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Complete List of Authors:	Alageel, Samah; King's College London, Primary Care and Public Health Wright, Alison; King's College London, Primary care and public health McDermott, Lisa; King's College London, Primary Care and Public Health Sciences Gulliford, Martin; King's College London, UK
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Multiple health behaviour change interventions for primary prevention of cardiovascular disease in primary care: systematic review and meta-analysis

Samah Alageel MPH, Alison J. Wright PhD, Lisa McDermott PhD, Martin C Gulliford FFPH

Department of Primary Care and Public Health Sciences, King's College London

Correspondence: **Samah Alageel**
Department of Primary Care and Public Health Sciences,
Faculty of Life Sciences and Medicine.
King's College London, Addison House, Guy's Campus,
London SE1 1UL, United Kingdom
Email: samah.alageel@kcl.ac.uk
Tel: 0207 848 6631
Fax: 0207 848 6620

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ABSTRACT

Objectives: It is uncertain whether multiple health behaviour change interventions (MHBC) are effective at reducing cardiovascular disease (CVD) risk in primary care. A systematic review and meta-analysis were performed to evaluate the effectiveness of MHBC interventions on CVD-risk; the study also evaluated associations of theoretical frameworks and intervention components with intervention effectiveness.

Methods: The search included randomised controlled trials of MHBC interventions aimed at reducing CVD-risk in primary care up to 2015. Theoretical frameworks and intervention components were evaluated using standardised methods. Meta-analysis with stratification and meta-regression were used to evaluate intervention effects.

Results: We identified 27 trials (34,839 participants) with a minimum duration of 12 months follow-up. Pooled net change in systolic blood pressure (12 trials) was -1.45 (95% confidence interval -2.98 to 0.09, P= 0.06) mm Hg, diastolic blood pressure (11 trials) -1.01 (-1.91 to -0.11, P= 0.03) mm Hg, body mass index (10 trials) -0.11 (-0.25 to 0.02, P= 0.10) Kg/m^2 and serum total cholesterol (10 trials) -0.11 (-0.17 to -0.05, P <0.001) mmol/L. There was no significant association between interventions with a reported theoretical basis and intervention outcomes, except for body weight (β 1.14, 0.06 to 2.22, P= 0.04). No association was observed between intervention intensity (number of sessions and intervention duration) and intervention outcomes.

Conclusions: MHBC interventions delivered to participants in primary care did not appear to have quantitatively important effects on CVD-risk and CVD risk factors.

Key words: Cardiovascular Diseases, Health Behaviour, Primary Health Care, Meta-analysis, Primary Prevention, Risk Factors.

Strengths and limitations:

- The review includes all 27 published randomised controlled trials of MHBC interventions and cardiovascular risk with follow-up for 12 months or longer
- The study employed standardised instruments to evaluate the impact of theory use and behaviour change techniques in MHBC interventions.
- The majority of trials included were conducted in Europe and United States and only English language publications were included
- Not all studies evaluated all outcomes of interest and some lacked detail concerning intervention design and delivery

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death worldwide, accounting for over 30% of global mortality [1]. CVD is mediated by several antecedent behavioural risk factors, and its onset might be prevented or delayed by altering one or several risk factors [1]. Risk factors for CVD are inter-related and often coexist [2-4]. This observation has informed the development of multiple health behaviour change (MHBC) interventions for reduction of CVD-risk. Identifying individuals at high-risk of CVD in primary care, and encouraging lifestyle change to reduce risk factors, represents a widely used strategy for CVD prevention. Randomised controlled trials have been conducted in primary care to evaluate the effectiveness of MHBC interventions using lifestyle modification techniques instead of, or in addition to, pharmacological treatment to modify CVD risk factors. These trials have generally provided only equivocal evidence for reduction of CVD incidence through MHBC but the degree of effectiveness might be associated with level of risk [5-7]. Results from Ebrahim et al.'s [5] systematic review suggested that MHBC interventions have negligible effect on mortality in unselected populations, with a pooled odds ratio for coronary heart disease mortality of 0.99 (95% CI 0.92 to 1.07). Evidence of benefit was found in studies in high-risk populations including people with hypertension (OR 0.78, 0.68 to 0.89) or diabetes (OR 0.71, 0.61 to 0.83) [5]. However, general health checks were not found to reduce all cause-mortality, nor CVD- or cancer-related morbidity and mortality [8].

Previous reviews have assessed the effectiveness of MHBC interventions in reducing CVD morbidity and mortality [5 6 8], less is known about the effectiveness of these interventions in reducing CVD-risk and risk factor values in primary care.

In recent years, there has been growing appreciation of the role of employing psychological theory in behaviour change intervention design, and studying the impact of specific behaviour change techniques (BCT) on intervention outcomes [9]. Theories of the psychological determinants of behaviour can inform the development and evaluation of behaviour change interventions [10]. Interventions that systematically target psychological constructs, that evidence shows are more predictive of behaviour, are likely to be more effective [11]. A review of internet-based interventions suggested that more intensive use of theory was associated with greater behaviour change [12], but another review found little evidence of an association between theory use and intervention effects on healthy eating or physical activity [13]. This equivocal evidence could arise if a high proportion of behaviour change interventions are not based on a theory or the theory is not applied extensively [14].

Behaviour change techniques (BCT) are 'the active components of an intervention designed to change behaviour' [15]. Identifying specific BCTs associated with greater impact on intervention effectiveness is essential for future intervention design [16]. Previous reviews suggested that interventions using the BCTs "provision of instructions," "self-monitoring of behaviour," "relapse prevention," and "prompt practice" led to greater reductions in weight among obese individuals [17], while interventions designed to modify physical activity and/or diet were more effective when they included self-monitoring and particularly when they combined self-monitoring with another BCT associated with control theory [18]. Identifying BCTs associated with greater intervention effectiveness and exploring the impact of applying theory will contribute to the design of future MHBC interventions targeting CVD risk in primary care.

Objectives

This systematic review had three objectives: first, to assess the effectiveness of MHBC interventions, directed at changing two or more behaviours, at reducing CVD-risk and CVD risk factors in adults without existing cardiovascular conditions; secondly, to evaluate whether using theory to develop interventions is associated with intervention effectiveness; and thirdly, to evaluate the association between behaviour change techniques employed and intervention effects.

METHODS

Studies were selected according to the following criteria:

Participants

Trials that recruited an adult population free of CVD were included. Following previous reviews [5], we included trials with less than 20% participants with CVD. Studies of patient populations with established disease, such as diabetes, were excluded.

Interventions

We included studies that evaluated behaviour change interventions aimed at reducing CVD-risk by intervening on two or more risk behaviours at the same time. Risk behaviours included: physical activity, diet, alcohol consumption, use of stress management and smoking. Comparators were usual care or less intensive interventions.

Settings

Interventions where participants were recruited, and interventions were delivered by trained healthcare professionals or primary care staff, in primary care premises (including general practice, family practice or primary care clinic).

Study design

Controlled trials, with individual or cluster randomisation, providing ≥12 month follow-up for outcome evaluation.

Outcome measures

Long term outcomes of MHBC interventions including CVD mortality and clinical events have been reported previously [5 6] and were not included in this systematic review. Primary outcomes were changes in CVD-risk scores, body mass index (BMI) or body weight, blood pressure, and serum total cholesterol levels. Secondary outcomes were changes in physical activity, diet, smoking and alcohol consumption.

Language

Studies reported in English.

Search strategy

Multiple sources of ascertainment were used, including electronic databases (Medline, EMBASE, PsycINFO and CENTRAL) and searching reference lists of included papers. The search results and search terms of the previous review [5] were used with searching extended from 2006 until May 2015. Search strategies are displayed in appendix A. Titles were screened by one reviewer (SA) and a second reviewer (MG) checked a random set of studies, approximately 10% of the search results. The selection process is displayed in Figure 1.

Methodologic quality

Studies were evaluated using the Cochrane risk of bias tool [19]. This assesses six domains of bias including selection bias, performance bias, detection bias, attrition bias, reporting bias and other biases [19].

Data extraction

Interventions were coded by country, target behaviours, participant and intervention characteristics, mode of delivery and intervention outcomes. In addition, Michie and Prestwich's [20] method of assessing the application of theory in the development and evaluation of behaviour change interventions was used. The Theory Coding Scheme (TCS) consists of 19 items that cover different aspects that may be informed by theory [20]. We used three measures to reflect the extent of theory use as reported in previous reviews [12 13]: whether the theory was used to develop intervention's BCTs (item 5 of TCS); the degree to which BCTs were linked to a theory-relevant construct (items 7-9); and the extent to which theory-relevant constructs were explicitly targeted by BCTs (items 9-11).

The theory-based taxonomy of 93 behaviour change techniques developed by Michie, Richardson et al.[9] was used to identify intervention techniques. The assessment was completed by two researchers (LM and SA) with good agreement for intervention groups (77.8% agreement) and control groups (92.6% agreement). Discrepancies were discussed and resolved to reach full agreement. Intervention characteristics and BCTs were also extracted from descriptions of the control group, because the chosen nature of the control group can influence the apparent effectiveness of interventions [21]. We attempted to contact study authors to provide additional information where necessary. However, when information was not available, we assumed missing outcome data to occur at random.

Data analysis

Outcome data were combined in random effects meta-analyses using 'metan' commands in STATA. We quantified statistical heterogeneity using I^2 statistic. Random effects models were chosen due to the considerable heterogeneity for certain outcomes. For continuous outcomes we used mean changes in each trial arm to calculate net effects. We expressed

effects for binary variables as risk differences. Meta-regression were used to examine the effect of number of interventions' sessions, intervention duration, types of BCTs used on intervention outcomes. Intervention duration was calculated by multiplying the number of sessions and the sessions' duration. Publication bias was assessed using Egger's regression test [22] using 'metabias' and 'metafunnel' commands in STATA. Mendis et al [23] Nigeria site's study had unusually high summary estimates, and heterogeneity diminished substantially after this study was excluded. This study was therefore treated as an outlier and results were reported with the exclusion of this study.

RESULTS

The initial search identified 21,290 references, with 55 relevant trials identified from the previous systematic review [5]. After removing duplicates, 16,793 titles were screened. A total of 27 trials were included in this review (Figure 1).

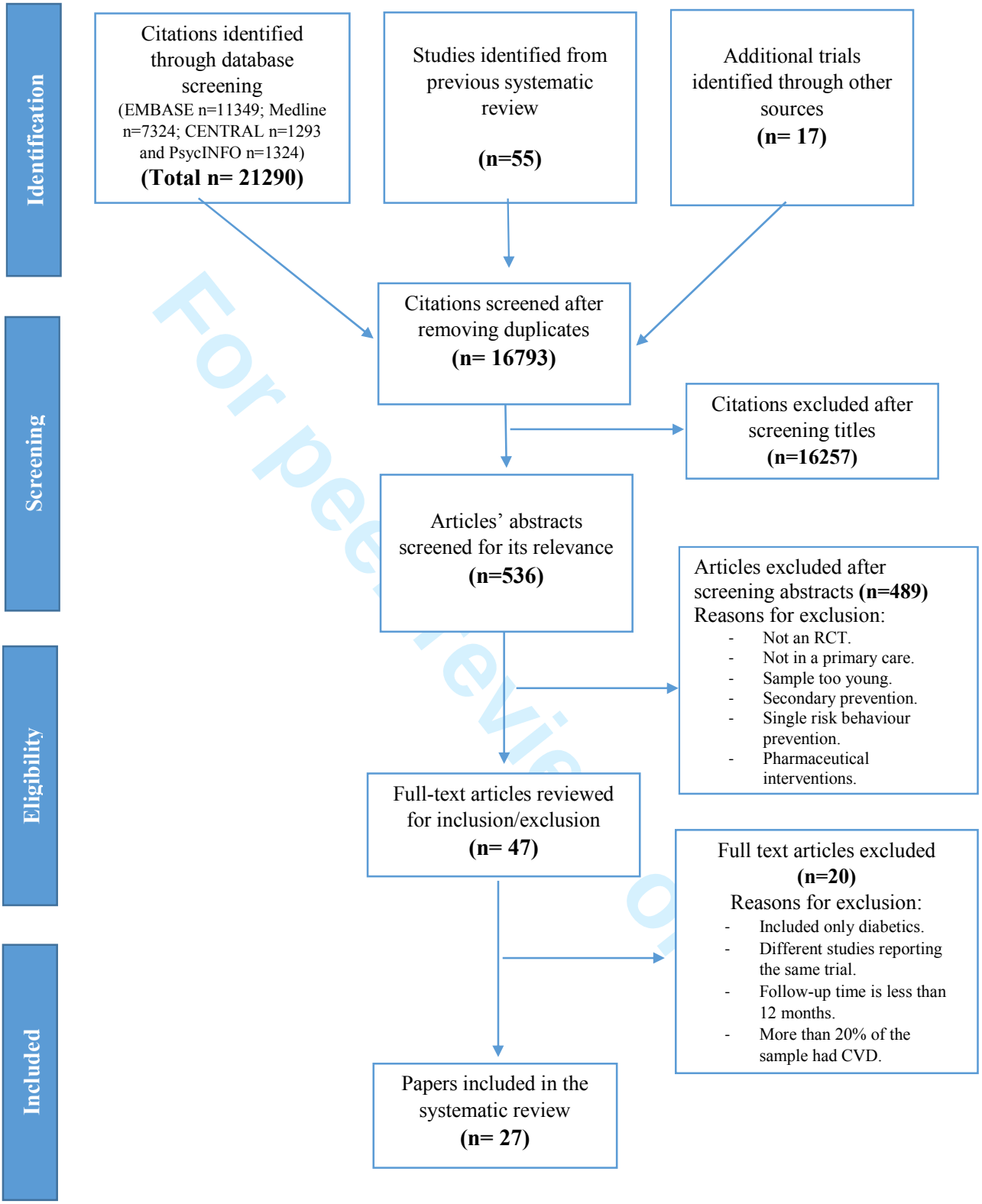

Figure 1: PRISMA flow diagram outlining the systematic review process.

Included studies

We identified a total of 27 trials of MHBC intervention in primary care with 34839 participants. The duration of follow-up ranged from 12 months to 6 years (median 12 months). Intervention duration ranged from three months up to three years (median 12 months). Summary of included studies characteristics are presented in table 1 and supplementary table 1.

Table 1: Summary of characteristics of 27 trials included in the review. Figures are frequencies (column percent).

Characteristics		Freq. (%)
Total		27 (100)
Country	UK	5 (18.5)
	USA	4 (14.8)
	Europe	14 (51.8)
	Others	4 (14.8)
Number of participants	Median (IQR)	419 (224-1200)
Gender	Male only	1 (3.7)
	Female only	1 (3.7)
	Both	25 (92.6)
Age	Minimum age, median (IQR)	30 (21-40)
	Maximum age, median (IQR)	65 (59-70)
Intervention outcomes	CVD risk	12 (44.4)
	Body weight	21 (77.7)
	Blood pressure	22 (81.5)
	Serum cholesterol	22 (81.5)
	Diet	15 (55.5)
	Physical activity	18 (66.7)
	Alcohol	6 (22.2)
	Smoking	14 (51.8)
Number of targeted behaviours	2 behaviours	8 (29.6)
	3 behaviours	12 (44.4)
	4 behaviours	6 (22.2)
	5 behaviours	1 (3.7)
Follow-up duration	12 months	15 (55.5)
	>12 months	12 (44.4)

CVD, cardiovascular disease; IQR, interquartile range

Study characteristics

Diet and physical activity were targeted in eight trials, with nine trials targeting diet, physical activity and smoking. Diet, physical activity, smoking and alcohol consumption were targeted in six interventions and two interventions targeted diet, physical activity and stress management. Only one intervention targeted diet, physical activity, stress and alcohol consumption and one intervention targeted all five behaviours. A wide range of intervention modalities was investigated (Table 2 and supplementary table 2), including individual and group sessions, telephone conversations and provision of written materials. The majority of the included trials reported offering “usual care” to the control group, with few details provided. Six trials offered face-to-face sessions and six trials offered face-to-face sessions and written materials. Written materials alone were offered in three trials and no intervention was offered to the control group in three interventions.

Table 2: Summary of interventions characteristics for 27 trials included in the review. Figures are frequencies (column percents).

		Intervention N (%)	Control N (%)
Type of staff delivering intervention	GPs and physicians	7 (25.9)	
	Nurses	13 (48.1)	
	Dietitian	6 (22.2)	
	Others	10 (37.0)	
Mode of intervention delivery	Face to face sessions	27 (100)	11 (40.7)
	Group sessions	6 (22.2)	1 (3.7)
	Written materials	12 (44.4)	6 (22.2)
	Telephone sessions	7 (25.9)	-
	Unclear	-	11 (40.7)
Number of intervention sessions	1-4 sessions	5 (18.5)	9 (33.3)
	5-9 sessions	10 (37.0)	2 (7.4)
	10-15 sessions	3 (11.1)	1 (3.7)
	>15 sessions	3 (11.1)	-
	Unclear	6 (22.2)	15 (55.5)
Number of behaviour change techniques (BCT)	1-2 BCTs	5 (18.5)	12 (44.4)
	3-4 BCTs	10 (37.0)	1 (3.7)
	5-6 BCTs	9 (33.3)	-
	7-9 BCTs	2 (7.4)	-
	10 BCTs	1 (3.7)	-
	Unclear	-	14 (51.8)
Frequently used behaviour change techniques	Credible source (9.1)	19 (70.4)	5 (18.5)
	Goal setting (behaviour) (1.1)	17 (62.9)	2 (7.4)
	Information about health consequences (5.1)	8 (29.6)	5 (18.5)
	Self-monitoring of behaviour (2.3)	7 (25.9)	-
	Instruction on how to perform a behaviour (4.1)	7 (25.9)	1 (3.7)
	Action planning (1.4)	6 (22.2)	-

Risk of bias in included studies

Risk of bias assessment is presented in supplementary table 3. Almost half of the included trials (n=13) reported using intention-to-treat (ITT) analysis, while 14 studies did not state ITT procedures. Loss to follow-up ranged from 1.5% to 43%. Not all trials reported sufficient detail to assess risk of bias and these were rated as 'unclear'.

Treatment fidelity

Few studies reported using fidelity checks [24-28] to confirm that interventions were delivered as intended and this raises a question of whether the interventions were delivered as planned, and in a consistent manner.

Effect of interventions

Pooled effect sizes for all outcomes are presented in Table 3 and forest plots are presented in Appendix B.

Table 3: Pooled effects from meta-analysis of multiple health behaviour interventions on CVD-risk and CVD risk factors.

Outcome	N		Pooled effect size	95% confidence interval	P value	I^2 (%)
Systolic blood pressure (mmHg)	12		-1.45	-2.98, 0.09	0.06	68.3
Systolic blood pressure (mmHg) by medication use	6	Medication	-2.03	-4.84, 0.77	0.16	79.9
	6	None	-0.55	-1.69, 0.59	0.35	3.4
Diastolic blood pressure (mmHg)	11		-1.01	-1.91, -0.11	0.03	62.4
Diastolic blood pressure (mmHg) by medication use	6	Medication	-1.34	-1.95, -0.73	<0.001	0.0
	5	None	-0.78	-2.50, 0.93	0.37	73.0
Serum total cholesterol (mmol/L)	10		-0.11	-0.17, -0.05	<0.001	0.0
Serum total cholesterol (mmol/L) by medication use	4	Medication	-0.11	-0.21, -0.02	0.01	0.0
	6	None	-0.11	-0.18, -0.03	0.01	0.0
Smoking (%)	10		-0.01	-0.02, 0.01	0.57	20.2
Body mass index (Kg/m^2)	10		-0.11	-0.25, 0.02	0.10	0.0
Body weight (Kg)	8		-0.87	-1.50, -0.24	0.01	35.4
CVD-risk using SCORE (%)	2		0.12	-0.37, 0.61	0.62	0.0
Systolic blood pressure (mmHg) by theory use	5	Theory	-2.18	-5.92, 1.56	0.25	72.3
	7	None	-1.07	-2.77, 0.63	0.22	69.2
Diastolic blood pressure (mmHg) by theory use	5	Theory	-1.25	-2.43, -0.06	0.04	0.4
	6	None	-0.94	-2.17, 0.29	0.13	75.7
Serum total cholesterol (mmol/L) by theory use	4	Theory	-0.03	-0.15, 0.10	0.68	0.0
	6	None	-0.13	-0.20, -0.07	<0.001	0.0
Body mass index(Kg/m^2) by theory use	5	Theory	-0.15	-0.41, 0.10	0.24	0.0
	5	None	-0.12	-0.30, 0.07	0.22	13.1
Body weight by (Kg) theory use	4	Theory	-0.24	-0.94, 0.45	0.49	0.0
	4	None	-1.33	-2.08, -0.59	<0.001	23.9

N, number of trials; I^2, index of heterogeneity

Changes in CVD risk factors

Blood pressure: twelve trials [23 25 29-38] reported changes in participants' systolic blood pressure (SBP) with no evidence of publication bias (Egger's test, P= 0.82). The weighted mean difference in SBP was -1.45 mm Hg (95% CI -2.98 to 0.09 mm Hg; P= 0.06). Diastolic blood pressure (DBP) was reported in 11 trials [23 25 29-31 33-38], with no evidence of publication bias (Egger's test, P= 0.38). Weighted mean difference in DBP was -1.01 mmHg (-1.91 to -0.11 mm Hg; P= 0.03). Out of the 12 interventions that evaluated blood pressure, four reported that participants in all study groups were taking antihypertensive medications and two reported they were taking unspecified medications. In the subgroup of trials that reported use of medications there was a greater effect on SBP (-2.03 vs. -0.55 mmHg) and DBP (-1.34 vs. -0.78 mmHg) compared to trials that did not report using medications.

Serum total cholesterol: Ten trials [25 29-31 33-35 37-39] evaluated serum total cholesterol and provided sufficient data for analysis (Egger's test, P= 0.53). Serum total cholesterol levels showed a small decrease in favour of intervention (-0.11 mmol/L; 95% -0.17 to -0.05; P<0.001). Three of the trials included in the analysis reported the use of lipid lowering medication and one reported the use of unspecified medication by all study groups. The weighted mean difference for total cholesterol was not different between trials that reported using medication and trials that have not stated using medications (Table 3).

