wide health promotion activities, and/or structural and systemic changes such as improving availability of affordable fresh fruits and vegetables in corner stores demonstrated more pronounced effects. Thus, development and implementation of context-specific preventive intervention is beneficial to improve dietary factors, which in turn decrease morbidity and mortality associated with CVDs and other non-communicable diseases. Furthermore, favorable intervention effects need to be sustained for longer through linkages with existing primary care centers or community organizations.

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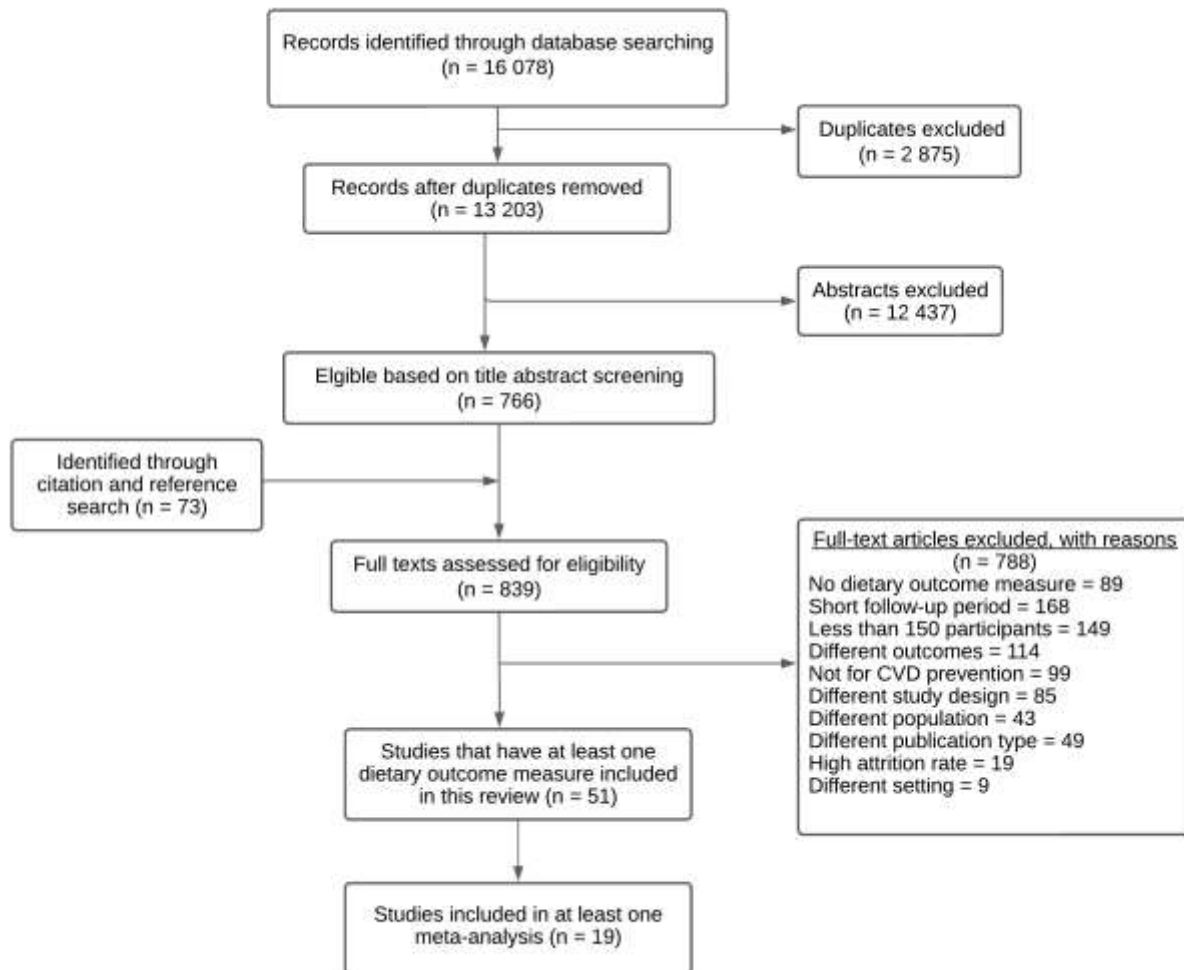
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**Figure 1.** PRISMA flow chart illustrating the article selection process