Smoking: Ten studies [23 24 27-30 32 35 40 41] reported smoking prevalence following the intervention. The pooled analysis showed no evidence of reductions in smoking behaviour (RD -0.01 %; 95% CI -0.02 to 0.01; P=0.57). All studies included in the analysis relied on self-reported smoking status and only one [27] reported using smoking cessation medication. There was no evidence of publication bias (P=0.55).

Weight and body mass index (BMI): Ten studies [23 25 29 31 33-38] reported on BMI as an outcome. Egger's test suggested possible publication bias (P=0.049). The weighted mean change was -0.11 kg/m^2 (95% CI -0.25 to 0.02; P=0.10). Fewer studies (n=8) [25 31 33-35 38 41 42] reported on weight changes, showing a reduction of -0.87 kg (CI -1.50 to -0.24 kg; P= 0.01) with no evidence of publication bias (P=0.62).

Dietary behaviour: Thirteen trials [23-28 31 32 39 41-44] reported dietary behaviours as an outcome of the interventions. Outcomes of dietary interventions were measured using diverse methods, therefore, a meta-analysis was not conducted. Trials used a range of dietary self-report instruments to assess dietary behaviour, and none have used additional objective measures. Fruit and vegetable consumption was reported either as portions per day [23-25 41 44], or proportion of participants who met the recommendation for fruits and vegetable intake [24 31 32]. There was no positive effect of the intervention on fruits and vegetable consumption in most of the trials [24 25 32 41], and some trials did report improvement following the intervention [31 44], Fat intake was commonly measured as a dietary outcome either in terms of fat intake per day, [25 31 42 43] or as a fat score [27 32]. All the trials reported reductions in fat intake after the intervention, except Koelewijn-van Loon et al.[32] trial, where there was no significant difference between the intervention and control group.

Physical activity behaviour: Seventeen trials reported changes in physical activity [24-32 34 35 37 38 40 41 44 45]. Physical activity was assessed via self-report. Due to the variety of measurements used, meta-analysis was not feasible. Some trials reported physical activity as the proportion of participants who are physically active [27 29 37 40 44]. Other studies measured physical activity as the number of minutes per week, [25 32] or classified participants based on their weekly exercise [24 26 44]. Eight of these trials [25 27 28 34 35 38 41 44] resulted in an

increase in reported physical activity following the intervention, and nine [24 26 29-31 37 40 42 45] trials concluded that the intervention had no impact on physical activity.

Alcohol consumption: Alcohol consumption was reported as an outcome in seven trials [28 32 38 40-42 44]. However, it was measured differently, which did not allow for pooled effect analysis. Two trials [38 40] reported reductions in alcohol consumption following the interventions, whereas the majority of the studies [28 32 41 42 44] did not find significant reductions in alcohol intake.

Cardiovascular disease risk: Studies used different risk scores to examine the effect of interventions on CVD-risk. Two studies [36 45] used the Framingham risk equation [46] and two studies [28 47] used the Dundee risk score [48]. These trials reported larger CVD-risk reductions in the intervention group compared to the control group. All of these trials had missing data making it not possible to analyse the pooled effect. Four studies [24 32 37 40] used the SCORE risk equation [49], however because of missing data we only included two studies [24 32] in the analysis, both conducted in the Netherlands. There was a non-significant increase in weighted mean difference of 0.12% CVD-risk (95% CI -0.37 to 0.61; P= 0.62).

Study characteristics:

Intervention time and number of sessions: The number of sessions was reported in 20 trials, ranging from three to 56 sessions (median=6 sessions). No significant associations were detected between the number of sessions and SBP (β= -0.16, P=0.67), DBP (β= 0.15, P= 0.59), serum total cholesterol (β=-0.01, P= 0.59), BMI (β= -0.01, P=0.72) and weight (β= -0.13, P=0.72). Ten of the included trials provided enough details to calculate intervention delivery duration, which ranged from 45 to 630 mins (median=285 mins). No significant

associations were detected between intervention duration and SBP (β=-0.02, P=0.17), DBP (β=-0.01, P= 0.36), BMI (β= -0.00, P= 0.79) and weight (β= 0.00, P=0.75). Hence, more sessions and longer intervention duration were not necessarily associated with greater intervention effectiveness.

Theory use: Of the 27 trials included, nine reported using psychological theory (or a combination of two theories) to underpin the intervention. The Transtheoretical Model (TTM) [50] was used in eight trials [25 26 34-38 41], while Social Cognitive Theory (SCT) [51] was used in four [25 26 36 52] interventions.

We tested the extent of theory use using Theory Coding Scheme (TCS) [20] in three ways (supplementary table 4). The first method was based on the use of theory in developing intervention techniques (item 5 in TCS). Only four of nine trials were coded yes for this item. The second method was used to reflect the extent to which each BCT was linked to a theory-relevant construct (items 7 to 9). Only four out of nine trials were coded yes to at least one of these items. The third method was used to reflect the extent to which theory-relevant constructs were targeted by BCTs (items 9 to 11). Only four out of nine trials were coded yes to at least one of these items. We were not able to examine the impact of differing levels of theory use on intervention outcomes due to the small number of trials using theory extensively. However, we were able to test whether studies that merely reported using a theory had greater impact on outcomes using meta-regression. There was no significant association between studies which stated using a theory and SBP (β= -1.15, P= 0.54), DBP (β= -0.37, P= 0.73), serum total cholesterol (β= 0.11, P= 0.17) and BMI (β= -0.06, P= 0.72). Studies that reported using a theory had increased weight outcomes (β= 1.14, P= 0.04, CI= 0.06, 2.22) compared to studies that did not report using a theory.

Effectiveness of specific behaviour change techniques: The number of behaviour change techniques (BCTs) in the intervention group varied, ranging from two to ten BCTs

(median= 4). Behaviour change techniques in the control group were generally poorly described as the majority of trials (n= 14) did not appear to offer any BCTs.

Twenty nine different BCTs were identified from the included trials (supplementary table 2). The most commonly used BCTs in the intervention group were 'credible source' and 'Goal setting (behaviour)', which were used in 19 and 17 trials respectively. In the control group, 'Information about health consequences' and 'Credible source' were most commonly used, which were each used in five interventions.

We tested the potential impact of using specific BCTs on intervention outcomes (table 4). For SBP, one BCT had a significant influence on effect sizes. Interventions employing 'Review of behaviour goal(s)' resulted in an increase in SBP (β=3.96, P= 0.05) than those not using this BCT. For DBP, using 'Information about health consequences' was associated with less change in DBP (β=1.87, P= 0.04). For total cholesterol, there were no BCTs significantly associated with the effectiveness of the interventions. The same was the case for BMI, but for weight, interventions that included 'Action planning' resulted in greater reductions than those that did not (β= -1.22, P= 0.04).

Table 4: Meta-regression results of intervention effects for studies using or not using particular behaviour change techniques.

Outcome	BCT	BCT included			BCT not included					
		MD	CI	N	MD	CI	N	β	CI	P
Systolic blood pressure	1.1 Goal setting (behaviour).	-0.98	-2.58 to 0.63	9	-3.63	-4.93 to -2.34	3	2.16	-2.03 to 6.36	0.28
	1.2 Problem solving.	-3.19	-9.21 to 2.83	3	-1.14	-2.70 to 0.42	9	-1.63	-6.16 to 2.90	0.45
	1.4 Action planning.	-1.99	-5.38 to 1.39	4	-1.29	-3.12 to 0.53	8	-0.60	-4.83 to 3.62	0.76
	1.5 Review behaviour goal(s)	**1.76**	**-1.66 to 5.19**	**3**	**-2.19**	**-3.73 to -0.66**	**9**	**3.96**	**0.02 to 7.90**	**0.05**
	5.1 Info. about consequences.	-0.38	-1.99 to 1.23	4	-2.08	-4.31 to 0.14	8	1.54	-2.09 to 5.16	0.37
	9.1 Credible source.	-2.37	-4.28 to -0.46	6	-0.19	-2.85 to 2.47	6	-2.37	-6.10 to 1.35	0.19
	9.2 Pros and cons.	0.16	-3.89 to 4.20	4	-1.98	-3.56 to -0.40	8	2.31	-1.68 to 6.31	0.23
	11.2 Reduce negative emotions.	-1.65	-9.80 to 6.51	3	-1.38	-2.84 0.08	9	-0.22	-5.48 to 5.03	0.93
Diastolic blood pressure	1.1 Goal setting (behaviour).	-0.88	-2.04 to 0.28	8	-1.54	-2.33 to -0.74	3	0.77	-1.71 to 3.25	0.50
	1.4 Action planning.	-1.33	-3.99 to 1.33	3	-0.97	-1.98 to 0.03	8	-0.21	-3.02 to 2.59	0.87
	4.1 Instruction on how to perform the behaviour.	-0.15	-1.78 to 1.49	3	-1.53	-2.48 to -0.58	8	1.54	-0.49 to 3.58	0.12
	5.1 Information about health consequences.	**0.15**	**-1.32 to 1.63**	**3**	**-1.53**	**-2.29 to -0.78**	**8**	**1.87**	**0.11 to 3.63**	**0.04**
	9.1 Credible source.	-0.91	-2.51 to 0.70	6	-1.32	-1.94 to -0.69	5	0.70	-1.44 to 2.84	0.48
	9.2 Pros and cons.	-1.46	-3.05 to 0.13	3	-0.93	-2.01 to 0.15	8	-0.58	-3.31 to 2.16	0.65
	11.2 Reduced negative emotions.	-2.79	-4.60 to -0.97	3	-0.68	-1.66 to 0.30	8	-2.10	-4.81 to 0.61	0.12
Serum total cholesterol	1.1 Goal setting (behaviour).	-0.11	-0.18 to -0.05	7	-0.10	-0.23 to 0.04	3	-0.02	-0.19 to 0.15	0.83
	1.4 Action planning.	-0.02	-0.18 to 0.14	3	-0.12	-0.19 to -0.06	7	0.10	-0.09 to 0.29	0.27
	5.1 Information about health consequences.	-0.11	-0.19 to -0.02	4	-0.11	-0.21 to -0.01	6	0.01	-0.13 to 0.14	0.94
	9.1 Credible source.	-0.09	-0.16 to -0.01	6	-0.14	-0.25 to -0.03	4	0.06	-0.08 to 0.19	0.39
	9.2 Pros and cons.	-0.07	-0.31 to 0.16	3	-0.11	-0.18 to -0.05	7	0.03	-0.18 to 0.24	0.77
Body mass index	1.4 Action planning.	-0.33	-0.68 to 0.01	3	-0.07	-0.22 to 0.07	7	-0.26	-0.67 to 0.16	0.20
	5.1 Information about health consequences.	-0.10	-0.33 to 0.14	3	-0.12	-0.28 to 0.04	7	0.03	-0.30 to 0.35	0.86
	9.1 Credible source.	-0.23	-0.43 to -0.02	5	-0.02	-0.20 to 0.16	5	-0.20	-0.51 to 0.10	0.17
	9.2 Pros and cons.	-0.47	-1.29 to 0.34	3	-0.10	-0.24 to 0.03	7	-0.37	-1.31 to 0.57	0.39
Weight	1.3 Goal setting (outcome)	-0.97	-2.06 to 0.12	3	-0.78	-1.67 to 0.10	5	-0.18	-1.95 to 1.59	0.81
	1.4 Action planning.	**-1.30**	**-1.92 to -0.67**	**4**	**-0.10**	**-0.88 to 0.68**	**4**	**-1.22**	**-2.37 to -0.07**	**0.04**
	4.1 Instruction on how to perform the behaviour.	-0.81	-1.91 to 0.30	3	-0.89	-1.86 to 0.08	5	0.06	-1.77 to 1.89	0.94
	9.1 Credible source.	-0.97	-1.73 to -0.21	5	-0.02	-1.70 to 1.65	3	-0.91	-3.35 to 1.53	0.40
	9.2 Pros and cons.	-0.91	-3.91 to 2.09	3	-0.84	-1.61 to -0.07	5	-0.05	-3.98 to 3.88	0.98

Note: BCT, behaviour change technique; MD, mean difference; CI, 95% confidence interval; N, number of trials; β, meta-regression coefficient

DISCUSSION

This systematic review is among the first to evaluate the impact of theory use and BCTs in MHBC interventions for reducing CVD-risk. The results of this systematic review suggest that MHBC interventions evaluated to date for the primary prevention of CVD may generally have very limited effects in reducing CVD-risk and CVD risk factors in primary care populations.

Previous systematic reviews have investigated the effectiveness of interventions aimed at individual risk factors including diet, physical activity and body weight [6 53]. These reviews generally find that behaviour change interventions in primary care have minor impact on risk factors values. The Cochrane review up to 2011 reported modest reductions in CVD risk factors following MHBC interventions that were wlgithly greater than we report [5]. However, the Cochrane review did not restrict the intervention setting to primary care.

Estimated changes in CVD risk factors should be viewed with caution. The observed effects were heterogeneous, therefore pooled estimates might be questionable. In the present set of trials, the average duration of follow-up was 12 months and changes in risk factors observed may be unlikely to reflect changes occurring over a longer periods. This review found reductions in blood pressure and total cholesterol following intervention, but in some instances this might be mediated by pharmacological treatment. There are clear benefits of drug treatments in lowering blood pressure and cholesterol in primary prevention populations [54 55].

Although this review focused on interventions for the primary prevention population, we also included trials that recruited a small minority of participants with some evidence of CVD.

Including these trials might have biased the results, as health promotion interventions might have more positive effects in people with established cardiovascular disease [56-58].

In order to account for heterogeneity, we focused on trial level covariates and identified characteristics that might be associated with more favourable outcomes. When coding BCTs, we were limited by the lack of detail provided in reports. We only coded what was explicitly referred to in intervention descriptions and could be fitted to BCT taxonomy definitions.

This review suggested no association between the number of intervention sessions or intervention duration and improved outcomes. Quantity of sessions would not necessarily have a beneficial impact on outcomes unless additional sessions deliver BCTs that effectively influence behaviours. Fewer reports provided sufficient information to permit calculating duration for analysis. Increasing use of the TIDieR checklist [59], requiring intervention reports to detail the number and duration of sessions offered to participants, will be helpful for future reviews.

Our analyses suggested that using certain BCTs has a moderator effect on intervention outcomes. In terms of biomarkers of CVD risk, no BCTs were identified as being particularly likely to influence cholesterol levels, while including review of behaviour goals or information about health consequences appeared to be associated with slightly worse blood pressure outcomes.

“Action planning” was associated with greater weight loss, while “instruction on how to perform the behaviour” was not. Both of these findings differ to those of a previous review [17], perhaps because it focused only on interventions for obese individuals. The previous review

also identified the BCTs of self-monitoring, relapse prevention/problem solving and prompt practice as beneficial to weight loss, but too few of the interventions included in the present review incorporated these BCTs for it to be possible to test their influence. A review of interventions promoting healthy eating and exercise also found that including the BCT of self-monitoring was associated with bigger changes in these behaviours [18]. Therefore, one explanation for the relatively limited effectiveness of the interventions reviewed in the present review is that they failed to include BCTs that were more likely to lead to health-promoting changes. A second possibility is that not all BCTs were delivered as the intervention designers intended. This cannot be ruled out as monitoring of treatment fidelity was rarely described in the included studies.

This review showed no association between the use of psychological theory and improved intervention outcomes. However, only a limited range of theories were employed – mostly TTM and SCT. A previous review also found that interventions based on these theories were not significantly more effective than interventions not explicitly based on theory [13]. A second issue is that the links between the psychological determinants specified by a theory and the BCTs employed in interventions were sometimes poorly articulated, with little evidence cited to justify choice of BCTs to change specific constructs. Furthermore, it was not always clear which BCTs were being used to target which behaviours as part of the MHBC interventions. Both this and previous reviews [13 60] found that reported theory use in intervention design was not as extensive as it could be. It is possible that interventions based on other theories or that more explicitly link theoretical constructs to select BCTs might be more effective.

Limitations

The results of this review must be viewed with caution because of several limitations. First, the majority of trials included were undertaken in Europe (70%) and the United States (14.8%). Declines in CVD mortality and CVD-risk have been observed in these countries, and the results should be considered in the context of these trends. Groups of BCTs may have synergistic effects on behaviour [16]. However, due to the relatively small numbers of studies and under-description of the BCTs used in interventions, it was not possible to explore the impact of clusters of BCTs on CVD risk factors, as too few studies used the same clusters of BCTs and measured the same outcome. Behavioural risk factors were assessed by self-report and so values were subject to social desirability and recall biases. Finally, as this review involved testing for the impact of MHBC interventions and intervention characteristics on intervention outcomes, we are aware of the need to adjust p-values based on the number of testes being made [61]. However, tests were examining independent hypotheses, therefore the p-values were not adjusted.

CONCLUSION

Existing multiple health behaviour change interventions delivered to individual participants in primary care appear to have limited effectiveness at reducing CVD-risk and CVD risk factors over twelve months or longer. Trial reports needs to provide explicit explanation of the intervention theory, content and delivery, including fidelity, in order to understand why an intervention may or may not prove effective. This is essential for future development of effective CVD prevention interventions.

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Contributorship statement:

SA, AW and MG conceptualised and designed the study. SA and MG performed the paper search. SA and LM performed the coding. SA wrote the first draft and all authors have read and made improvements of the contents and the wording.

Competing interests:

There are no competing interests.

Data sharing statement:

No additional data are available.

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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3 & 4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4 - 6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6 & 7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix A
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7 & 8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7 & 8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7 & 14

Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	8 & 9
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8 & 9
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	8 & 9
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10 and figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Supplementary table 1&2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplementary table 3
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Appendix B
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	15
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	16-20
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	19 - 21
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	22
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	25
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	25
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	25

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed100009

Appendix A

Search strategy

CENTRAL search strategy

ID	Search	Hits
#1	MeSH descriptor CARDIOVASCULAR DISEASES this term only	480
#2	MeSH descriptor CORONARY DISEASE explode all trees	356
#3	cardiovascular in All Text	2052
#4	(coronary in All Text near/3 disease* in All Text)	9
#5	(heart in All Text near/3 disease* in All Text)	11
#6	MeSH descriptor HYPERTENSION this term only	643
#7	hypertension in All Text	1781
#8	(atherosclerosis in All Text or arteriosclerosis in All Text)	258
#9	(hyperlipidaemia in All Text or hyperlipidemia in All Text)	224
#10	MeSH descriptor ARTERIOSCLEROSIS explode all trees	79
#11	MeSH descriptor CHOLESTEROL explode trees all trees	209
#12	MeSH descriptor HYPERLIPIDEMIA explode all trees	33
#13	cholesterol in All Text	630
#14	multiple next risk next factor* in All Text	51
#15	coronary next risk next factor* in All Text	30
#16	(#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10)	3105
#17	(#11 or #12 or #13 or #14 or #15)	682
#18	(#16 or #17)	3234
#19	MeSH descriptor HEALTH EDUCATION explode all trees	630
#20	MeSH descriptor HEALTH PROMOTION explode all trees	191
#21	MeSH descriptor HEALTH BEHAVIOR explode all trees	215
#22	MeSH descriptor PRIMARY PREVENTION this term only	1021
#23	MeSH descriptor COUNSELLING this term only	237
#24	counsel* in All Text	1186
#25	(health in All Text near/3 educat* in All Text)	31
#26	(patient in All Text near/3 educat* in All Text)	20
#27	(education* in All Text near/3 program* in All Text)	23
#28	(health in All Text near/3 promotion* in All Text)	2
#29	(health in All Text near/3 behaviour* in All Text)	11
#30	(health in All Text near/3 behavior* in All Text)	9
#31	primary next prevention in All Text	379
#32	(multiple next risk in All Text near/3 intervention* in All Text)	6
#33	(multifactor* in All Text near/3 intervention* in All Text)	9
#34	(multifactor* in All Text near/3 prevention in All Text)	1
#35	(risk next factor* in All Text near/3 reduc* in All Text)	10
#36	(risk next factor* in All Text near/3 manag* in All Text)	20
#37	(risk next factor* in All Text near/3 intervent* in All Text)	49

#38 (lifestyle in All Text near/3 intervention* in All Text) 34
#39 (lifestyle in All Text near/3 advice in All Text) 6
#40 (life-style in All Text near/3 intervention* in All Text) 12
#41 (life-style in All Text near/3 advice in All Text) 2
#42 (life-style in All Text near/3 alter* in All Text) 1
#43 (lifestyle in All Text near/3 alter* in All Text) 5
#44 (lifestyle in All Text near/3 educat* in All Text) 15
#45 (life-style in All Text near/3 educat* in All Text) 5
#46 (life-style in All Text near/3 chang* in All Text) 8
#47 (lifestyle in All Text near/3 chang* in All Text) 18
#48 (behavior* in All Text near/3 chang* in All Text) 24
#49 (behaviour* in All Text near/3 chang* in All Text) 37
#50 (health next care in All Text near/3 advice in All Text) 7
#51 (healthcare in All Text near/3 advice in All Text) 8
#52 nonpharmacologic* in All Text 46
#53 non-pharmacologic* in All Text 562
#54 (#19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29) 2311
#55 (#30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39) 451
#56 (#40 or #41 or #42 or #43 or #44 or #45 or #46 or #47 or #48 or #49 or #50 or #51 or #52 or #53) 646
#57 (#54 or #55 or #56) 2915
#58 (#18 and #57) 1293

Embase search strategy

1. cardiovascular disease/
2. exp ischemic heart disease/
3. (Coronary adj3 disease$).tw.
4. heart disease$.tw.
5. Hypertension/
6. hypertension.tw.
7. (cardiovascular adj3 (disease$ or fit of fitness)).tw.
8. exp arteriosclerosis/
9. exp hyperlipidemia/
10. hyperlipid?emia.tw.
11. cholesterol.tw.
12. arteriosclero$.tw.
13. atherosclero$.tw.
14. coronary risk factor$.tw.
15. multiple risk factor$.tw.
16. cardiovascular risk factor$.tw.
17. or/1-16
18. exp health education/
19. exp health behavior/

20. primary prevention/
21. exp counseling/
22. (multifactor$ adj5 (intervent$ or prevent$)).tw.
23. ((life-style or life style or lifestyle or healthcare or health care) adj3 (intervention$ or educat$ or advice or alter$ or change$)).tw.
24. primary prevention.tw.
25. (risk factor$ adj3 (reduc$ or manage$ or managing or intervent$ or program$)).tw.
26. (educat$ adj3 (program$ or patient$)).tw.
27. (non pharmacologic$ or nonpharmacologic$).tw.
28. (risk factor$ adj3 modif$).tw.
29. ((lifestyle or life-style or life style) adj3 modif$).tw.
30. exp behavior therapy/
31. (behavi?r$ adj3 (intervention$ or program$ or modif$ or change$ or alter$)).tw.
32. (promot$ adj3 (health or healthcare or health care)).tw.
33. or/18-32
34. 17 and 33
35. random$.ti,ab.
36. factorial$.ti,ab.
37. (crossover$ or cross over$ or cross-over$).ti,ab.
38. placebo$.ti,ab.
39. (double$ adj blind$).ti,ab.
40. (singl$ adj blind$).ti,ab.
41. assign$.ti,ab.
42. allocat$.ti,ab.
43. volunteer$.ti,ab.
44. Crossover Procedure/
45. Double Blind Procedure/
46. Randomized Controlled Trial/
47. Single Blind Procedure/
48. or/35-47
49. exp animal/
50. nonhuman/
51. exp animal experiment/
52. or/49-51
53. exp human/
54. 52 not 53
55. 48 not 54
56. 55 and 34
57. limit 56 to yr="2006 -Current"

Medline search strategy

1. Cardiovascular Diseases/
2. exp coronary disease/
3. Hypertension/

4. exp Arteriosclerosis/
5. exp Hyperlipidemia/
6. (cardiovascular adj3 disease$).tw.
7. (cardiovascular adj3 (fit or fitness)).tw.
8. (Coronary adj3 disease$).tw.
9. heart disease$.tw.
10. hypertension.tw.
11. hyperlipid?emia.tw.
12. cholesterol.tw.
13. atherosclerosis.tw.
14. arteriosclerosis.tw.
15. coronary risk factor$.tw.
16. multiple risk factor$.tw.
17. cardiovascular risk factor$.tw.
18. or/1-17
19. health promotion/
20. exp health education/
21. exp health behavior/
22. exp counseling/
23. Primary Prevention/
24. (multifactor$ adj5 (intervent$ or prevent$)).tw.
25. ((lifestyle or life-style) adj3 (intervention$ or educat$ or advice$ or alter$ or change$)).tw.
26. ((lifestye or life-style or behavior?r$) adj3 (intervention$ or educat$ or advice$ or alter$ or change$)).tw.
27. ((healthcare or health care) adj3 advice).tw.
28. primary prevention.tw.
29. (risk factor$ adj3 (reduc$ or manage$ or managing or intervent$ or program$)).tw.
30. (educat$ adj3 (program$ or patient$)).tw.
31. ((health or healthcare or health care) adj3 (educat$ or advice or promot$)).tw.
32. (nonpharmacologic$ or non-pharmacologic$).tw.
33. ((lifestyle or life style or life-style or behavio?r$ or risk factor$) adj3 modif$).tw.
34. or/19-33
35. 18 and 34
36. randomized controlled trial.pt.
37. controlled clinical trial.pt.
38. Randomized controlled trials/
39. random allocation.sh.
40. double blind method.sh.
41. single-blind method.sh.
42. or/36-41
43. clinical trial.pt.
44. exp Clinical trial/
45. (clin$ adj25 trial$).ti,ab.