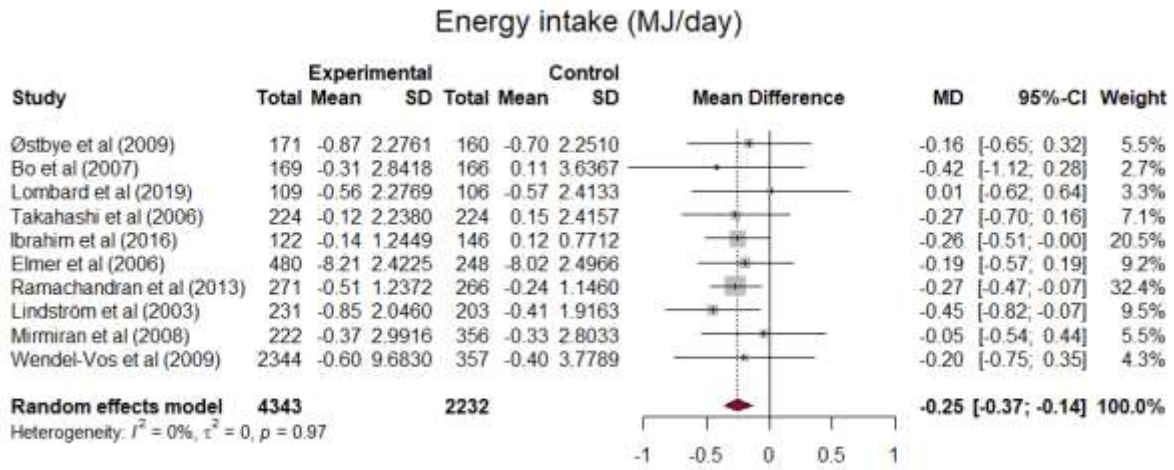


Fig. (a)

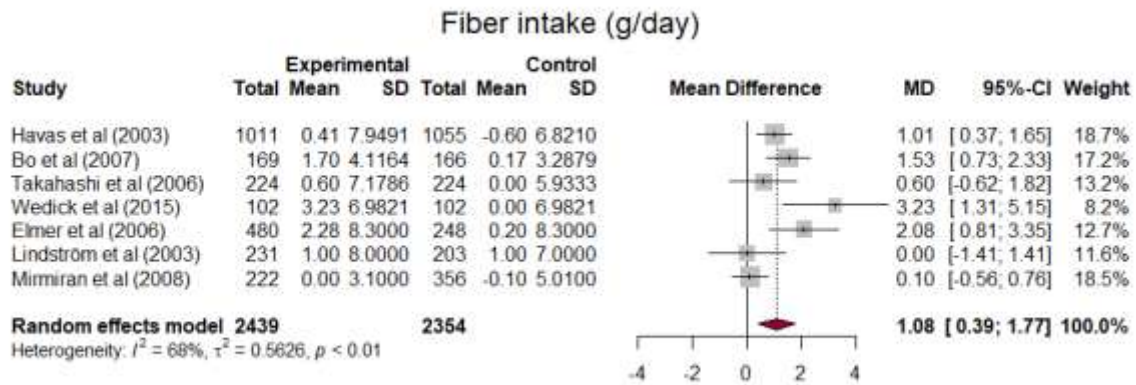


Fig. (b)