46. ((singl$ or doubl$ or trebl$ or tripl$) adj (blind$ or mask$)).ti,ab.
47. placebos.sh.
48. placebo$.ti,ab.
49. random$.ti,ab.
50. research design.sh.
51. or/43-50
52. exp animal/ not humans/
53. 42 or 51
54. 53 not 52
55. 54 and 35

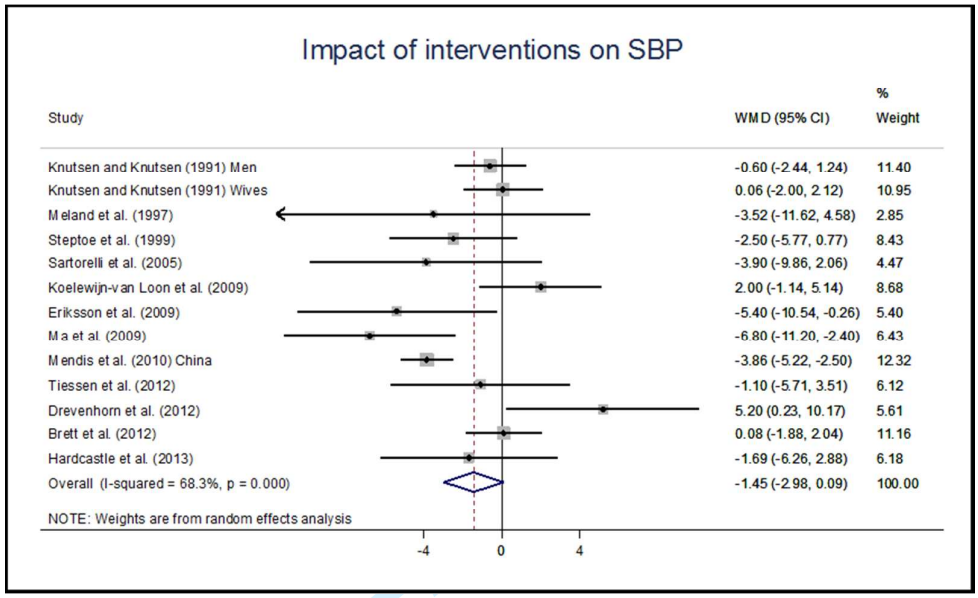
PsycINFO search strategy:

1. cardiovascular disease.mp.
2. hypertension.mp.
3. (Coronary adj3 disease$).mp.
4. heart disease$.mp.
5. (cardiovascular adj3 (disease$ or fit of fitness)).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
6. exp Arteriosclerosis/
7. hyperlipid?emia.mp.
8. cholesterol.mp.
9. arteriosclero$.mp.
10. atherosclero$.mp.
11. coronary risk factor$.mp.
12. multiple risk factor$.mp.
13. cardiovascular risk factor$.mp.
14. or/1-13
15. exp health education/
16. exp health education/
17. exp health promotion/
18. exp preventive medicine/
19. exp counseling/
20. primary prevention.mp.
21. (multifactor$ adj5 (intervent$ or prevent$)).mp.
22. behavior change.mp.
23. exp Obesity/ or exp Food Intake/ or diet intervention.mp. or exp Weight Loss/ or exp Diets/ or exp Overweight/ or exp Weight Control/ or exp Nutrition/
24. exp Nicotine/ or exp Tobacco Smoking/ or exp Smoking Cessation/ or cigarette.mp. or exp Drug Dependency/
25. exp Alcohol Drinking Patterns/ or exp Drinking Behavior/ or exp Alcohol Drinking Attitudes/ or exp Binge Drinking/ or drinking.mp.
26. exp Physical Activity/ or exp Intervention/ or exp Exercise/ or exp Physical Fitness/ or exp Motor Performance/ or physical training.mp.
27. 23 and 24
28. 23 and 25

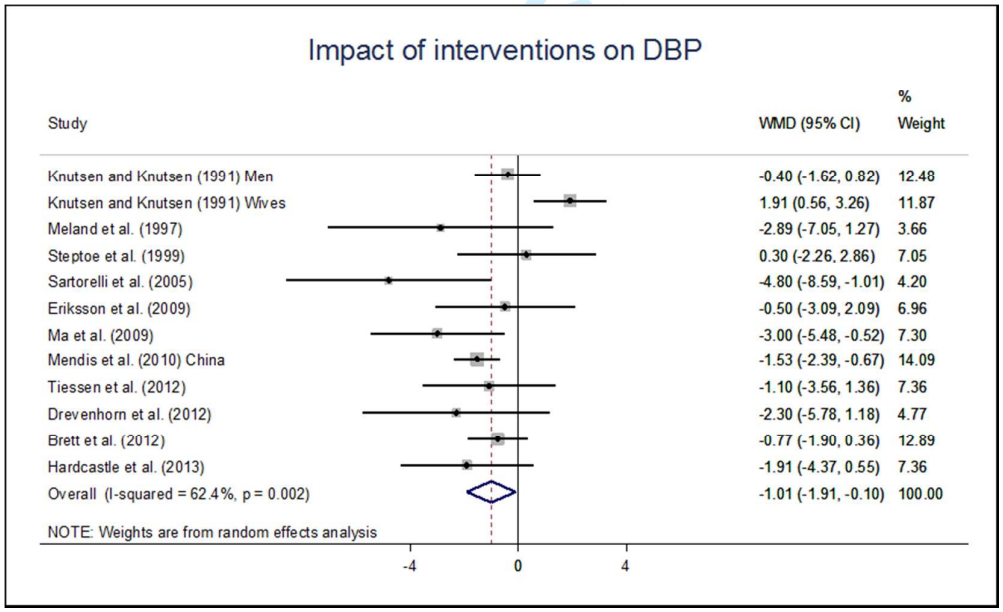
29. 23 and 26
30. 24 and 25
31. 24 and 26
32. 25 and 26
33. ((life-style or life style or lifestyle or healthcare or health care) adj3 (intervention$ or educat$ or advice or alter$ or change$)).mp.
34. primary prevention.mp.
35. (risk factor$ adj3 (reduc$ or manage$ or managing or intervent$ or program$)).sh.
36. (educat$ adj3 (program$ or patient$)).mp.
37. (non pharmacologic$ or nonpharmacologic$).mp.
38. (risk factor$ adj3 modif$).mp.
39. ((lifestyle or life-style or life style) adj3 modif$).mp.
40. (behavi?r$ adj3 (intervention$ or program$ or modif$ or change$ or alter$)).mp.
41. (promot$ adj3 (health or healthcare or health care)).mp.
42. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41
43. 14 and 42
44. random$.ti,ab.
45. factorial$.ti,ab.
46. (crossover$ or cross over$ or cross-over$).ti,ab.
47. placebo$.ti,ab.
48. (double$ adj blind$).ti,ab.
49. (singl$ adj blind$).ti,ab.
50. assign$.ti,ab.
51. allocat$.ti,ab.
52. volunteer$.ti,ab.
53. ("double-blind" or "random* assigned" or control).mp.
54. treatment effectiveness evaluation.mp.
55. treatment outcome clinical trial$.mp.
56. (controlled trial$ and clinical trial$).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
57. 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56
58. 43 and 57

Appendix B

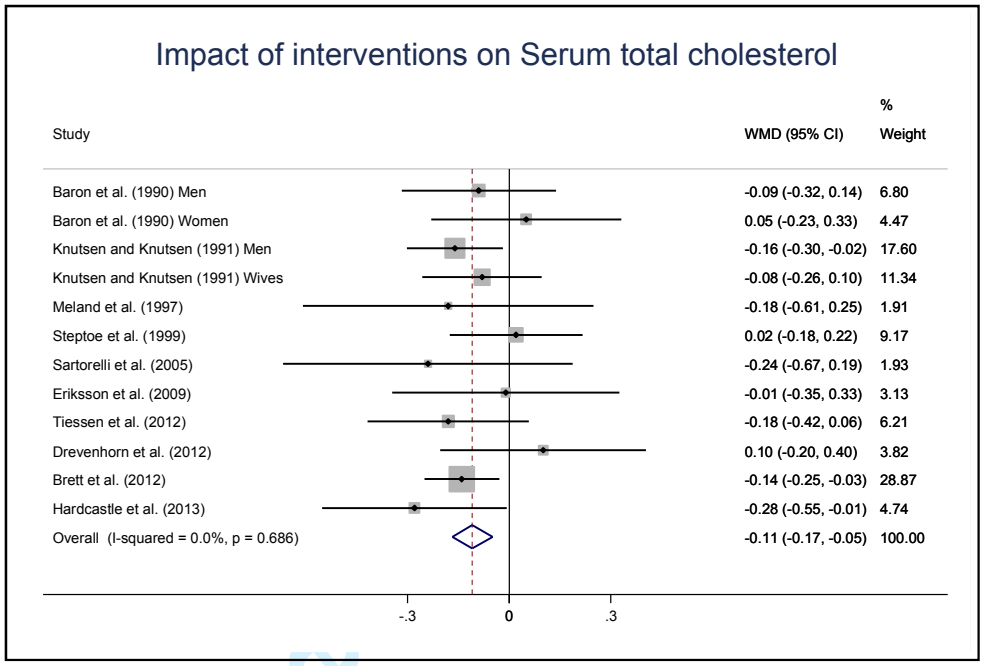
Forest plots of pooled effect of multiple behaviour interventions on intervention outcomes.



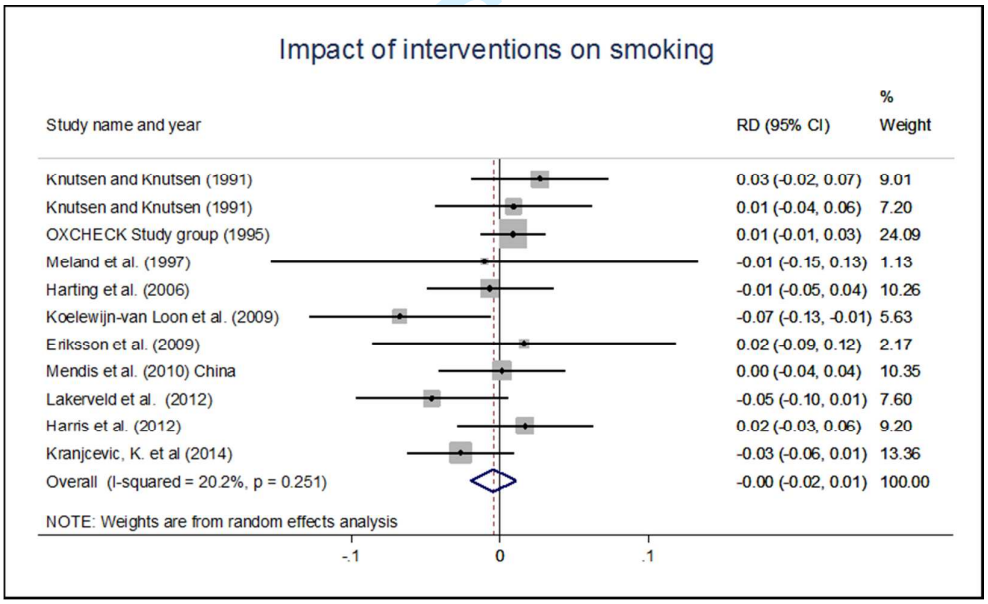
Pooled effect of multiple behaviour interventions on systolic blood pressure (mmHg). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



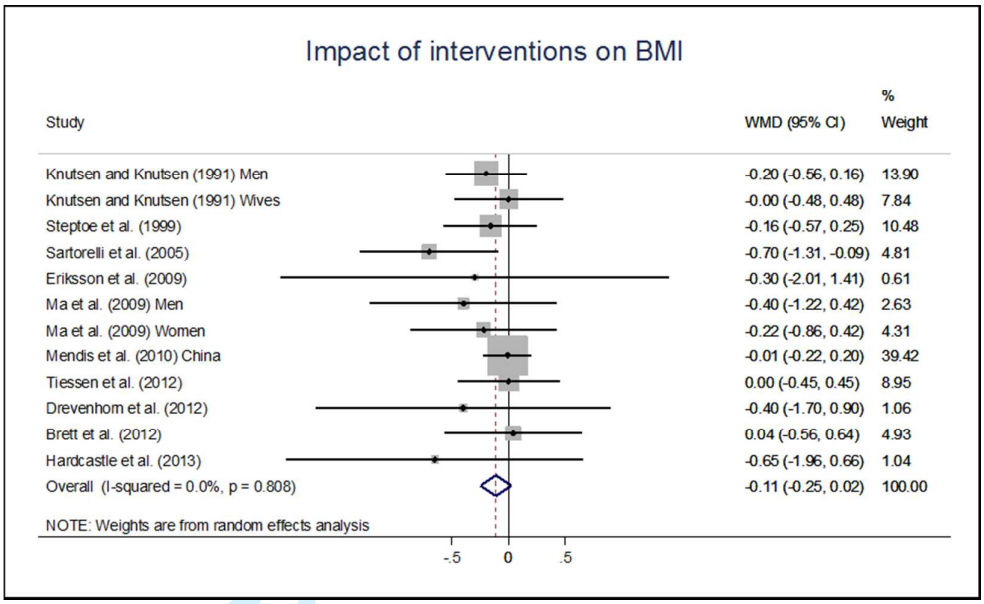
Pooled effect of multiple behaviour interventions on diastolic blood pressure (mmHg). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



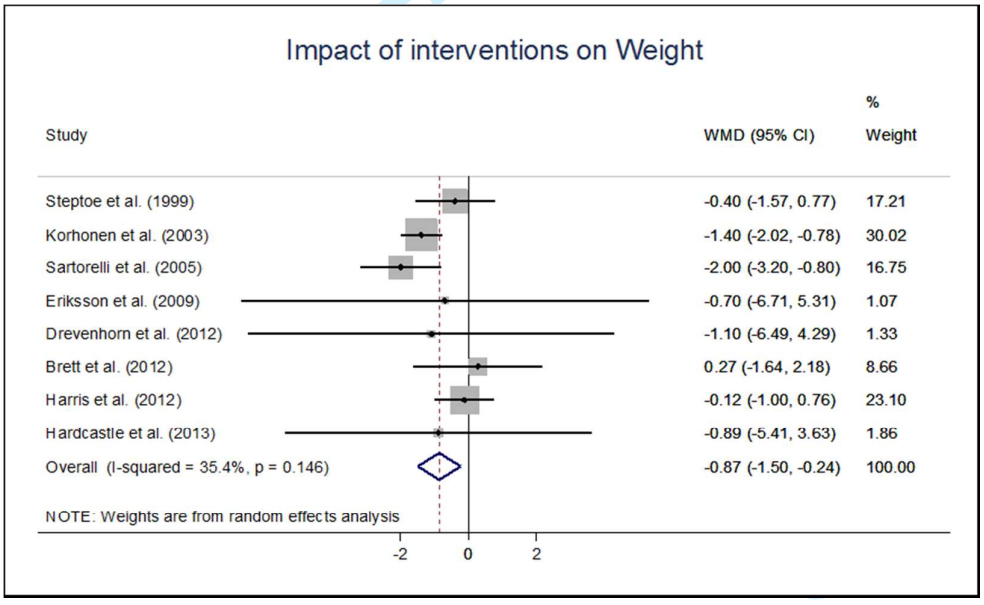
Pooled effect of multiple behaviour interventions on serum total cholesterol (mmol/L). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



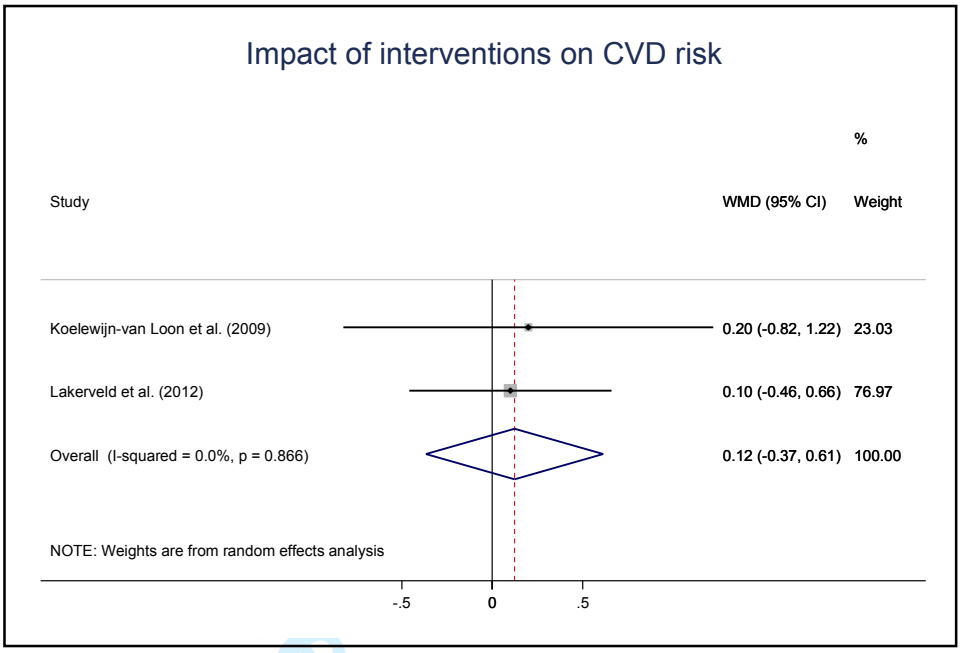
Pooled effect of multiple behaviour interventions on smoking prevalence. Random effects models used. RD= risk difference. 95% CI = 95% confidence intervals.



Pooled effect of multiple behaviour interventions on body mass index (Kg/m^2). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



Pooled effect of multiple behaviour interventions on weight (Kg). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



Pooled effect of multiple behaviour interventions on cardiovascular risk (SCORE). Random effect models used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.

Supplementary table 1: Trial characteristics of included studies.

Study (Year)	Country	Number of Participants	Selection criteria	Targeted behaviours	Follow-up duration	Intervention reported outcomes
Kranjčević, et al. [1]	Croatia	1957	Men and women, aged ≥40.	Diet and PA.	18 months	CVD-risk, weight, BP, cholesterol, smoking, alcohol and PA.
Vetter, et al. [2]	United States	390	Men and women, aged≥21 years, BMI= 30-50kg/m^2, elevated waist circumference.	Diet and PA.	2 years	Weight, BP and cholesterol.
Lakerveld, et al. [3]	Netherlands	622	Men and women, aged: 30-50 years.	Diet, PA and smoking.	12 months	CVD-risk, smoking, diet and PA.
Hardcastle, et al. [4]	United Kingdom	334	Men and women, aged 18-65 years and have at least one CVD risk factor.	Diet and PA.	18 months	Weight, BP, cholesterol, diet and PA.
Tiessen, et al. [5]	Netherlands	201	Men aged: 50-75 years old and women aged: 55-75 years and CVD-risk (SCORE) ≥ 5%.	PA, diet and smoking.	12 months	CVD-risk, weight, BP, cholesterol, smoking and PA.
Parra-Medina, et al. [6]	United States	266	African-American women, aged≥35 years, baseline BP <160/95.	PA and diet.	12 months	Diet and PA.
Drevenhorn, et al. [7]	Sweden	153	Hypertensive patients, men and women aged <75 years, elevated BP, BMI ≥ 25, serum cholesterol ≥ 6.5 and/or serum triglycerides ≥ 2.3 and not reporting regular PA.	Smoking, alcohol, weight, PA and stress	2 years	Weight, BP, cholesterol, alcohol and PA.
Brett, et al. [8]	Australia	1200	Men and women aged 40-80 years, without a history of CVD.	Diet, PA and smoking.	12 months	CVD-risk, weight, BP and cholesterol.
Harris, et al. [9]	Australia	814	Men and women, aged 40-55 years with recorded diagnosis of hypertension and/or hyperlipidaemia or aged 56-64 years.	Diet, PA, smoking and alcohol.	12 months	CVD-risk, weight, BP, cholesterol, smoking, alcohol, diet and PA.
Mendis, et al. [10]	China	1209	Men and women aged 30-70 years with SBP in the range (140-179 mmHg).	Smoking cessation, PA and diet.	12 months	Weight, BP, smoking and diet.
	Nigeria	1188				
Koelewijn-van Loon, et al. [11]	Netherlands	615	One or more of the following: BP≥ 140 or on treatment for high BP; total cholesterol ≥ 6.5 or on treatment for high cholesterol; smoker aged ≥ 50 years (men) or ≥ 55 years (women); diabetes; a family history of CVD; and obese.	Smoking status, diet, PA and alcohol use.	12 months	CVD-risk, BP, cholesterol, smoking, diet and PA.
Eriksson, et al. [12]	Sweden	151	Men and women aged 18–65 years with hypertension, dyslipidaemia, type 2 diabetes or obesity.	Diet and PA.	3 years	Weight, BP, cholesterol, smoking and PA.
Phelan, et al. [13]	United States	224	Men and women aged 18–65 years and BMI of 30–45 kg/m^2.	Diet and PA.	12 months	Weight, BP, cholesterol and diet.