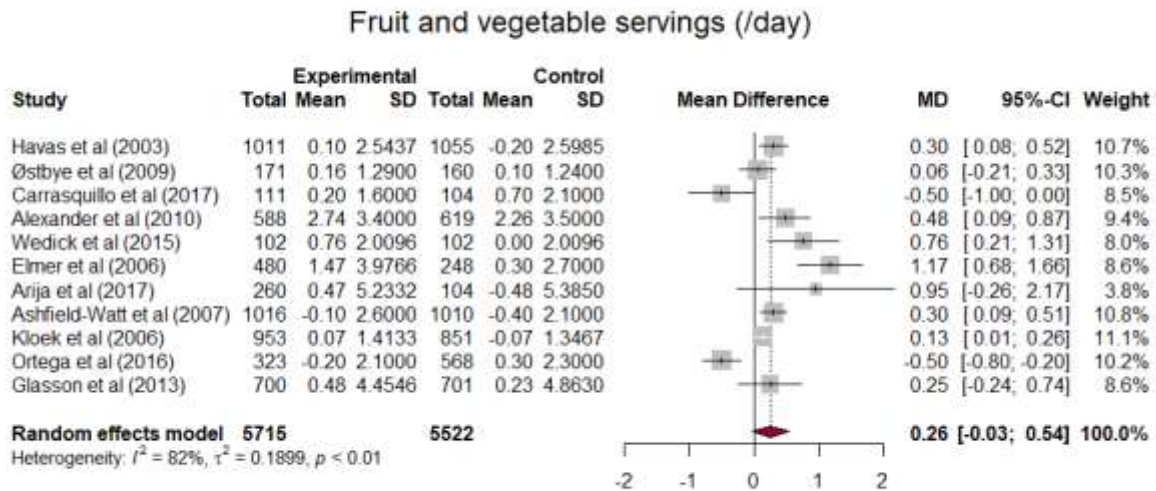


Fig. (c)

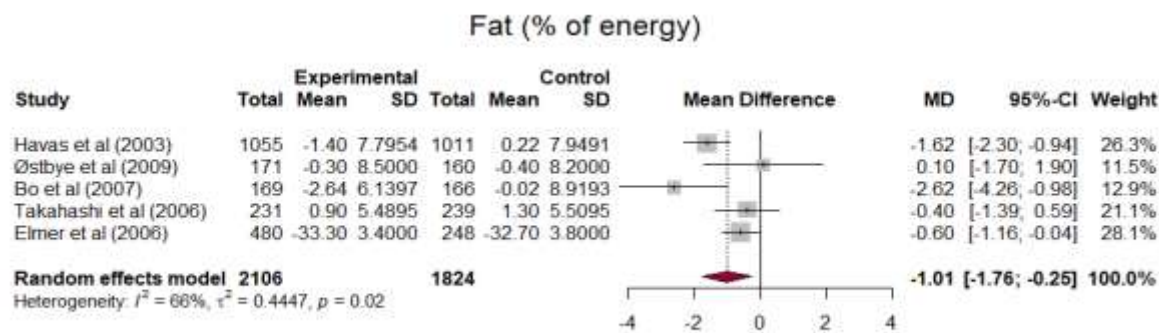
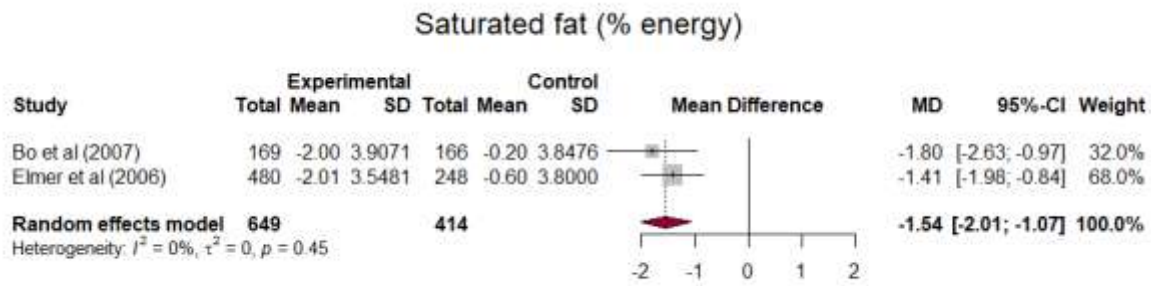


Fig. (d)



**Fig. (e)**

**Figure 2.** Forest plots indicating the effect of community-based cardiovascular disease preventive interventions on a) energy intake, b) fiber intake, c) fruit and vegetable serving per day, d) fat % of energy, and e) saturated fat % of energy.