Harting, et al. [14]	Netherlands	1300	Men and women who have a greater than 20% risk (Framingham) of incurring a CVD event within 10 years.	Diet, PA and smoking.	18 months	Smoking, diet and PA.
Korhonen, et al. [15]	Finland	715	Men and women aged 25–74 years, with systolic BP 140–179 and/or diastolic BP 90–109 and/or on treatment for hypertension.	Diet and alcohol (also PA and smoking).	24 months	Weight, BP, cholesterol, alcohol, diet and PA.
Baron, et al. [16]	United Kingdom	368	Men and women aged 25 – 60 years.	Diet mainly, but changes in PA, alcohol and smoking were also mentioned.	12 months	Cholesterol and diet.
Knutsen and Knutsen [17]	Norway	1373 men, 1143 wives	Men aged 20 – 54 years and women aged 20-49 years, with no known CHD at baseline.	Diet changes, PA and smoking cessation.	6 years	CVD-risk, weight, BP, cholesterol, smoking and PA.
Nilsson, et al. [18]	Sweden	86	Men and women, born during the period 1925 – 1952, treated hypertensives.	Diet, smoking, PA and alcohol.	12 months	Weight, BP, cholesterol, smoking and diet.
Wood, et al. [19]	United Kingdom	7460 men, 5012 women	Men aged 40-59 and their families.	Smoking, weight, diet, alcohol, and PA.	12 months	CVD-risk, weight, BP, cholesterol and smoking.
OXCHECK Study Group [20]	United Kingdom	5559	Men and women aged 35-64.	Diet, smoking and PA.	3 years	CVD-risk, weight, BP, cholesterol, alcohol, diet, PA and smoking.
Lindholm, et al. [21]	Sweden	681	Men and women aged 30-59 years, had a moderate hyperlipidaemia, and at least two CVD risk factors.	Diet, smoking and PA.	18 months	CVD-risk, weight, BP, cholesterol, PA and smoking.
Meland, et al. [22]	Norway	127	Men aged 30 to 59 years.	Diet, smoking and PA.	12 months	CVD-risk, BP, cholesterol, PA and smoking.
Avram, et al. [23]	Romania	253	Men and women under 80 years, without history of CVD but defined as high risk individuals.	Diet and PA.	18 months	Weight, alcohol, diet and PA.
Steptoe, et al. [24]	United Kingdom	883	Men and women aged 18 – 69, total cholesterol of 6.5-9; smoker, BMI of 25-35 and lack of regular PA.	Smoking, diet and PA.	12 months	Weight, BP, cholesterol, diet and PA.
Sartorelli, et al. [25]	Brazil	104	Men and women aged 30-65 years, body mass index of 24-35 kg/m^2, and non-diabetic.	Diet and PA.	12 months	Weight, BP, cholesterol, diet and PA.
Ma, et al. [26]	United States	419	Men and women aged 35 to 85 years, had moderately to severely elevated levels of major modifiable CVD risk factors.	PA, diet and stress reduction.	15 months	CVD-risk, weight, BP and cholesterol.
Tibblin and Åberg [27]	Sweden	400	Men and women aged 30 - 69 years, on hypertensive drugs	Diet, PA and stress management.	12 months	Weight, BP and cholesterol.

Note: BMI: body mass index, PA: physical activity, BP: blood pressure, CVD: cardiovascular disease

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Supplementary table 2: Intervention components and behaviour change techniques employed.

Study (Year)	Study groups	Who delivered it	BCTs [1]	Mode of delivery	No. of sessions	Duration of sessions (in mins)
Kranjčević, et al. [1]	Intervention	GPs	1.3, 2.1, 9.1	Face to face and written materials	5	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Vetter, et al. [2]	Intervention 1	PCP and lifestyle coach.	1.1, 1.5, 2.3, 8.7, 9.1	Face to face and written materials	32	Visits: 5-7, counselling: 10-15.
	Intervention 2		1.1, 1.5, 2.3, 8.7, 9.1, 11.1	Face to face and written materials	32	Visits: 5-7, counselling: 10-15.
	Control		1.7	Face to face	8	Visits: 5-7.
Lakerveld, et al. [3]	Intervention	Nurse	1.2, 1.6	Face to face and phone sessions.	9	Face to face sessions: 30.
	Control		4.1, 5.1	Written materials.	Unclear	Unclear
Hardcastle, et al. [4]	Intervention	PA specialist and dietician	1.1, 1.5, 9.2	Face to face.	5	20-30.
	Control		5.1	Written materials.	Unclear	Unclear
Tiessen, et al. [5]	Intervention	Practice nurses.	2.2, 2.3, 2.4, 5.1	Face to face.	7	First session: 20 min, other sessions based on patient preference.
	Control		5.1	Face to face and written materials.	One	Unclear.
Parra-Medina, et al. [6]	Intervention	PCP, health educators and nurses	1.1, 1.2.	Face to face and telephone sessions and written materials.	Up to 15	First session: 60. Following sessions: 20.
	Control		1.1	Face to face and written materials.	One	5-10 mins.
Drevenhorn, et al. [7]	Intervention	Nurses	1.1, 1.5, 5.3, 9.2, 10.4, 11.2	Face to face	Unclear	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Brett, et al. [8]	Intervention	GPs	1.1, 1.3, 2.7	Face to face	5	Unclear
	Control		1.1, 1.3, 2.7	Face to face	2	Unclear
Harris, et al. [9]	Intervention	Health practitioner, dietitian or PT	1.1, 1.2, 2.3, 4.1, 6.1, 9.1	Face to face	6	90 mins/ session.
	Control		Unclear	Unclear	Unclear	Unclear
Mendis, et al. [10]	Intervention	Health-care workers	2.6, 4.1	Face to face and written materials	4	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Koelewijn-van Loon, et al. [11]	Intervention	Nurses	1.1, 1.2, 1.4, 1.5, 5.1, 9.2	Face to face and telephone sessions	3	Face to face: 10-20, telephone: 10.
	Control		5.1	Face to face	One	Unclear
Eriksson, et al. [12]	Intervention	Dietician, PT and assistants.	1.1, 1.2, 1.3, 1.4, 4.1, 5.1, 8.1, 8.7, 9.1, 9.2	Face to face	56	Unclear.
	Control		9.1	Face to face and written materials.	One	Unclear

Phelan, et al. [13]	Intervention 1	PCP	2.3, 11.1.	Face to face and written materials.	8	5-10.
	Intervention 2	Psychologist	1.5, 2.3, 9.1	Group sessions.	29	90
	Intervention 3	Psychologist, PCP	1.5, 2.3, 9.1, 11.1	Face to face, group sessions and written material.	37	Face to face: 5-10, group sessions: 90.
	Intervention 4	PCP	1.5, 2.3, 9.1, 11.1	Face to face and written materials.	8	5-10.
Harting, et al. [14]	Intervention	Practice assistant and dietician.	1.1, 1.4, 9.1, 11.1	Face to face, telephone sessions and written materials.	Unclear	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Korhonen, et al. [15]	Intervention	Healthcare centre personnel.	1.1, 1.3, 1.4, 2.3, 2.5,4.1, 9.1	Face to face.	7	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Baron, et al. [16]	Intervention	Nurse	5.1, 9.1	Face to face, group sessions and written material.	Unclear	30.
	Control		Unclear	Unclear	Unclear	Unclear
Knutsen and Knutsen [17]	Intervention	Physicians and dieticians	1.1, 4.1, 5.1, 6.1, 9.1	Face to face and telephone sessions.	8	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Nilsson, et al. [18]	Intervention	Nurse, dietician or PT.	1.1, 2.2, 3.1, 4.1, 6.1, 9.1, 12.5	Face to face, group sessions and videotapes.	Unclear	Unclear
	Control		2.2, 5.1	Face to face	One	Unclear
Wood, et al. [19]	Intervention	Nurses	1.1, 2.7, 5.1, 6.2, 9.1	Face to face and written materials	Unclear	First session: 90.
	Control		9.1	Face to face	One	45 mins
OXCHECK Study Group [20]	Intervention	Nurses	1.3, 2.7, 9.1,	Face to face	Unclear	Initial session: 45-60, following sessions: 10-20.
	Control		Unclear	None	None	None
Lindholm, et al. [21]	Intervention	Doctors and nurses	2.3, 4.1, 5.1, 6.2, 9.1	Face to face, group sessions and written materials	11	Five group sessions: 90, one group session: all day.
	Control		9.1	Face to face and written materials	5	Unclear
Meland, et al. [22]	Intervention	GPs	1.8, 2.3, 8.7, 9.1, 11.2	Face to face and written materials	4	Unclear
	Control		9.1	Face to face and written materials	4	Unclear
Avram, et al. [23]	Intervention	GPs	1.1, 9.1	Face to face and telephone sessions	21	Face to face sessions: 30.
	Control		Unclear	Written materials	None	None
Steptoe, et al. [24]	Intervention	Nurses	1.1, 1.4, 9.1, 11.1	Face to face and telephone sessions	2-3	Face to face sessions: 20.
	Control		Unclear	Unclear	Unclear	Unclear
Sartorelli, et al.	Intervention	Nutritionist	1.1, 1.4, 9.1	Face to face and group sessions and	4	Unclear

[25]				written materials.		
	Control		Unclear	Group session and written materials	1	Unclear
Ma, et al. [26]	Intervention	Nurses and dietitians	1.1, 1.2, 1.7, 9.1, 11.1, 11.2	Face to face	8-10	30-60
	Control		Unclear	Unclear	Unclear	Unclear
Tibblin and Åberg [27]	Intervention	Nurses and physicians	2.5, 6.1, 9.1	Face to face, group sessions and videotapes and audiotapes.	15	Unclear
	Control		2.5, 9.1	Face to face	15	Unclear

[1] as coded in Michie, Richardson et al.[28] taxonomy of behaviour change technique

Note: 1.1 Goal setting (behaviour); 1.2 Problem solving; 1.3 Goal setting (outcome); 1.4 Action planning; 1.5 Review behaviour goals(s); 1.6 Discrepancy between current behaviour and goal; 2.1 Monitoring of behaviour by others without feedback; 2.2 Feedback on behaviour; 2.3 self-monitoring of behaviour; 2.4 Self-monitoring of outcome(s) of behaviour; 2.5 Monitoring of outcomes of behaviour without feedback; 2.6 Biofeedback; 2.7 Feedback on outcome(s) of behaviour; 3.1 Social support (unspecified); 4.1 Instructions on how to perform a behaviour; 5.1 Information about health consequences; 5.3 Information about social and environmental consequences; 6.1 Demonstration of the behaviour; 6.2 Social comparison; 8.1 Behavioural practice/rehearsal; 8.7 Graded tasks; 9.1 Credible source; 9.2 Pros and cons; 10.4 Social reward; 11.1 Pharmacological support; 11.2 Reduce negative emotions; 12.5 Adding objects to the environment; PT Physiotherapist, PA Physical activity

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Supplementary table 3: Risk of bias assessment.

Study (Year)	Risk of bias					
	Sequence generation (randomisation methods) [a]	Allocation concealment [b]	Blinding of participants to study group allocation [c]	Blinding of trial personnel or outcome assessors [d]	Incomplete outcome data [e]	Selective reporting [f]
Kranjčević, K. et al (2014)	Unclear	Unclear	Unclear	Unclear	High	Low
Vetter et al. (2013)	Low	Low	High	Low	High	Low
Lakerveld et al. (2012)	Low	Low	High	High	High	Low
Hardcastle et al. (2013)	Low	Low	Low	Low	High	Low
Tiessen et al. (2012)	Low	Low	High	High	Unclear	Low
Parra-Medina et al. (2011)	Unclear	Unclear	Low	Low	High	High
Drevenhorn et al. (2012)	Unclear	Unclear	Unclear	Unclear	High	Low
Brett et al. (2012)	Low	High	High	High	Low	High
Harris et al. (2012)	Low	Low	High	Low	Low	Low
Mendis et al. (2010)	Unclear	Unclear	High	High	Low	Unclear
Koelewijn-van Loon et al. (2009)	Low	Low	High	High	High	Low
Eriksson et al. (2009)	Low	Low	High	High	Unclear	Low
Phelan et al. (2007)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Harting et al. (2006)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Korhonen et al. (2003)	High	High	High	Unclear	High	Low
Baron et al. (1990)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Knutsen and Knutsen (1991)	Low	Low	Unclear	Low	Low	Low
Nilsson et al. (1992)	Unclear	Unclear	Unclear	Low	Low	Low
Wood et al. (1994)	Unclear	Unclear	Unclear	Unclear	Unclear	Low
OXCHECK Study group (1995)	Unclear	Unclear	High	Low	Unclear	Low
Lindholm et al. (1995)	Unclear	Unclear	High	Unclear	Low	Low
Meland et al. (1997)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Avram et al. (2011)	Unclear	Unclear	Low	Low	Low	Unclear

Steptoe et al. (1999)	Low	Low	High	High	High	Low
Sartorelli et al. (2005)	Low	Low	Low	High	High	Unclear
Ma et al. (2009)	Low	Low	Low	Low	Unclear	Low
Åberg and Tibblin (1989)	Low	Low	Unclear	Unclear	Low	Unclear

[a] Assessment of whether or not methods used to generate the allocation sequence should produce comparable groups.
[b] Assessment of whether or not the method used to conceal allocation sequence is sufficient or not.
[c] Assessment of the methods used to blind study participants and personnel from knowing intervention allocation.
[d] Assessment of the methods used to blind study outcome assessors from knowing intervention allocation, and whether or not this method of blinding is sufficient.
[e] Assessment of whether incomplete outcome data were adequately dealt with. Studies missing outcome data for >20% of participants who underwent randomization were considered at high risk of bias, while studies missing <10% of participants who underwent randomization were considered at low risk of bias.
[f] Assessment of whether all outcome measures described in the introduction and methods section of the paper (and published protocols) were reported.

Supplementary table 4: Theory use evaluation using Theory Coding Scheme.

Study	**Vetter et al. (2013)**	**Lakerveld et al. (2012)**	**Tiessen et al. (2012)**	**Parra-Medina et al. (2011)**	**Drevenhorn et al. (2012)**	**Harris et al. (2012)**	**Eriksson et al. (2009)**	**Steptoe et al. (1999)**	**Ma et al. (2009)**
Theoretical base	Social cognitive and behavioural self-management theory	Theory of planned behaviour and theory of self-regulation.	Stages of change	Trans-theoretical model and social cognitive theory	Stages of changes model	Stages of change model	Stages of change model	Stages of change model	Social cognitive theory and trans-theoretical model
1) Theory/ model of behaviour mentioned	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
2) Targeted construct mentioned	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
3) Intervention based on single theory	No	No	Yes	No	Yes	Yes	Yes	Yes	No
4) theory used to select recipients	No	No	Yes	No	No	No	No	No	No
5) Theory used to select intervention techniques	Yes	Yes	Do not know	Yes	Yes	No	No	No	No
6) theory used to tailor intervention techniques to recipients	No	No	Do not know	Yes	Yes	Yes	No	No	No
7) All intervention techniques are explicitly linked to theory construct	No	Yes	No	Yes	Yes	No	No	No	No
8) at least one of the intervention techniques are explicitly linked to theory construct	Yes	No	No	No	No	No	No	No	No
9) Group of techniques are linked to a group of constructs	Yes	Yes	No	Yes	Yes	No	No	No	No
10) All theory relevant constructs are explicitly linked to at least one intervention technique.	No	No	No	No	Yes	No	No	No	No
11) At least one of the theory relevant constructs are explicitly linked to at least one intervention technique.	Yes	Yes	No	Yes	No	No	No	No	No
12) theory-relevant constructs are	No	B	No	No	No	No	No	Yes	No

measured									
13) Quality of measures	N/A	A	N/A	No	N/A	N/A	N/A	C and F	N/A
14) Randomization of participants condition	A, B, C and D	A and B	A,B,C and D	A	A and C	A and B	No	N/A	N/A
15) Changes in measured theory-relevant constructs	No	Yes	Do not know	Do not know	No	No	No	N/A	N/A
16) Mediational analysis of constructs	No	No	No	No	No	No	No	N/A	N/A
17) results discussed in relation to theory	No	Yes	No	No	No	No	No	N/A	No
18) Appropriate support for theory	No	No	Do not know	Do not know	No	No	No	N/A	No
19) Results used to refine theory	No	No	No	No	No	No	No	No	No

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Multiple health behaviour change interventions for primary prevention of cardiovascular disease in primary care: systematic review and meta-analysis

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Multiple health behaviour change interventions for primary prevention of cardiovascular disease in primary care: systematic review and meta-analysis

Samah Alageel MPH, Martin C Gulliford FFPH, Lisa McDermott PhD, Alison J. Wright PhD

Department of Primary Care and Public Health Sciences, King's College London

Correspondence: **Samah Alageel**
Department of Primary Care and Public Health Sciences,
Faculty of Life Sciences and Medicine.
King's College London, Addison House, Guy's Campus,
London SE1 1UL, United Kingdom
Email: samah.alageel@kcl.ac.uk
Tel: 0207 848 6631
Fax: 0207 848 6620

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ABSTRACT

Background: It is uncertain whether multiple health behaviour change interventions (MHBC) are effective for the primary prevention of cardiovascular disease (CVD) in primary care. A systematic review and meta-analysis were performed to evaluate the effectiveness of MHBC interventions on CVD-risk and CVD risk factors; the study also evaluated associations of theoretical frameworks and intervention components with intervention effectiveness.

Methods: The search included randomised controlled trials of MHBC interventions aimed at reducing CVD-risk in primary prevention population up to 2017. Theoretical frameworks and intervention components were evaluated using standardised methods. Meta-analysis with stratification and meta-regression were used to evaluate intervention effects.

Results: We identified 31 trials (36,484 participants) with a minimum duration of 12 months follow-up. Pooled net change in systolic blood pressure (16 trials) was -1.86 (95% confidence interval -3.17 to -0.55, P= 0.01) mm Hg, diastolic blood pressure (15 trials) -1.53 (-2.43 to -0.62, P= 0.001) mm Hg, body mass index (14 trials) -0.13 (-0.26 to -0.01, P= 0.04) Kg/m^2 and serum total cholesterol (14 trials) -0.13 (-0.19 to -0.07, P <0.001) mmol/L. There was no significant association between interventions with a reported theoretical basis and improved intervention outcomes. No association was observed between intervention intensity (number of sessions and intervention duration) and intervention outcomes. There was significant heterogeneity for some risk factor analyses, leading to uncertain validity of some pooled net changes.

Conclusions: MHBC interventions delivered to CVD-free participants in primary care did not appear to have quantitatively important effects on CVD risk factors. Better reporting of interventions' rationale, content and delivery is essential to understanding their effectiveness.

Key words: Cardiovascular Diseases, Health Behaviour, Primary Health Care, Meta-analysis, Primary Prevention, Risk Factors.

Strengths and limitations:

- The review presents evidence of head to head meta-analysis of 31 published randomised controlled trials of MHBC interventions and cardiovascular risk with follow-up for 12 months or longer.
- The study employed standardised instruments to evaluate the impact of theory use and behaviour change techniques in MHBC interventions.
- The majority of trials included were conducted in Europe and United States and only English language publications were included.
- Not all studies evaluated all outcomes of interest and some lacked detail concerning intervention design and delivery.

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death worldwide, accounting for over 30% of global mortality [1]. CVD is mediated by several antecedent behavioural risk factors, and its onset might be prevented or delayed by altering one or several risk factors [1]. Risk factors for CVD are inter-related and often coexist [2-4]. This observation has informed the development of multiple health behaviour change (MHBC) interventions for reduction of CVD-risk. Identifying individuals at high-risk of CVD in primary care, and encouraging lifestyle change to reduce risk factors, represents a widely used strategy for the primary prevention of cardiovascular diseases. Randomised controlled trials have been conducted in primary care to evaluate the effectiveness of MHBC interventions using lifestyle modification techniques instead of, or in addition to, pharmacological treatment to modify CVD risk factors. These trials have generally provided only equivocal evidence for reduction of CVD incidence through MHBC but the degree of effectiveness might be associated with level of risk [5-7]. Results from Ebrahim et al.'s [5] systematic review suggested that MHBC interventions have negligible effect on mortality in unselected populations, with a pooled odds ratio for coronary heart disease mortality of 0.99 (95% CI 0.92 to 1.07). Evidence of benefit was found in studies in high-risk populations including people with hypertension (OR 0.78, 0.68 to 0.89) or diabetes (OR 0.71, 0.61 to 0.83) [5]. However, general health checks were not found to reduce all cause-mortality, nor CVD- or cancer-related morbidity and mortality [8].

Previous reviews have assessed the effectiveness of MHBC interventions in reducing CVD morbidity and mortality [5 6 8], less is known about the effectiveness of these interventions in reducing CVD-risk and risk factor values in primary care.

In recent years, there has been growing appreciation of the role of employing psychological theory in behaviour change intervention design, and studying the impact of specific behaviour change techniques (BCT) on intervention outcomes [9]. Theories of the psychological determinants of behaviour can be used to inform the development and evaluation of behaviour change interventions [10]. Interventions are likely to be more effective when they systematically target psychological determinants of behaviour[11]. A review of internet-based interventions suggested that more intensive use of theory was associated with greater behaviour change [12], but another review found little evidence of an association between theory use and intervention effects on healthy eating or physical activity [13]. This equivocal evidence could arise if a high proportion of behaviour change interventions are not based on a theory or the theory is not applied extensively [14].

Behaviour change techniques (BCT) are 'the active components of an intervention designed to change behaviour' [15]. Identifying specific BCTs associated with greater impact on intervention effectiveness is essential for future intervention design [16]. Previous reviews suggested that interventions using the BCTs "provision of instructions," "self-monitoring of behaviour," "relapse prevention," and "prompt practice" led to greater reductions in weight among obese individuals [17], while interventions designed to modify physical activity and/or diet were more effective when they included self-monitoring plus one of the four following behaviour change techniques: prompting intention formation, specific goal setting, review of behavioural goals or providing feedback on performance[18]. Identifying BCTs associated with greater intervention effectiveness and exploring the impact of applying theory will contribute to the design of future MHBC interventions targeting CVD risk in primary care.

Objectives

This systematic review had three objectives: first, to assess the effectiveness of MHBC interventions, directed at changing two or more behaviours, at reducing CVD-risk and CVD risk factors in adults without existing cardiovascular conditions; secondly, to evaluate whether using theory to develop interventions is associated with intervention effectiveness; and thirdly, to evaluate the association between behaviour change techniques employed and intervention effects.

METHODS

Studies were selected according to the following criteria:

Participants

Trials that recruited an adult population (>18 years old) free of CVD were included. Following previous reviews [5], we included trials with less than 20% participants with CVD. Studies of patient populations with established disease, such as diabetes, were excluded.

Interventions

We included studies that evaluated behaviour change interventions aimed at reducing CVD-risk by intervening on two or more risk behaviours at the same time. Risk behaviours included: physical activity, diet, alcohol consumption, use of stress management and smoking. Comparators were usual care or less intensive interventions.

Settings

Interventions where participants were recruited, and interventions were delivered by trained healthcare professionals or primary care staff, in primary care premises (including general practice, family practice or primary care clinic).

Study design

Controlled trials, with individual or cluster randomisation, providing ≥12 month follow-up for outcome evaluation.

Outcome measures

Long term outcomes of MHBC interventions including CVD mortality and clinical events have been reported previously [5 6] and only one study in 2015 included clinical events as an outcome. Therefore long term outcomes were not included in this systematic review. Primary outcomes were changes in CVD-risk scores, body mass index (BMI) or body weight, blood pressure, and serum total cholesterol levels. We have excluded diabetes management trials, therefore, diabetes control outcomes were not included. Secondary outcomes were changes in physical activity, diet, smoking and alcohol consumption.

Language

Studies reported in English.

Search strategy

Multiple sources of ascertainment were used, including electronic databases (Medline, EMBASE, PsycINFO and CENTRAL) and searching reference lists of included papers. The search results and search terms of previous review [5] were used with searching extended from 2006 until February 2017. Search terms used included primary prevention, multiple risk factor, lifestyle intervention, health education and health promotion. Appendix A presents the search strategies used. Titles were screened by one reviewer (SA) and a second reviewer (MG) checked a random set of studies, approximately 10% of the search results, to assess agreement regarding whether they met the inclusion criteria. Disagreements were resolved through discussion, until full agreement was reached. The selection process is displayed in Figure 1.

Methodologic quality

Studies were evaluated using the Cochrane risk of bias tool [19]. This assesses six domains of bias including selection bias, performance bias, detection bias, attrition bias, reporting bias and other biases [19].

Data extraction

Interventions were coded by country, target behaviours, participant and intervention characteristics, mode of delivery and intervention outcomes. We attempted to contact study authors to provide additional information where necessary However, when information was not available, we assumed missing outcome data to occur at random.

In addition, Michie and Prestwich's [20] method of assessing the application of theory in the development and evaluation of behaviour change interventions was used. The Theory Coding Scheme (TCS) consists of 19 items that cover different aspects that may be informed by theory [20]. We used three measures to capture the extent of theory use, as employed in a previous review[13]: The first concerned whether the intervention was explicitly based on a theory or combination of theories or predictors (TCS item 5). Secondly, we assessed the degree to which each BCT reported as part of the intervention was linked to a theory-relevant construct (scored +2 for the ideal scenario of "yes" to TCS item 7 (all intervention techniques explicitly linked to at least one theory-relevant construct), +1 for studies coded "yes" for TCS item 8 (at least one, but not all, intervention techniques explicitly linked to at least one theory-relevant construct) and/or TCS item 9 (group of BCTs are linked to a group of constructs) and 0 for studies coded "no" for all of items 7-9. Finally, we rated the extent to which all constructs in the relevant theory had been explicitly targeted by BCTs. This was scored +2 for the ideal scenario of "yes" to TCS item 10 (all theory-relevant constructs explicitly linked to at least one BCT), +1 for "yes" to TCS item 9 (group of BCTs are linked to a group of constructs) and/or item 11 (at least one, but not all, theory relevant

constructs are explicitly linked to at least one BCT) and 0 for interventions coded "no" to all of items 9-11.

The theory-based taxonomy of 93 behaviour change techniques developed by Michie, Richardson et al.[9] was used to identify intervention techniques. The assessment was completed by two researchers (LM and SA) with good agreement for intervention groups (77.8% agreement) and control groups (92.6% agreement). Discrepancies were discussed and resolved to reach full agreement. Intervention characteristics and BCTs were also extracted from descriptions of the control group, because the chosen nature of the control group can influence the apparent effectiveness of interventions [21]. Where detail of interventions was lacking, we attempted to contact study authors to provide additional information.

Data analysis

Outcome data were combined in random effects meta-analyses using 'metan' commands in STATA. DerSimonian and Laird [22] random effect models were chosen due to the considerable heterogeneity for certain outcomes. For continuous outcomes we used mean changes in each trial arm to calculate net effects. We expressed effects for binary variables as risk differences. We quantified statistical heterogeneity using I^2 statistic. We have examined the influence of individual studies in outcomes with considerable heterogeneity (I^2>50%) by omitting one study at a time to see the extent to which heterogeneity could be explained by a study or group on studies (leave-one-out analysis).

Meta-regression analyses were used to examine the effect of medication use, number of interventions' sessions, intervention duration, types of BCTs used and theory use on intervention outcomes. Intervention duration was calculated by multiplying the number of sessions and the sessions' duration. Publication bias was assessed using Egger's

regression test [23] using 'metabias' and 'metafunnel' commands in STATA. If bias existed, the "trim and fill"[24] method was used to adjust for publication bias. Mendis et al [25] Nigeria site's study had unusually high summary estimates, and heterogeneity diminished substantially after this study was excluded. This study was therefore treated as an outlier and results were reported with the exclusion of this study.

RESULTS

The initial search identified 26656 references, with 55 relevant trials identified from the previous systematic review [5]. After removing duplicates, 21089 titles were screened. A total of 31 trials were included in this review (Figure 1).

Included studies

We identified a total of 31 trials of MHBC intervention for the primary prevention of CVD in primary care with 36484 participants. The duration of follow-up ranged from 12 months to 6 years (median 12 months). Intervention duration ranged from two months up to three years (median 12 months). Summary of included studies characteristics are presented in table 1 and supplementary table 1.

Table 1: Summary of characteristics of 27 trials included in the review. Figures are frequencies (column percent).

Characteristics		Freq. (%)
Total		31 (100)
Country	UK	6 (19.4%)
	Sweden	5 (16.1%)
	Netherlands	4 (12.9%)
	USA	4 (12.9%)
	Europe	7 (22.6%)
	Others	5 (16.1%)
Number of participants	Median (IQR)	419 (224-883)
Gender	Male only	1 (3.2)
	Female only	1 (3.2)
	Both	29 (93.5)
Age	Minimum age, median (IQR)	30 (20-40)
	Maximum age, median (IQR)	65 (60-74)
Intervention outcomes	CVD risk	14 (45.2)
	Body weight	25 (80.6)
	Blood pressure	26 (83.9)
	Serum cholesterol	26 (83.9)
	Diet	18 (58.1)
	Physical activity	21 (67.7)
	Alcohol	6 (19.4)
	Smoking	15 (48.4)
Number of targeted behaviours	2 behaviours	11 (35.5)
	3 behaviours	12 (38.7)
	4 behaviours	7 (22.6)
	5 behaviours	1 (3.2)
Follow-up duration	12 months	18 (58.1)
	>12 months	13 (41.9)

CVD, cardiovascular disease; IQR, interquartile range

Study characteristics

Diet and physical activity were targeted in 11 trials, with nine trials targeting diet, physical activity and smoking. Diet, physical activity, smoking and alcohol consumption were targeted in seven interventions and two interventions targeted diet, physical activity and stress management. Only one intervention targeted diet, physical activity, stress and alcohol consumption and one intervention targeted all five behaviours. A wide range of intervention modalities was investigated (Table 2 and supplementary table 2), including individual and group sessions, telephone conversations and provision of written materials. The majority of the included trials reported offering “usual care” to the control group, with few details provided. Seven trials offered face-to-face sessions and seven trials offered face-to-face sessions and written materials. Written materials alone were offered in three trials and no intervention was offered to the control group in three interventions.

Table 2: Summary of interventions characteristics for 27 trials included in the review. Figures are frequencies (column percents)

		Intervention N (%)	Control N (%)
Type of staff delivering intervention	GPs and physicians	10 (32.3)	
	Nurses	15 (48.4)	
	Dietitian	7 (22.6)	
	Others	12 (38.7)	
Mode of intervention delivery	Face to face sessions	30 (96.8)	14 (45.2)
	Group sessions	9 (29.0)	1 (3.2)
	Written materials	15 (48.4)	7 (22.6)
	Telephone sessions	8 (25.8)	-
	Unclear	-	13 (41.9)
Number of intervention sessions	1-4 sessions	5 (16.1)	9 (29.0)
	5-9 sessions	11 (35.5)	2 (6.5)
	10-15 sessions	4 (12.9)	1 (3.2)
	>15 sessions	5 (16.1)	1 (3.2)
	Unclear	6 (19.4)	18 (58.1)
Number of behaviour change techniques (BCT)	1-2 BCTs	5 (16.1)	14 (45.2)
	3-4 BCTs	10 (32.3)	1 (3.2)
	5-6 BCTs	12 (38.7)	-
	7-9 BCTs	3 (9.7)	-
	10 BCTs	1 (3.2)	-
	Unclear	-	16 (51.6)
Frequently used behaviour change techniques	Credible source (9.1)	22 (70.9)	6 (19.4)
	Goal setting (behaviour) (1.1)	19 (61.3)	2 (6.5)
	Information about health consequences (5.1)	9 (29.0)	5 (16.1)
	Instruction on how to perform a behaviour (4.1)	9 (29.0)	1 (3.2)
	Action planning (1.4)	9 (29.0)	-
	Self-monitoring of behaviour (2.3)	8 (25.8)	-

Risk of bias in included studies

Risk of bias assessment is presented in supplementary table 3. Half of the included trials (n=16) reported using intention-to-treat (ITT) analysis, while 15 studies did not state ITT procedures. Loss to follow-up ranged from 1.5% to 50.9%. Random allocation methods were not usually reported. In only 14 out 31 trials the method used was considered adequate. It is not possible to blind participants and personnel to treatment allocation in lifestyle intervention, which raises the possibility of bias inevitably. Only 5 trials have reported blinding of participants and personnel. Eleven trials have reported blinding outcomes assessors to treatment allocation, this too makes the assessment of outcomes likely biased (e.g. self-reported outcomes). Not all trials reported sufficient detail to assess risk of bias and these were rated as 'unclear'.

Treatment fidelity

Few studies reported using fidelity checks [26-30] to confirm that interventions were delivered as intended and this raises a question of whether the interventions were delivered as planned, and in a consistent manner.

Effect of interventions

Pooled effect sizes for all outcomes are presented in Table 3 and forest plots are presented in Appendix B.

Table 3: Pooled effects from meta-analysis of multiple health behaviour interventions on CVD-risk and CVD risk factors.

Outcome	N	Pooled effect size		95% confidence interval	P value	I^2 (%)	P value for heterogeneity	Tau^2
Systolic blood pressure (mmHg)	16		-1.86	-3.17 to -0.55	0.01	63.0	<0.001	3.91
Systolic blood pressure (mmHg)	10	Medication	-2.59	-4.48 to -0.69	0.01	68.3	0.001	5.31
by medication use	6	None [a]	-0.55	-1.69 to 0.59	0.35	3.4	0.40	0.09
Diastolic blood pressure (mmHg)	15		-1.53	-2.43 to -0.62	0.001	68.3	<0.001	1.92
Diastolic blood pressure (mmHg)	10	Medication [a]	-1.96	-2.79 to -1.11	<0.001	42.5	0.07	0.66
by medication use	5	None	-0.78	-2.50 to 0.93	0.37	73.0	<0.001	2.97
Serum total cholesterol (mmol/L)	14		-0.13	-0.19 to -0.07	<0.001	20.3	0.22	0.0
Serum total cholesterol (mmol/L)	8	Medication	-0.15	-0.26 to -0.03	0.01	43.8	0.09	0.01
by medication use	6	None [a]	-0.11	-0.18 to -0.03	0.01	0.0	0.60	0.0
Smoking (%)	11		-0.00	-0.02 to 0.01	0.66	13.4	0.31	0.0
Body mass index (Kg/m^2)	14		-0.13	-0.26 to -0.01	0.04	0.0	0.82	0.0
Body weight (Kg)	10		-0.91	-1.39 to -0.43	<0.001	12.1	0.33	0.08
CVD-risk using SCORE (%)	2		0.12	-0.37 to 0.61	0.61	0.0	0.87	0.0
Systolic blood pressure (mmHg)	5	Theory	-2.18	-5.92 to 1.56	0.25	72.3	0.01	13.0
by theory use	11	None [b]	-1.69	-3.01 to -0.29	0.02	61.3	<0.01	3.01
Diastolic blood pressure (mmHg)	5	Theory	-1.25	-2.43 to -0.06	0.04	0.4	0.40	0.01
by theory use	10	None [b]	-1.67	-2.83 to -0.52	<0.001	76.9	<0.001	2.42
Serum total cholesterol (mmol/L)	4	Theory	-0.03	-0.15 to 0.10	0.68	0.0	0.48	0.0
by theory use	10	None [b]	-0.13	-0.20 to -0.07	<0.001	0.0	0.29	0.0
Body mass index(Kg/m^2) by	5	Theory	-0.15	-0.41 to 0.10	0.24	0.0	0.96	0.0
theory use	9	None [b]	-0.13	-0.28 to 0.02	0.10	0.0	0.44	0.0
Body weight by (Kg) theory use	4	Theory	-0.24	-0.94 to 0.45	0.49	0.0	0.97	0.0
	8	None [b]	-1.32	-1.80 to -0.83	<0.001	0.0	0.53	0.0

N, number of trials; I^2, index of heterogeneity; a, medication use is not reported; b, theory use is not reported.

Changes in CVD risk factors

Blood pressure: Sixteen trials [25 27 31-44] reported changes in participants' systolic blood pressure (SBP) with no evidence of publication bias (Egger's test, P= 0.79). The weighted mean difference in SBP was -1.86 mm Hg (95% CI -3.17 to -0.55 mm Hg; P= 0.01). Diastolic blood pressure (DBP) was reported in 15 trials [25 27 31-33 35-44], with no evidence of publication bias (Egger's test, P= 0.19). Weighted mean difference in DBP was -1.53 mmHg (-2.43 to -0.62 mm Hg; P= 0.001). Out of the 12 interventions that evaluated blood pressure, seven reported that participants in all study groups were taking antihypertensive medications and three reported they were taking unspecified medications. There is no significant differences between the impact of trials that reported use of medication on SBP (β=-1.72, P= 0.23) and DBP (β= -1.46, P=0.12) compared to trials that did not report using medications.

Serum total cholesterol: Fourteen trials [27 31-33 35-37 39-45] evaluated serum total cholesterol and provided sufficient data for analysis (Egger's test, P= 0.55). Serum total cholesterol levels showed a small decrease in favour of intervention (-0.13 mmol/L; 95% -0.19 to -0.07; P<0.001). Six of the trials included in the analysis reported the use of lipid lowering medication and two reported the use of unspecified medication by all study groups. The weighted mean difference for total cholesterol was not different between trials that reported using medication and trials that have not stated using medications (β= 0.01, P=0.75) (Table 3).

Smoking: Eleven studies [25 26 29-32 34 37 44 46 47] reported smoking prevalence following the intervention. The pooled analysis showed no evidence of reductions in smoking behaviour (RD -0.00%; 95% CI -0.02 to 0.01; P=0.66). All studies included in the analysis relied on

self-reported smoking status and only two [29 44] reported using smoking cessation medication. There was no evidence of publication bias (P=0.47).

Weight and body mass index (BMI): Fourteen studies [25 27 31 33 35-44] reported on BMI as an outcome. The weighted mean change was -0.13 kg/m^2 (95% CI -0.26 to -0.01; P=0.04). The results of "trim and fill" method indicated that the weighted mean did not change despite the existence of publication bias (Egger's test P=0.002). Fewer studies (n=12) [27 33 35-37 40-44 47 48] reported on weight changes, showing a reduction of -0.91 kg (CI -1.39 to -0.43 kg; P< 0.001) with no evidence of publication bias (P=0.97).

Dietary behaviour: Sixteen trials [25-30 33 34 42-45 47-50] reported dietary behaviours as an outcome of the interventions. Outcomes of dietary interventions were measured using diverse methods, therefore, a meta-analysis was not conducted. Trials used a range of dietary self-report instruments to assess dietary behaviour, and none have used additional objective measures. Fruit and vegetable consumption was reported either as portions per day [25-27 43 47 50], or proportion of participants who met the recommendation for fruits and vegetable intake [26 33 34]. There was no positive effect of the intervention on fruits and vegetable consumption in most of the trials [26 27 34 47], and some trials did report improvement following the intervention [33 43 50], Fat intake was commonly measured as a dietary outcome either in terms of fat intake per day, [27 33 48 49] or as a fat score [29 34]. All the trials reported reductions in fat intake after the intervention, except Koelewijn-van Loon et al.[34] trial, where there was no significant difference between the intervention and control group.

Physical activity behaviour: Twenty trials reported changes in physical activity [26-34 36 37 39 40 42-44 46 47 50 51]. Physical activity was assessed via self-report. Due to the variety of measurements used, meta-analysis was not feasible. Some trials reported physical activity

as the proportion of participants who are physically active [29 31 39 46 50]. Other studies measured physical activity as the number of minutes per week, [27 34 42 43] or classified participants based on their weekly exercise [26 28 44 50]. Eight of these trials [27 29 30 36 37 40 42 44 47 50] resulted in an increase in reported physical activity following the intervention, and nine [26 28 31-33 39 43 46 48 51] trials concluded that the intervention had no impact on physical activity.

Alcohol consumption: Alcohol consumption was reported as an outcome in seven trials [30 34 40 46-48 50]. However, it was measured differently, which did not allow for pooled effect analysis. Two trials [40 46] reported reductions in alcohol consumption following the interventions, whereas the majority of the studies [30 34 47 48 50] did not find significant reductions in alcohol intake.

Cardiovascular disease risk: Studies used different risk scores to examine the effect of interventions on CVD-risk. Two studies [38 51] used the Framingham risk equation [52], two studies [30 53] used the Dundee risk score [54] and one study[44] used QRISK2 score[55]. These trials reported larger CVD-risk reductions in the intervention group compared to the control group. All of these trials had missing data making it not possible to analyse the pooled effect. Four studies [26 34 39 46] used the SCORE risk equation [56], however because of missing data we only included two studies [26 34] in the analysis, both conducted in the Netherlands. There was a non-significant increase in weighted mean difference of 0.12% CVD-risk (95% CI -0.37 to 0.61; P= 0.62).

Sensitivity analysis:

In outcomes of considerable heterogeneity (I^2>50%) we sought to identify possible causes by exploring the effect of included studies using leave-one-out sensitivity analysis. The absence of study Mendis et al. (China site) [25] and Koelewijn-van Loon, et al. [34] in analysing

the impact of interventions of systolic blood pressure reduces heterogeneity from I^2= 63% to I^2= 49.4% and generated a weighted mean difference (-1.86; CI -3.17 to -0.54; P=0.001) similar to the one obtained with all 16 trials. For diastolic blood pressure, removing Knutsen and Knutsen [31] from the analysis have resulted in reducing heterogeneity from I^2= 68.3% to I^2= 37.8% and produced a larger weighted mean difference (-1.93; CI -2.69 to -1.18; P<0.001).

Intervention components:

Intervention time and number of sessions: The number of sessions was reported in 24 trials, ranging from three to 56 sessions (median=6 sessions). No significant associations were detected between the number of sessions and SBP (β= -0.17, P=0.15), DBP (β= -0.15, P= 0.08), BMI (β= -0.01, P=0.57) and weight (β= 0.02, P=0.68). Interventions with more sessions were associated with slight reductions in serum total cholesterol (β=-0.01, P= 0.02). Thirteen of the included trials provided enough details to calculate intervention delivery duration, which ranged from 45 mins to 2.5 hrs (median=300 mins). No significant associations were detected between intervention duration and SBP (β=-0.00, P=0.26), DBP (β=-0.00, P= 0.45), BMI (β= -0.00, P= 0.53) and weight (β= -0.00, P=0.55). Hence, more sessions and longer intervention duration were not necessarily associated with greater intervention effectiveness.

Theory use: Of the 31 trials included, nine reported some use of psychological theory (or a combination of two theories) in relation to the intervention. The Transtheoretical Model [57] was used in eight trials [27 28 36-40 47], while Social Cognitive Theory [58] was used in four [27 28 38 59] interventions.

We tested the extent of theory use using Theory Coding Scheme (TCS) [20] in three ways (supplementary table 4). The first method was based on the use of theory in selecting intervention techniques (item 5 in TCS). Only four trials were coded yes for this item. The

second method was used to reflect the extent to which reported BCTs were linked to theory-relevant constructs (items 7 to 9). Only four trials were coded yes to at least one of these items. The third method was used to reflect the extent to which all theory-relevant constructs were targeted by BCTs (items 9 to 11). Only four trials were coded yes to at least one of these items. Therefore, we were not able to examine the impact of differing levels of theory use on intervention outcomes due to the small number of trials using theory extensively. However, we were able to test whether studies that merely reported using a theory had greater impact on outcomes using meta-regression. There was no significant association between studies which reported using a theory and SBP (β= -0.13, P= 0.89), DBP (β= -0.37, P= 0.73), and BMI (β= -0.03, P= 0.87). Studies that reported using a theory had increased weight (β= 1.07, P= 0.03, CI= 0.11, 2.04) and serum total cholesterol outcomes (β= 0.19, P= 0.04) compared to studies that did not report using a theory.

Effectiveness of specific behaviour change techniques: The number of behaviour change techniques (BCTs) in the intervention group varied, ranging from two to ten BCTs (median= 5). Behaviour change techniques in the control group were generally poorly described as the majority of trials (n= 16) did not appear to offer any BCTs.

Twenty nine different BCTs were identified from the included trials (supplementary table 2). The most commonly used BCTs in the intervention group were 'credible source' and 'Goal setting (behaviour)', which were used in 22 and 19 trials respectively. In the control group, 'Credible source' and 'Information about health consequences' were most commonly used, which were used in six and five interventions respectively.

We tested the potential impact of using specific BCTs on intervention outcomes (table 4). For SBP, one BCT had a significant influence on effect sizes. Interventions employing 'Review of behaviour goal(s)' resulted in an increase in SBP (β=3.45, P= 0.04) compared with those not using this BCT. For DBP and total cholesterol, there were no BCTs

significantly associated with the effectiveness of the interventions. The same was the case for BMI, but for weight, interventions that included 'Action planning' resulted in greater reductions than those that did not (β= -1.10, P= 0.04).

Table 4: Meta-regression results of intervention effects for studies using or not using particular behaviour change techniques.

Outcome	BCT	BCT included			BCT not included					
		MD	CI	N	MD	CI	N	β	CI	P
Systolic blood pressure	1.1 Goal setting (behaviour).	-1.12	-2.49 to 0.25	11	-3.87	-5.07 to -2.67	5	2.79	-0.19 to 5.78	0.07
	1.2 Problem solving.	-3.19	-9.21 to 2.83	3	-1.69	-2.99 to -0.39	13	-0.98	-5.12 to 3.16	0.62
	1.3 Goal setting (outcome).	-3.01	-6.99 to 0.97	3	-1.65	-3.12 to -0.18	13	-1.11	-4.95 to 2.73	0.55
	1.4 Action planning.	-2.84	-5.29 to -0.39	7	-1.39	-3.01 to 0.23	9	-1.39	-4.54 to 1.76	0.36
	1.5 Review behaviour goal(s)	**0.93**	**-2.10 to 3.95**	**4**	**-2.49**	**-3.82 to -1.16**	**12**	**3.45**	**0.13 to 6.76**	**0.04**
	4.1 Instruction on how to perform the behaviour.	-2.77	-4.89 to -0.68	5	-1.23	-2.89 to 0.44	11	-1.53	-4.53 to 1.47	0.29
	5.1 Information about health consequences.	-0.70	-2.13 to 0.73	5	-2.59	-4.43 to -0.76	11	1.75	-1.15 to 4.65	0.22
	9.1 Credible source.	-2.75	-4.34 to -1.17	9	-0.43	-2.81 to 1.96	7	-2.47	-5.51 to 0.58	0.10
	9.2 Pros and cons.	0.16	-3.89 to 4.20	4	-2.31	-3.59 to -1.02	12	2.67	-0.84 to 6.18	0.13
	11.2 Reduce negative emotions.	-3.52	-4.93 to -2.11	4	-1.05	-2.46 to 0.37	12	-0.22	-5.48 to 5.03	0.93
Diastolic blood pressure	1.1 Goal setting (behaviour).	-1.18	-2.31 to -0.04	10	-3.37	-3.78 to -0.96	5	1.35	-0.89 to 3.60	0.22
	1.4 Action planning.	-2.17	-4.13 to -0.20	6	-1.28	-2.30 to -0.25	9	-0.82	-3.02 to 1.38	0.44
	2.3 Self-monitoring of behaviour.	-1.29	-3.03 to 0.46	3	-1.58	-2.60 to -0.55	12	0.18	-2.73 to 3.08	0.89
	4.1 Instruction on how to perform the behaviour.	-1.12	-2.80 to 0.56	5	-1.84	-2.77 to -0.91	10	0.87	-1.17 to 2.91	0.38
	5.1 Information about health consequences.	-0.64	-2.52 to 1.24	4	-1.92	-2.79 to -1.05	11	1.46	-0.53 to 3.46	0.14
	9.1 Credible source.	-1.85	-3.44 to -0.26	9	-1.29	-1.91 to -0.68	6	-0.37	-2.51 to 1.77	0.72
	9.2 Pros and cons.	-1.46	-3.05 to 0.13	3	-0.93	-1.46 to 0.12	12	0.04	-2.73 to 2.80	0.98
	11.2 Reduced negative emotions.	-2.98	-4.71 to -1.25	4	-1.25	-2.25 to -0.25	11	-1.78	-4.46 to 0.89	0.17
Serum total cholesterol	1.1 Goal setting (behaviour).	-0.11	-0.17 to -0.5	9	-0.17	-0.34 to -0.01	5	0.09	-0.08 to 0.26	0.29
	1.3 Goal setting (outcome).	-0.21	-0.45 to 0.02	3	-0.10	-0.16 to -0.03	11	-0.12	-0.27 to 0.03	0.11
	1.4 Action planning.	-0.15	-0.34 to 0.05	6	-0.12	-0.18 to -0.06	8	-0.05	-0.22 to -0.12	0.52
	4.1 Instruction on how to perform the behaviour.	-0.18	-0.19 to -0.07	4	-0.10	-0.17 to -0.04	10	-0.09	-0.25 to 0.06	0.20
	5.1 Information about health consequences.	-0.11	-0.18 to -0.07	5	-0.15	-0.28 to -0.03	9	0.07	-0.08 to -0.22	0.35
	9.1 Credible source.	-0.12	-0.21 to -0.04	9	-0.14	-0.22 to -0.05	5	-0.00	-0.18 to 0.17	0.96
	9.2 Pros and cons.	-0.07	-0.31 to 0.16	3	-0.14	-0.20 to -0.07	11	0.05	-0.18 to 0.28	0.64
Body mass index	1.1 Goal setting (behaviour).	-0.24	-0.42 to -0.05	10	-0.03	-0.21 to 0.15	4	-0.20	-0.49 to 0.08	0.14
	1.3 Goal setting (outcome).	-0.09	-0.50 to 0.32	3	-0.14	-0.27 to -0.00	11	0.05	-0.42 to 0.52	0.83

	1.4 Action planning.	-0.32	-0.61 to -0.04	6	-0.09	-0.23 to 0.06	8	-0.24	-0.59 to 0.11	0.17
	1.5 Review behaviour goal(s)	-0.66	-1.51 to 0.20	3	-0.12	-0.25 to 0.01	11	-0.54	-1.48 to 0.41	0.25
	4.1 Instructions on how to perform the behaviour.	-0.07	-0.23 to 0.09	5	-0.24	-0.45 to -0.03	9	0.17	-0.12 to 0.46	0.23
	5.1 Information about health consequences.	-0.13	-0.36 to 0.10	4	-0.14	-0.29 to 0.02	10	0.01	-0.29 to 0.31	0.96
	9.1 Credible source.	-0.24	-0.43 to -0.06	8	-0.03	-0.21 to 0.15	6	-0.21	-0.49 to 0.07	0.13
	9.2 Pros and cons.	-0.47	-1.29 to 0.34	3	-0.13	-0.26 to 0.01	11	-0.35	-1.25 to 0.55	0.42
	11.2 Reduce negative emotions.	-0.33	-0.79 to 0.14	3	-0.12	-0.25 to 0.02	11	-0.21	-0.74 to 0.32	0.41
Weight	1.3 Goal setting (outcome)	-1.02	-1.73 to -0.31	4	-0.83	-1.53 to -0.12	8	-0.17	-1.33 to 0.99	0.75
	1.4 Action planning.	**-1.27**	**-1.74 to -0.79**	**7**	**-0.17**	**-0.94 to 0.58**	**5**	**-1.10**	**-2.11 to -0.09**	**0.04**
	1.5 Review behaviour goal(s)	-1.67	-4.77 to 1.40	3	-0.86	-1.42 to -0.29	9	-0.82	-4.41 to 2.77	0.62
	2.3 Self-monitoring of behaviour.	-0.91	-2.13 to 0.31	3	-0.89	-1.55 to -0.25	9	-0.04	-1.27 to 1.10	0.95
	4.1 Instruction on how to perform the behaviour.	-0.81	-1.57 to -0.05	5	-0.99	-1.77 to -0.22	7	0.17	-1.08 to 1.42	0.77
	9.1 Credible source.	-0.95	-1.52 to -0.38	8	-0.27	-1.89 to 1.35	4	-0.65	-2.66 to 1.36	0.49
	9.2 Pros and cons.	-0.91	-3.91 to 2.09	3	-0.88	-1.48 to -0.28	9	-0.01	-3.51 to 3.49	0.99

Note: BCT, behaviour change technique; MD, mean difference; CI, 95% confidence interval; N, number of trials; β, meta-regression coefficient

DISCUSSION

This systematic review is among the first to evaluate the impact of theory use and BCTs in MHBC interventions for reducing CVD-risk. Although pooled effects of interventions on risk factors were statistically significant but clinically modest. The results of this systematic review suggest that MHBC interventions evaluated to date for the primary prevention of CVD may generally have very limited effects in reducing CVD-risk and CVD risk factors in primary care populations.

Previous systematic reviews have investigated the effectiveness of interventions aimed at individual risk factors including diet, physical activity and body weight [6 60]. These reviews generally find that behaviour change interventions in primary care have minor impact on risk factors values. The Cochrane review up to 2011 reported modest reductions in CVD risk factors following MHBC interventions that were slightly greater than we report [5]. However, the Cochrane review did not restrict the intervention setting to primary care.

Estimated changes in CVD risk factors should be viewed with caution. In the present set of trials, the average duration of follow-up was 12 months and changes in risk factors observed may be unlikely to reflect changes occurring over longer periods. This review found reductions in blood pressure and total cholesterol following intervention, but in some instances this might be mediated by pharmacological treatment. There are clear benefits of drug treatments in lowering blood pressure and cholesterol in primary prevention populations [61 62].

Although this review focused on interventions for the primary prevention population, we also included trials that recruited a small minority of participants with some evidence of CVD.

Including these trials might have biased the results, as health promotion interventions might have more positive effects in people with established cardiovascular disease [63-65].

In order to account for heterogeneity, we focused on trial level covariates and identified characteristics that might be associated with more favourable outcomes. When coding BCTs, we were limited by the lack of detail provided in reports. We only coded what was explicitly referred to in intervention descriptions and could be fitted to BCT taxonomy definitions.

This review suggested no association between the number of intervention sessions or intervention duration and improved outcomes. Quantity of sessions would not necessarily have a beneficial impact on outcomes unless additional sessions deliver BCTs that effectively influence behaviours. Few reports provided sufficient information to permit calculating duration for analysis. Increasing use of the TIDieR checklist [66], requiring intervention reports to detail the number and duration of sessions offered to participants, will be helpful for future reviews.

Our analyses suggested that using certain BCTs has a moderator effect on intervention outcomes. In terms of biomarkers of CVD risk, no BCTs were identified as being particularly likely to influence cholesterol levels, while including review of behaviour goals appeared to be associated with slightly worse blood pressure outcomes.

“Action planning” was associated with greater weight loss, while “instruction on how to perform the behaviour” was not. Both of these findings differ to those of a previous review [17], perhaps because it focused only on interventions for obese individuals. The previous review also identified the BCTs of self-monitoring, relapse prevention/problem solving and prompt

practice as beneficial to weight loss, but too few of the interventions included in the present review incorporated these BCTs for it to be possible to test their influence. A review of interventions promoting healthy eating and exercise also found that including the BCT of self-monitoring was associated with bigger changes in these behaviours [18]. Therefore, one explanation for the relatively limited effectiveness of the interventions reviewed in the present review is that they failed to include BCTs that were more likely to lead to health-promoting changes. A second possibility is that not all BCTs were delivered as the intervention designers intended. This cannot be ruled out as monitoring of treatment fidelity was rarely described in the included studies.

This review showed no association between the use of psychological theory and improved intervention outcomes. However, only a limited range of theories were employed – mostly the Transtheoretical Model and Social Cognitive Theory. A previous review also found that interventions based on these theories were not significantly more effective than interventions not explicitly based on theory [13]. A second issue is that the links between the psychological determinants specified by a theory and the BCTs employed in interventions were sometimes poorly articulated, with little evidence cited to justify choice of BCTs to change specific constructs. Furthermore, it was not always clear which BCTs were being used to target which behaviours as part of the MHBC interventions. Both this and previous reviews [13 67] found that reported theory use in intervention design was not as extensive as it could be. It is possible that interventions based on other theories or that more explicitly link theoretical constructs to select BCTs might be more effective.

Future trials need to test interventions that provide explicit links between intervention components (i.e. theoretical basis, BCTs and intended mechanisms of action, intervention duration) and intervention outcomes as it is essential step towards understanding MHBC intervention effects. Higher priority should also be given to different population-level approaches to facilitate behaviour change.

Limitations

The results of this review must be viewed with caution because of several limitations. First, the observed effects were heterogeneous, therefore pooled estimates might be questionable. DerSimonian and Laird (DL) [22] random effects models were used. The DL method may lead to under-estimation of between trial variance leading to narrower confidence intervals in the presence of heterogeneity[68 69]. However, Thorlund, et al. [70] concluded that inferences concerning pooled effects were only infrequently influenced by the choice of between-trial variance estimator. The majority of trials included were undertaken in Europe (71%) and the United States (13%). Declines in CVD mortality and CVD-risk have been observed in these countries, and the results should be considered in the context of these trends. Groups of BCTs may have synergistic effects on behaviour [16]. However, due to the relatively small numbers of studies and under-description of the BCTs used in interventions, it was not possible to explore the impact of clusters of BCTs on CVD risk factors, as too few studies used the same clusters of BCTs and measured the same outcome. Furthermore, the differences between subgroups and covariates (i.e. theory use and BCTs) and effect size are observational and do not imply causality. Behavioural risk factors were assessed by self-report and so values were subject to social desirability and recall biases. Finally, as this review involved testing for the impact of MHBC interventions and intervention characteristics on intervention outcomes, we are aware of the need to adjust p-values based on the number of tests being made [71]. Although adjusting p-values reduces type 1 error, it increases the chances of false negatives [72]. Furthermore, tests were examining independent hypotheses, therefore p-values were not adjusted[73].

CONCLUSION

Existing multiple health behaviour change interventions delivered to individual participants in primary care appear to have limited effectiveness at reducing CVD-risk and CVD risk factors over twelve months or longer. Trial reports need to provide explicit explanation of the intervention theory, content and delivery, including fidelity and care provided to the control group in order to understand why an intervention may or may not prove effective. This is essential for future development and evaluation of effective CVD prevention interventions.

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SA, AW and MG conceptualised and designed the study. SA and MG performed the paper search. SA and LM performed the coding. SA wrote the first draft and all authors have read and made improvements of the contents and the wording.

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There are no competing interests.

Data sharing statement:

No additional data are available.

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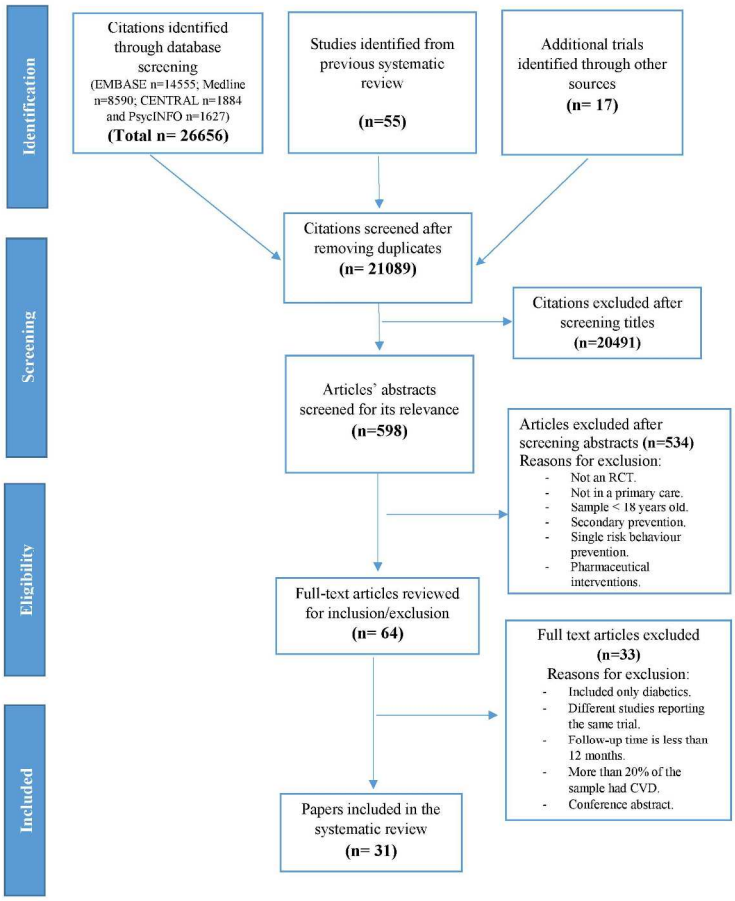


Figure 1: PRISMA flow diagram outlining the systematic review processes.

Figure 1: PRISMA flow diagram outlining the systematic review processes.

210x297mm (300 x 300 DPI)

Appendix A

Search strategy

CENTRAL search strategy

ID	Search	Hits
#1	MeSH descriptor CARDIOVASCULAR DISEASES this term only	480
#2	MeSH descriptor CORONARY DISEASE explode all trees	356
#3	cardiovascular in All Text	2052
#4	(coronary in All Text near/3 disease* in All Text)	9
#5	(heart in All Text near/3 disease* in All Text)	11
#6	MeSH descriptor HYPERTENSION this term only	643
#7	hypertension in All Text	1781
#8	(atherosclerosis in All Text or arteriosclerosis in All Text)	258
#9	(hyperlipidaemia in All Text or hyperlipidemia in All Text)	224
#10	MeSH descriptor ARTERIOSCLEROSIS explode all trees	79
#11	MeSH descriptor CHOLESTEROL explode trees all trees	209
#12	MeSH descriptor HYPERLIPIDEMIA explode all trees	33
#13	cholesterol in All Text	630
#14	multiple next risk next factor* in All Text	51
#15	coronary next risk next factor* in All Text	30
#16	(#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10)	3105
#17	(#11 or #12 or #13 or #14 or #15)	682
#18	(#16 or #17)	3234
#19	MeSH descriptor HEALTH EDUCATION explode all trees	630
#20	MeSH descriptor HEALTH PROMOTION explode all trees	191
#21	MeSH descriptor HEALTH BEHAVIOR explode all trees	215
#22	MeSH descriptor PRIMARY PREVENTION this term only	1021
#23	MeSH descriptor COUNSELLING this term only	237
#24	counsel* in All Text	1186
#25	(health in All Text near/3 educat* in All Text)	31
#26	(patient in All Text near/3 educat* in All Text)	20
#27	(education* in All Text near/3 program* in All Text)	23
#28	(health in All Text near/3 promotion* in All Text)	2
#29	(health in All Text near/3 behaviour* in All Text)	11
#30	(health in All Text near/3 behavior* in All Text)	9
#31	primary next prevention in All Text	379
#32	(multiple next risk in All Text near/3 intervention* in All Text)	6
#33	(multifactor* in All Text near/3 intervention* in All Text)	9
#34	(multifactor* in All Text near/3 prevention in All Text)	1
#35	(risk next factor* in All Text near/3 reduc* in All Text)	10
#36	(risk next factor* in All Text near/3 manag* in All Text)	20
#37	(risk next factor* in All Text near/3 intervent* in All Text)	49

#38 (lifestyle in All Text near/3 intervention* in All Text) 34
#39 (lifestyle in All Text near/3 advice in All Text) 6
#40 (life-style in All Text near/3 intervention* in All Text) 12
#41 (life-style in All Text near/3 advice in All Text) 2
#42 (life-style in All Text near/3 alter* in All Text) 1
#43 (lifestyle in All Text near/3 alter* in All Text) 5
#44 (lifestyle in All Text near/3 educat* in All Text) 15
#45 (life-style in All Text near/3 educat* in All Text) 5
#46 (life-style in All Text near/3 chang* in All Text) 8
#47 (lifestyle in All Text near/3 chang* in All Text) 18
#48 (behavior* in All Text near/3 chang* in All Text) 24
#49 (behaviour* in All Text near/3 chang* in All Text) 37
#50 (health next care in All Text near/3 advice in All Text) 7
#51 (healthcare in All Text near/3 advice in All Text) 8
#52 nonpharmacologic* in All Text 46
#53 non-pharmacologic* in All Text 562
#54 (#19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29) 2311
#55 (#30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39) 451
#56 (#40 or #41 or #42 or #43 or #44 or #45 or #46 or #47 or #48 or #49 or #50 or #51 or #52 or #53) 646
#57 (#54 or #55 or #56) 2915
#58 (#18 and #57) 1293

Embase search strategy

1. cardiovascular disease/
2. exp ischemic heart disease/
3. (Coronary adj3 disease$).tw.
4. heart disease$.tw.
5. Hypertension/
6. hypertension.tw.
7. (cardiovascular adj3 (disease$ or fit of fitness)).tw.
8. exp arteriosclerosis/
9. exp hyperlipidemia/
10. hyperlipid?emia.tw.
11. cholesterol.tw.
12. arteriosclero$.tw.
13. atherosclero$.tw.
14. coronary risk factor$.tw.
15. multiple risk factor$.tw.
16. cardiovascular risk factor$.tw.
17. or/1-16
18. exp health education/
19. exp health behavior/

20. primary prevention/
21. exp counseling/
22. (multifactor$ adj5 (intervent$ or prevent$)).tw.
23. ((life-style or life style or lifestyle or healthcare or health care) adj3 (intervention$ or educat$ or advice or alter$ or change$)).tw.
24. primary prevention.tw.
25. (risk factor$ adj3 (reduc$ or manage$ or managing or intervent$ or program$)).tw.
26. (educat$ adj3 (program$ or patient$)).tw.
27. (non pharmacologic$ or nonpharmacologic$).tw.
28. (risk factor$ adj3 modif$).tw.
29. ((lifestyle or life-style or life style) adj3 modif$).tw.
30. exp behavior therapy/
31. (behavi?r$ adj3 (intervention$ or program$ or modif$ or change$ or alter$)).tw.
32. (promot$ adj3 (health or healthcare or health care)).tw.
33. or/18-32
34. 17 and 33
35. random$.ti,ab.
36. factorial$.ti,ab.
37. (crossover$ or cross over$ or cross-over$).ti,ab.
38. placebo$.ti,ab.
39. (double$ adj blind$).ti,ab.
40. (singl$ adj blind$).ti,ab.
41. assign$.ti,ab.
42. allocat$.ti,ab.
43. volunteer$.ti,ab.
44. Crossover Procedure/
45. Double Blind Procedure/
46. Randomized Controlled Trial/
47. Single Blind Procedure/
48. or/35-47
49. exp animal/
50. nonhuman/
51. exp animal experiment/
52. or/49-51
53. exp human/
54. 52 not 53
55. 48 not 54
56. 55 and 34
57. limit 56 to yr="2006 -Current"

Medline search strategy

1. Cardiovascular Diseases/
2. exp coronary disease/
3. Hypertension/

4. exp Arteriosclerosis/
5. exp Hyperlipidemia/
6. (cardiovascular adj3 disease$).tw.
7. (cardiovascular adj3 (fit or fitness)).tw.
8. (Coronary adj3 disease$).tw.
9. heart disease$.tw.
10. hypertension.tw.
11. hyperlipid?emia.tw.
12. cholesterol.tw.
13. atherosclerosis.tw.
14. arteriosclerosis.tw.
15. coronary risk factor$.tw.
16. multiple risk factor$.tw.
17. cardiovascular risk factor$.tw.
18. or/1-17
19. health promotion/
20. exp health education/
21. exp health behavior/
22. exp counseling/
23. Primary Prevention/
24. (multifactor$ adj5 (intervent$ or prevent$)).tw.
25. ((lifestyle or life-style) adj3 (intervention$ or educat$ or advice$ or alter$ or change$)).tw.
26. ((lifestye or life-style or behavior?r$) adj3 (intervention$ or educat$ or advice$ or alter$ or change$)).tw.
27. ((healthcare or health care) adj3 advice).tw.
28. primary prevention.tw.
29. (risk factor$ adj3 (reduc$ or manage$ or managing or intervent$ or program$)).tw.
30. (educat$ adj3 (program$ or patient$)).tw.
31. ((health or healthcare or health care) adj3 (educat$ or advice or promot$)).tw.
32. (nonpharmacologic$ or non-pharmacologic$).tw.
33. ((lifestyle or life style or life-style or behavio?r$ or risk factor$) adj3 modif$).tw.
34. or/19-33
35. 18 and 34
36. randomized controlled trial.pt.
37. controlled clinical trial.pt.
38. Randomized controlled trials/
39. random allocation.sh.
40. double blind method.sh.
41. single-blind method.sh.
42. or/36-41
43. clinical trial.pt.
44. exp Clinical trial/
45. (clin$ adj25 trial$).ti,ab.

46. ((singl$ or doubl$ or trebl$ or tripl$) adj (blind$ or mask$)).ti,ab.
47. placebos.sh.
48. placebo$.ti,ab.
49. random$.ti,ab.
50. research design.sh.
51. or/43-50
52. exp animal/ not humans/
53. 42 or 51
54. 53 not 52
55. 54 and 35

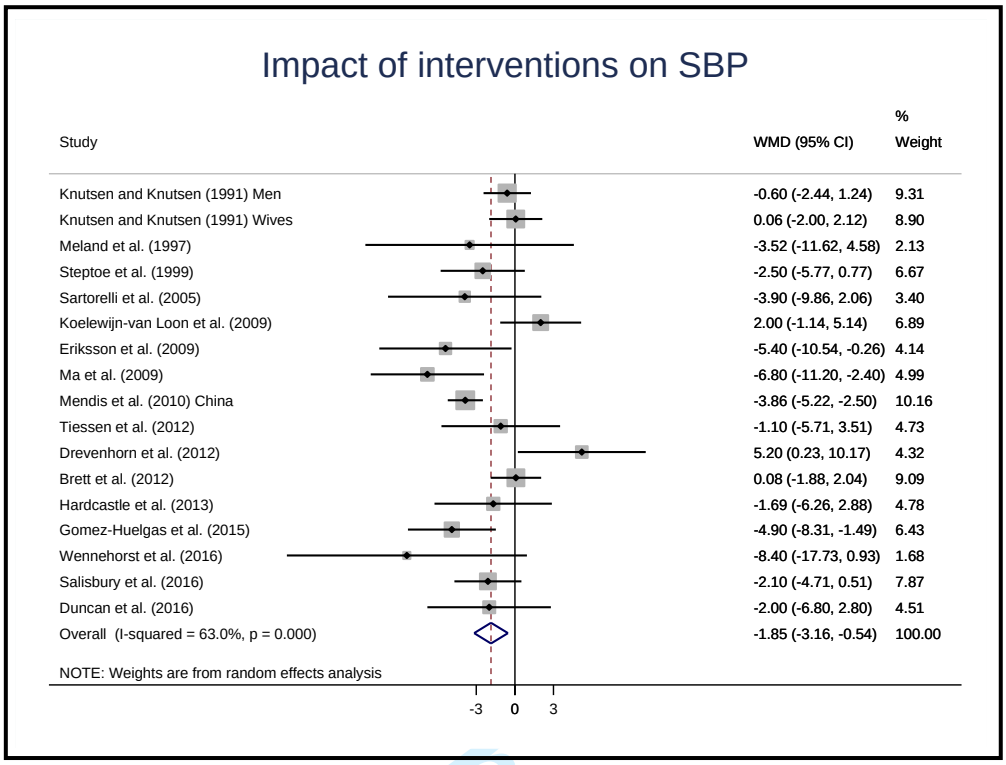
PsycINFO search strategy:

1. cardiovascular disease.mp.
2. hypertension.mp.
3. (Coronary adj3 disease$).mp.
4. heart disease$.mp.
5. (cardiovascular adj3 (disease$ or fit of fitness)).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
6. exp Arteriosclerosis/
7. hyperlipid?emia.mp.
8. cholesterol.mp.
9. arteriosclero$.mp.
10. atherosclero$.mp.
11. coronary risk factor$.mp.
12. multiple risk factor$.mp.
13. cardiovascular risk factor$.mp.
14. or/1-13
15. exp health education/
16. exp health education/
17. exp health promotion/
18. exp preventive medicine/
19. exp counseling/
20. primary prevention.mp.
21. (multifactor$ adj5 (intervent$ or prevent$)).mp.
22. behavior change.mp.
23. exp Obesity/ or exp Food Intake/ or diet intervention.mp. or exp Weight Loss/ or exp Diets/ or exp Overweight/ or exp Weight Control/ or exp Nutrition/
24. exp Nicotine/ or exp Tobacco Smoking/ or exp Smoking Cessation/ or cigarette.mp. or exp Drug Dependency/
25. exp Alcohol Drinking Patterns/ or exp Drinking Behavior/ or exp Alcohol Drinking Attitudes/ or exp Binge Drinking/ or drinking.mp.
26. exp Physical Activity/ or exp Intervention/ or exp Exercise/ or exp Physical Fitness/ or exp Motor Performance/ or physical training.mp.
27. 23 and 24
28. 23 and 25

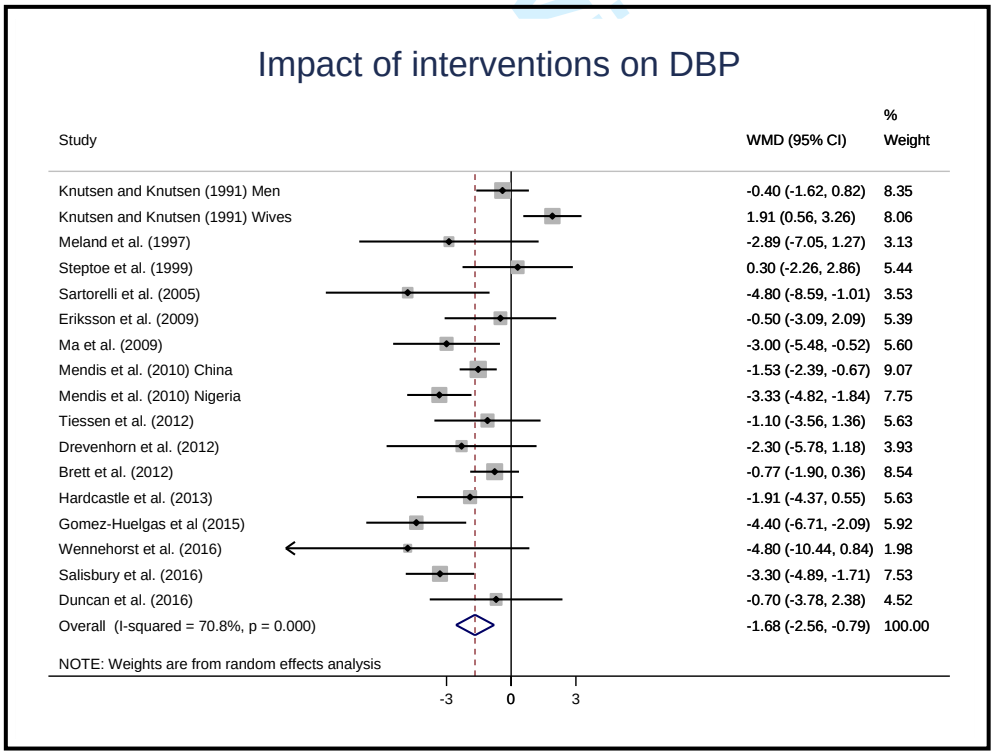
29. 23 and 26
30. 24 and 25
31. 24 and 26
32. 25 and 26
33. ((life-style or life style or lifestyle or healthcare or health care) adj3 (intervention$ or educat$ or advice or alter$ or change$)).mp.
34. primary prevention.mp.
35. (risk factor$ adj3 (reduc$ or manage$ or managing or intervent$ or program$)).sh.
36. (educat$ adj3 (program$ or patient$)).mp.
37. (non pharmacologic$ or nonpharmacologic$).mp.
38. (risk factor$ adj3 modif$).mp.
39. ((lifestyle or life-style or life style) adj3 modif$).mp.
40. (behavi?r$ adj3 (intervention$ or program$ or modif$ or change$ or alter$)).mp.
41. (promot$ adj3 (health or healthcare or health care)).mp.
42. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41
43. 14 and 42
44. random$.ti,ab.
45. factorial$.ti,ab.
46. (crossover$ or cross over$ or cross-over$).ti,ab.
47. placebo$.ti,ab.
48. (double$ adj blind$).ti,ab.
49. (singl$ adj blind$).ti,ab.
50. assign$.ti,ab.
51. allocat$.ti,ab.
52. volunteer$.ti,ab.
53. ("double-blind" or "random* assigned" or control).mp.
54. treatment effectiveness evaluation.mp.
55. treatment outcome clinical trial$.mp.
56. (controlled trial$ and clinical trial$).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
57. 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56
58. 43 and 57

Appendix B

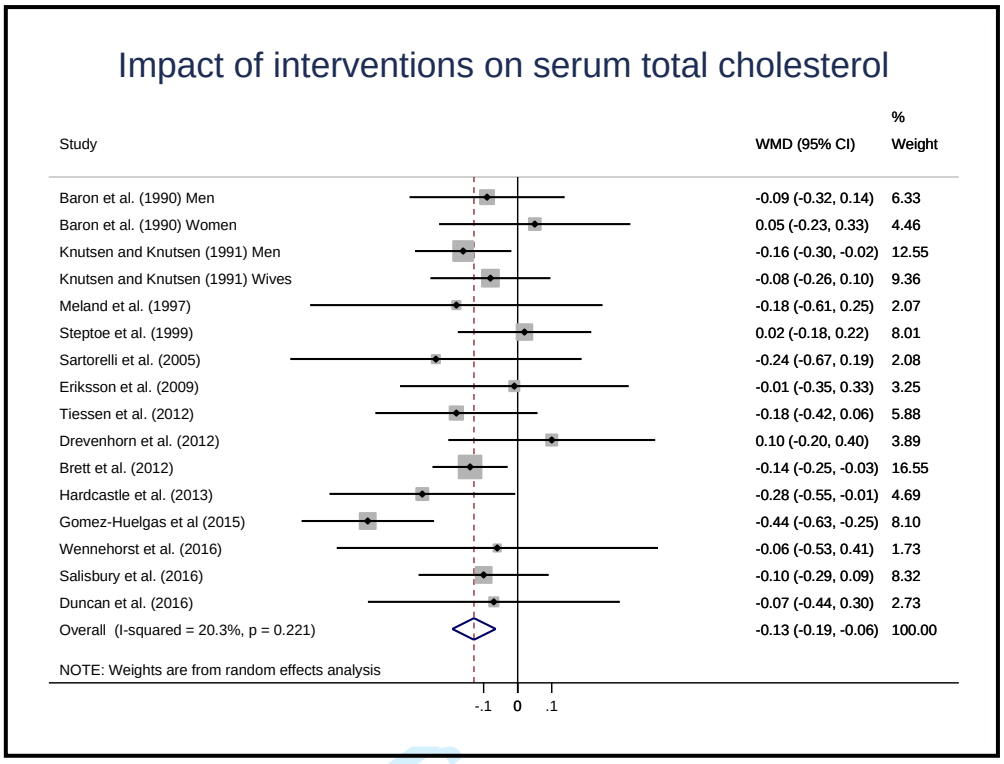
Forest plots of pooled effect of multiple behaviour interventions on intervention outcomes.



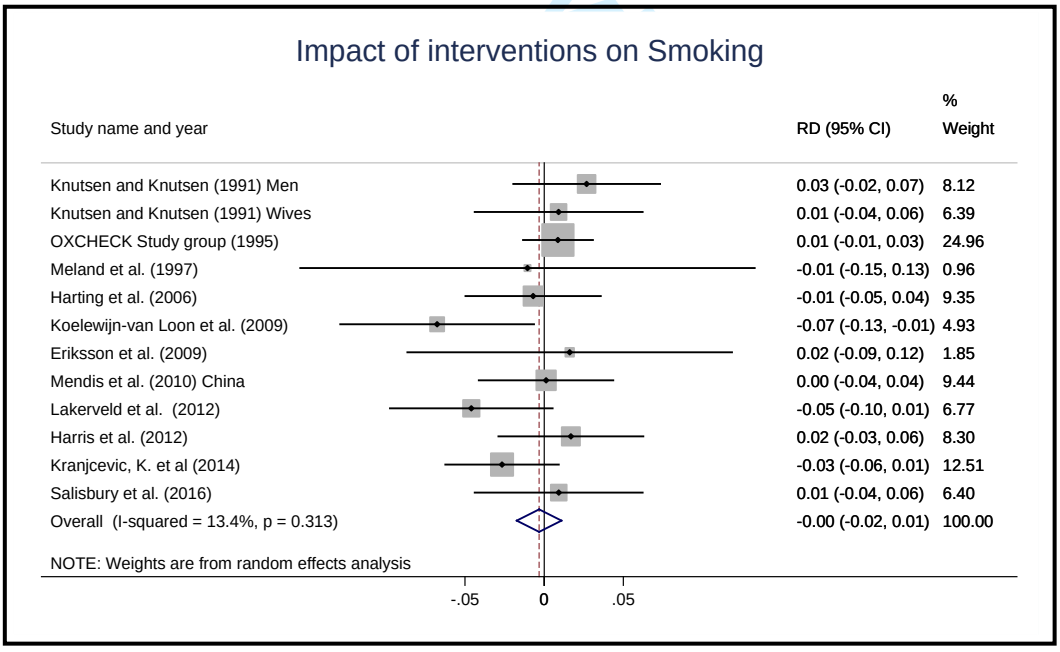
Pooled effect of multiple behaviour interventions on systolic blood pressure (mmHg). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



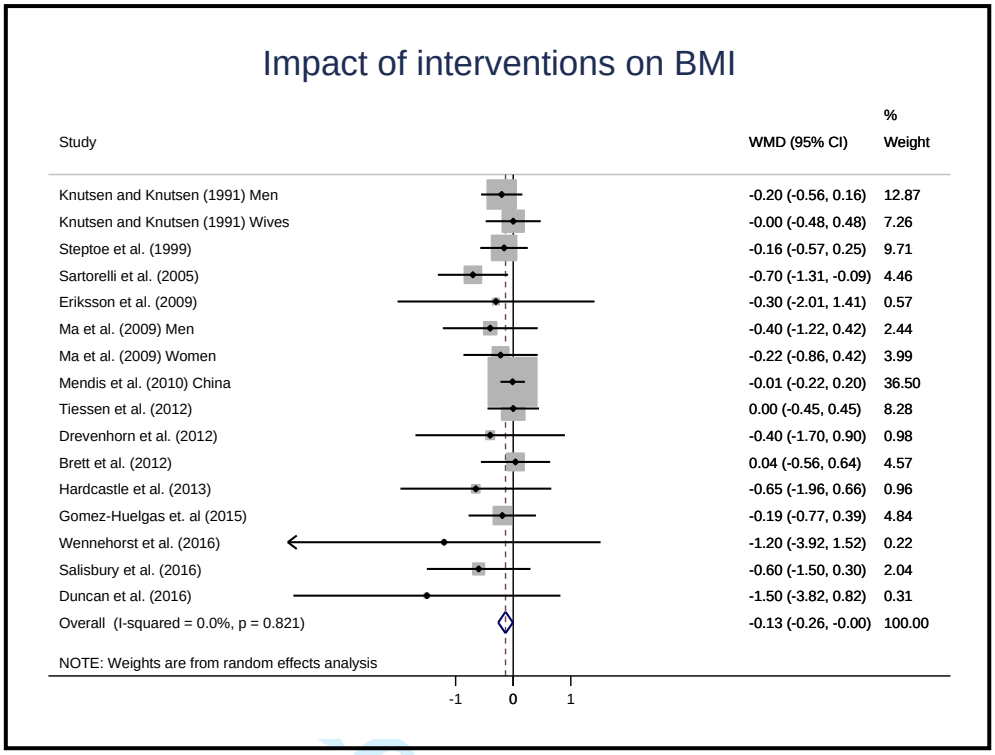
Pooled effect of multiple behaviour interventions on diastolic blood pressure (mmHg). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



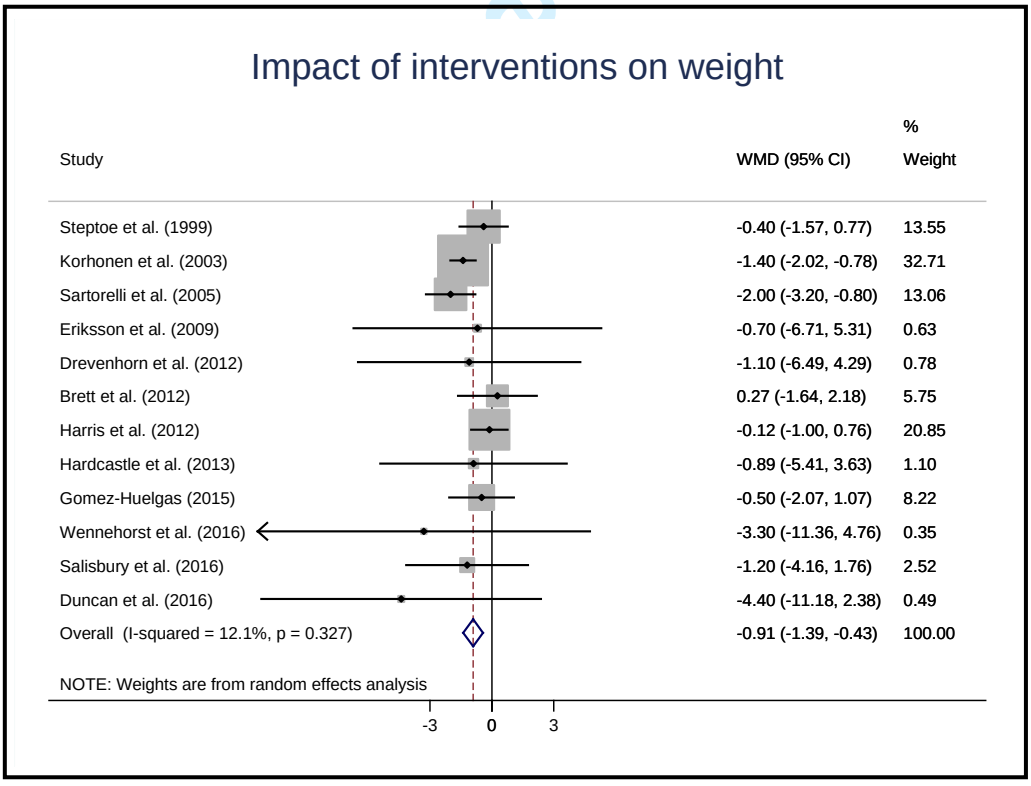
Pooled effect of multiple behaviour interventions on serum total cholesterol (mmol/L). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



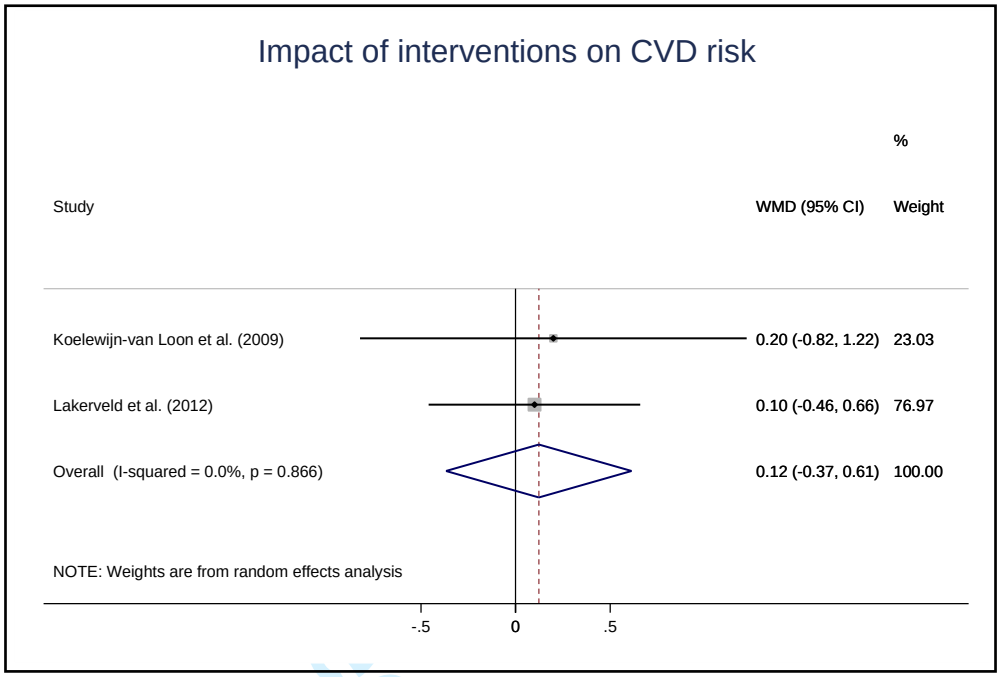
Pooled effect of multiple behaviour interventions on smoking prevalence. Random effects models used. RD= risk difference. 95% CI = 95% confidence intervals.



Pooled effect of multiple behaviour interventions on body mass index (Kg/m^2). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



Pooled effect of multiple behaviour interventions on weight (Kg). Random effects model used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.



Pooled effect of multiple behaviour interventions on cardiovascular risk (SCORE). Random effect models used. MWD= mean weighted difference. 95% CI = 95% confidence intervals.

Supplementary table 1: Trial characteristics of included studies.

Study (Year)	Country	Number of Participants	Selection criteria	Targeted behaviours	Follow-up duration	Intervention reported outcomes
Kranjčević, et al. [1]	Croatia	1957	Men and women, aged ≥40.	Diet and PA.	18 months	CVD-risk, weight, BP, cholesterol, smoking, alcohol and PA.
Vetter, et al. [2]	United States	390	Men and women, aged≥21 years, BMI= 30-50kg/m^2, elevated waist circumference.	Diet and PA.	2 years	Weight, BP and cholesterol.
Lakerveld, et al. [3]	Netherlands	622	Men and women, aged: 30-50 years.	Diet, PA and smoking.	12 months	CVD-risk, smoking, diet and PA.
Hardcastle, et al. [4]	United Kingdom	334	Men and women, aged 18-65 years and have at least one CVD risk factor.	Diet and PA.	18 months	Weight, BP, cholesterol, diet and PA.
Tiessen, et al. [5]	Netherlands	201	Men aged: 50-75 years old and women aged: 55-75 years and CVD-risk (SCORE) ≥ 5%.	PA, diet and smoking.	12 months	CVD-risk, weight, BP, cholesterol, smoking and PA.
Parra-Medina, et al. [6]	United States	266	African-American women, aged≥35 years, baseline BP <160/95.	PA and diet.	12 months	Diet and PA.
Drevenhorn, et al. [7]	Sweden	153	Hypertensive patients, men and women aged <75 years, elevated BP, BMI ≥ 25, serum cholesterol ≥ 6.5 and/or serum triglycerides ≥ 2.3 and not reporting regular PA.	Smoking, alcohol, weight, PA and stress	2 years	Weight, BP, cholesterol, alcohol and PA.
Brett, et al. [8]	Australia	1200	Men and women aged 40-80 years, without a history of CVD.	Diet, PA and smoking.	12 months	CVD-risk, weight, BP and cholesterol.
Harris, et al. [9]	Australia	814	Men and women, aged 40-55 years with recorded diagnosis of hypertension and/or hyperlipidaemia or aged 56-64 years.	Diet, PA, smoking and alcohol.	12 months	CVD-risk, weight, BP, cholesterol, smoking, alcohol, diet and PA.
Mendis, et al. [10]	China Nigeria	1209 1188	Men and women aged 30-70 years with SBP in the range (140-179 mmHg).	Smoking cessation, PA and diet.	12 months	Weight, BP, smoking and diet.
Koelewijn-van Loon, et al. [11]	Netherlands	615	One or more of the following: BP≥ 140 or on treatment for high BP; total cholesterol ≥ 6.5 or on treatment for high cholesterol; smoker aged ≥ 50 years (men) or ≥ 55 years (women); diabetes; a family history of CVD; and obese.	Smoking status, diet, PA and alcohol use.	12 months	CVD-risk, BP, cholesterol, smoking, diet and PA.
Eriksson, et al. [12]	Sweden	151	Men and women aged 18–65 years with hypertension, dyslipidaemia, type 2 diabetes or obesity.	Diet and PA.	3 years	Weight, BP, cholesterol, smoking and PA.
Phelan, et al. [13]	United States	224	Men and women aged 18–65 years and BMI of 30–45 kg/m^2.	Diet and PA.	12 months	Weight, BP, cholesterol and diet.

Harting, et al. [14]	Netherlands	1300	Men and women who have a greater than 20% risk (Framingham) of incurring a CVD event within 10 years.	Diet, PA and smoking.	18 months	Smoking, diet and PA.
Korhonen, et al. [15]	Finland	715	Men and women aged 25–74 years, with systolic BP 140–179 and/or diastolic BP 90–109 and/or on treatment for hypertension.	Diet and alcohol (also PA and smoking).	24 months	Weight, BP, cholesterol, alcohol, diet and PA.
Baron, et al. [16]	United Kingdom	368	Men and women aged 25 – 60 years.	Diet mainly, but changes in PA, alcohol and smoking were also mentioned.	12 months	Cholesterol and diet.
Knutsen and Knutsen [17]	Norway	1373 men, 1143 wives	Men aged 20 – 54 years and women aged 20-49 years, with no known CHD at baseline.	Diet changes, PA and smoking cessation.	6 years	CVD-risk, weight, BP, cholesterol, smoking and PA.
Nilsson, et al. [18]	Sweden	86	Men and women, born during the period 1925 – 1952, treated hypertensives.	Diet, smoking, PA and alcohol.	12 months	Weight, BP, cholesterol, smoking and diet.
Wood, et al. [19]	United Kingdom	7460 men, 5012 women	Men aged 40-59 and their families.	Smoking, weight, diet, alcohol, and PA.	12 months	CVD-risk, weight, BP, cholesterol and smoking.
OXCHECK Study Group [20]	United Kingdom	5559	Men and women aged 35-64.	Diet, smoking and PA.	3 years	CVD-risk, weight, BP, cholesterol, alcohol, diet, PA and smoking.
Lindholm, et al. [21]	Sweden	681	Men and women aged 30-59 years, had a moderate hyperlipidaemia, and at least two CVD risk factors.	Diet, smoking and PA.	18 months	CVD-risk, weight, BP, cholesterol, PA and smoking.
Meland, et al. [22]	Norway	127	Men aged 30 to 59 years.	Diet, smoking and PA.	12 months	CVD-risk, BP, cholesterol, PA and smoking.
Avram, et al. [23]	Romania	253	Men and women under 80 years, without history of CVD but defined as high risk individuals.	Diet and PA.	18 months	Weight, alcohol, diet and PA.
Steptoe, et al. [24]	United Kingdom	883	Men and women aged 18 – 69, total cholesterol of 6.5-9; smoker, BMI of 25-35 and lack of regular PA.	Smoking, diet and PA.	12 months	Weight, BP, cholesterol, diet and PA.
Sartorelli, et al. [25]	Brazil	104	Men and women aged 30-65 years, body mass index of 24-35 kg/m^2, and non-diabetic.	Diet and PA.	12 months	Weight, BP, cholesterol, diet and PA.
Ma, et al. [26]	United States	419	Men and women aged 35 to 85 years, had moderately to severely elevated levels of major modifiable CVD risk factors.	PA, diet and stress reduction.	15 months	CVD-risk, weight, BP and cholesterol.
Tibblin and Åberg [27]	Sweden	400	Men and women aged 30 - 69 years, on hypertensive drugs	Diet, PA and stress management.	12 months	Weight, BP and cholesterol.

Gomez-Huelgas et al (2015)[28]	Spain	601	Men and women aged 18-80 years, with metabolic syndrome.	Diet and PA.	3 years	Weight, BP, cholesterol, diet and PA.
Wennehorst et al. [29]	Germany	83	Men and women aged 18-80 years who had either prediabetes, type 2 diabetes, or were at risk of developing diabetes and/or cardiovascular diseases.	Diet and PA.	12 months	Weight, BP, cholesterol.
Salisbury et al. [30]	United Kingdom	641	Men and women aged between 40 and 74 years, had a high risk of a cardiovascular event in the next 10 years, and had one or more of the following modifiable risk factors (systolic blood pressure ≥140 mm Hg, body mass index ≥30, being a current smoker, or any combination of these).	Smoking status, diet, PA and alcohol use.	12 months	CVD-risk, weight, BP, cholesterol, diet, PA and smoking.
Duncan et al.[31]	New Zealand	320	Adults aged 35 to 65 years, a 5-year CVD risk of at least 7%, and/or a BMI of at least 33 kg/m2 for participants younger than 50 years	Diet and PA.	12 months	CVD-risk, weight, BP, cholesterol, diet and PA.

Note: BMI: body mass index, PA: physical activity, BP: blood pressure, CVD: cardiovascular diseas

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Supplementary table 2: Intervention components and behaviour change techniques employed.

Study (Year)	Study groups	Who delivered it	BCTs [1]	Mode of delivery	No. of sessions	Duration of sessions (in mins)
Kranjčević, et al. [1]	Intervention	GPs	1.3, 2.1, 9.1	Face to face and written materials	5	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Vetter, et al. [2]	Intervention 1	PCP and lifestyle coach.	1.1, 1.5, 2.3, 8.7, 9.1	Face to face and written materials	32	Visits: 5-7 mins, counselling: 10-15 mins.
	Intervention 2		1.1, 1.5, 2.3, 8.7, 9.1, 11.1	Face to face and written materials	32	Visits: 5-7 mins, counselling: 10-15 mins.
	Control		1.7	Face to face	8	Visits: 5-7 mins.
Lakerveld, et al. [3]	Intervention	Nurse	1.2, 1.6	Face to face and phone sessions.	9	Face to face sessions: 30 mins.
	Control		4.1, 5.1	Written materials.	Unclear	Unclear
Hardcastle, et al. [4]	Intervention	PA specialist and dietician	1.1, 1.5, 9.2	Face to face.	5	20-30 mins.
	Control		5.1	Written materials.	Unclear	Unclear
Tiessen, et al. [5]	Intervention	Practice nurses.	2.2, 2.3, 2.4, 5.1	Face to face.	7	First session: 20 min, other sessions based on patient preference.
	Control		5.1	Face to face and written materials.	One	Unclear.
Parra-Medina, et al. [6]	Intervention	PCP, health educators and nurses	1.1, 1.2.	Face to face and telephone sessions and written materials.	Up to 15	First session: 60 mins. Following sessions: 20 mins.
	Control		1.1	Face to face and written materials.	One	5-10 mins.
Drevenhorn, et al. [7]	Intervention	Nurses	1.1, 1.5, 5.3, 9.2, 10.4, 11.2	Face to face	Unclear	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Brett, et al. [8]	Intervention	GPs	1.1, 1.3, 2.7	Face to face	5	Unclear
	Control		1.1, 1.3, 2.7	Face to face	2	Unclear
Harris, et al. [9]	Intervention	Health practitioner, dietitian or PT	1.1, 1.2, 2.3, 4.1, 6.1, 9.1	Face to face	6	90 mins/ session.
	Control		Unclear	Unclear	Unclear	Unclear
Mendis, et al. [10]	Intervention	Health-care workers	2.6, 4.1	Face to face and written materials	4	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Koelewijn-van Loon, et al. [11]	Intervention	Nurses	1.1, 1.2, 1.4, 1.5, 5.1, 9.2	Face to face and telephone sessions	3	Face to face: 10-20 mins, telephone: 10 mins.
	Control		5.1	Face to face	One	Unclear
Eriksson, et al. [12]	Intervention	Dietician, PT and assistants.	1.1, 1.2, 1.3, 1.4, 4.1, 5.1, 8.1, 8.7, 9.1, 9.2	Face to face	56	Unclear.
	Control		9.1	Face to face and written materials.	One	Unclear

Phelan, et al. [13]	Intervention 1	PCP	2.3, 11.1.	Face to face and written materials.	8	5-10 mins.
	Intervention 2	Psychologist	1.5, 2.3, 9.1	Group sessions.	29	90 mins
	Intervention 3	Psychologist, PCP	1.5, 2.3, 9.1, 11.1	Face to face, group sessions and written material.	37	Face to face: 5-10 mins, group sessions: 90 mins.
	Intervention 4	PCP	1.5, 2.3, 9.1, 11.1	Face to face and written materials.	8	5-10 mins.
Harting, et al. [14]	Intervention	Practice assistant and dietician.	1.1, 1.4, 9.1, 11.1	Face to face, telephone sessions and written materials.	Unclear	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Korhonen, et al. [15]	Intervention	Healthcare centre personnel.	1.1, 1.3, 1.4, 2.3, 2.5,4.1, 9.1	Face to face.	7	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Baron, et al. [16]	Intervention	Nurse	5.1, 9.1	Face to face, group sessions and written material.	Unclear	30 mins.
	Control		Unclear	Unclear	Unclear	Unclear
Knutsen and Knutsen [17]	Intervention	Physicians and dieticians	1.1, 4.1, 5.1, 6.1, 9.1	Face to face and telephone sessions.	8	Unclear
	Control		Unclear	Unclear	Unclear	Unclear
Nilsson, et al. [18]	Intervention	Nurse, dietician or PT.	1.1, 2.2, 3.1, 4.1, 6.1, 9.1, 12.5	Face to face, group sessions and videotapes.	Unclear	Unclear
	Control		2.2, 5.1	Face to face	One	Unclear
Wood, et al. [19]	Intervention	Nurses	1.1, 2.7, 5.1, 6.2, 9.1	Face to face and written materials	Unclear	First session: 90 mins.
	Control		9.1	Face to face	One	45 mins
OXCHECK Study Group [20]	Intervention	Nurses	1.3, 2.7, 9.1,	Face to face	Unclear	Initial session: 45-60 mins, following sessions:10-20 mins.
	Control		Unclear	None	None	None
Lindholm, et al. [21]	Intervention	Doctors and nurses	2.3, 4.1, 5.1, 6.2, 9.1	Face to face, group sessions and written materials	11	Five group sessions: 90 mins, one group session: all day.
	Control		9.1	Face to face and written materials	5	Unclear
Meland, et al. [22]	Intervention	GPs	1.8, 2.3, 8.7, 9.1, 11.2	Face to face and written materials	4	Unclear
	Control		9.1	Face to face and written materials	4	Unclear
Avram, et al. [23]	Intervention	GPs	1.1, 9.1	Face to face and telephone sessions	21	Face to face sessions:30 mins.
	Control		Unclear	Written materials	None	None
Steptoe, et al. [24]	Intervention	Nurses	1.1, 1.4, 9.1, 11.1	Face to face and telephone sessions	2-3	Face to face sessions:20 mins.
	Control		Unclear	Unclear	Unclear	Unclear
Sartorelli, et al. [25]	Intervention	Nutritionist	1.1, 1.4, 9.1	Face to face and group sessions and written materials.	4	Unclear
	Control		Unclear	Group session and written materials	1	Unclear

Ma, et al. [26]	Intervention	Nurses and dietitians	1.1, 1.2, 1.7, 9.1, 11.1, 11.2	Face to face	8-10	30-60 mins
	Control		Unclear	Unclear	Unclear	Unclear
Tibblin and Åberg [27]	Intervention	Nurses and physicians	2.5, 6.1, 9.1	Face to face, group sessions and videotapes and audiotapes.	15	Unclear
	Control		2.5, 9.1	Face to face	15	Unclear
Gomez-Huelgas et al. [28]	Intervention	Nurses and physicians	1.3, 1.4, 2.5, 4.1, 9.1	Face to face, group sessions and written materials.	27	Health assessment: 15 mins, nursing visits: 30 mins.
	Control		2.5, 9.1	Face to face and written materials	24	10 mins.
Wennehorst et al. [29]	Intervention	Physician and nutritionist	1.4, 3.1, 4.1, 9.1, 11.2.	Face to face, group sessions and written materials.	16	2.5 hrs/ session.
	Control		Unclear	Unclear	Unclear	Unclear
Salisbury et al. [30]	Intervention	Health advisors	1.1, 1.6, 2.4, 5.1, 9.1, 11.1.	Computerised behavioural management programme and telephone sessions.	12	Telephone sessions: an average of 18 mins/session.
	Control		Unclear	Unclear	Unclear	Unclear
Duncan et al. [31]	Intervention	Trained health promoter	1.1, 1.4, 1.5, 2.3, 2.6, 3.1, 8.7.	Face to face group sessions and written materials.	5	60mins/ session.
	Control		2.6	Face to face	unclear	Unclear

[1] as coded in Michie, Richardson et al.[32] taxonomy of behaviour change technique

Note: 1.1 Goal setting (behaviour); 1.2 Problem solving; 1.3 Goal setting (outcome); 1.4 Action planning; 1.5 Review behaviour goals(s); 1.6 Discrepancy between current behaviour and goal; 1.7 Review outcome goal(s); 1.8 Behavioural contract; 2.1 Monitoring of behaviour by others without feedback; 2.2 Feedback on behaviour; 2.3 self-monitoring of behaviour; 2.4 Self-monitoring of outcome(s) of behaviour; 2.5 Monitoring of outcomes of behaviour without feedback; 2.6 Biofeedback; 2.7 Feedback on outcome(s) of behaviour; 3.1 Social support (unspecified); 4.1 Instructions on how to perform a behaviour; 5.1 Information about health consequences; 5.3 Information about social and environmental consequences; 6.1 Demonstration of the behaviour; 6.2 Social comparison; 8.1 Behavioural practice/rehearsal; 8.7 Graded tasks; 9.1 Credible source; 9.2 Pros and cons; 10.4 Social reward; 11.1 Pharmacological support; 11.2 Reduce negative emotions; 12.5 Adding objects to the environment; PT Physiotherapist, PA Physical activity

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Supplementary table 3: Risk of bias assessment.

Study (Year)	Risk of bias					
	Sequence generation (randomisation methods) [a]	Allocation concealment [b]	Blinding of participants and personnel to study group allocation [c]	Blinding of outcome assessors [d]	Incomplete outcome data [e]	Selective reporting [f]
Kranjčević, K. et al (2014)	Unclear	Unclear	Unclear	Unclear	High	Low
Vetter et al. (2013)	Low	Low	High	Low	High	Low
Lakerveld et al. (2012)	Low	Low	High	High	High	Low
Hardcastle et al. (2013)	Low	Low	Low	Low	High	Low
Tiessen et al. (2012)	Low	Low	High	High	Unclear	Low
Parra-Medina et al. (2011)	Unclear	Unclear	Low	Low	High	High
Drevenhorn et al. (2012)	Unclear	Unclear	Unclear	Unclear	High	Low
Brett et al. (2012)	Low	High	High	High	Low	High
Harris et al. (2012)	Low	Low	High	Low	Low	Low
Mendis et al. (2010)	Unclear	Unclear	High	High	Low	Unclear
Koelewijn-van Loon et al. (2009)	Low	Low	High	High	High	Low
Eriksson et al. (2009)	Low	Low	High	High	Unclear	Low
Phelan et al. (2007)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Harting et al. (2006)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Korhonen et al. (2003)	High	High	High	Unclear	High	Low
Baron et al. (1990)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Knutsen and Knutsen (1991)	Low	Low	Unclear	Low	Low	Low
Nilsson et al. (1992)	Unclear	Unclear	Unclear	Low	Low	Low
Wood et al. (1994)	Unclear	Unclear	Unclear	Unclear	Unclear	Low
OXCHECK Study group (1995)	Unclear	Unclear	High	Low	Unclear	Low
Lindholm et al. (1995)	Unclear	Unclear	High	Unclear	Low	Low
Meland et al. (1997)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Avram et al. (2011)	Unclear	Unclear	Low	Low	Low	Unclear

Steptoe et al. (1999)	Low	Low	High	High	High	Low
Sartorelli et al. (2005)	Low	Low	Low	High	High	Unclear
Ma et al. (2009)	Low	Low	Low	Low	Unclear	Low
Åberg and Tibblin (1989)	Low	Low	Unclear	Unclear	Low	Unclear
Gomez-Huelgas et al. (2015)	Unclear	Unclear	High	High	High	Unclear
Wennehorst et al. (2016)	Low	Low	Unclear	Unclear	High	Unclear
Salisbury et al. (2016)	Low	Low	High	Low	Low	Low
Duncan et al. (2016)	Low	Low	High	Low	High	Low

[a] Assessment of whether or not methods used to generate the allocation sequence should produce comparable groups.
[b] Assessment of whether or not the method used to conceal allocation sequence is sufficient or not.
[c] Assessment of the methods used to blind study participants and personnel from knowing intervention allocation.
[d] Assessment of the methods used to blind study outcome assessors from knowing intervention allocation, and whether or not this method of blinding is sufficient.
[e] Assessment of whether incomplete outcome data were adequately dealt with. Studies missing outcome data for >20% of participants who underwent randomization were considered at high risk of bias, while studies missing <10% of participants who underwent randomization were considered at low risk of bias.
[f] Assessment of whether all outcome measures described in the introduction and methods section of the paper (and published protocols) were reported.

Supplementary table 4: Theory use evaluation using Theory Coding Scheme.

Study	Theory used	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13	Item 14	Item 15	Item 16	Item 17	Item 18	Item 19
Kranjčević, K. et al (2014)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vetter et al. (2013)	Social cognitive and behavioural self-management theory	Yes	Yes	No	No	Yes	No	No	Yes	Yes	No	Yes	No	N/A	A, B,C and D	No	No	No	No	No
Lakerveld et al. (2012)	Theory of planned behaviour and theory of self-regulation.	Yes	Yes	No	No	Yes	No	Yes	No	Yes	No	Yes	B	A	A and B	Yes	No	Yes	No	No
Hardcastle et al. (2013)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tiessen et al. (2012)	Stages of change	Yes	No	Yes	Yes	Do not know	No	No	No	No	No	No	No	N/A	A, B,C and D	Do not now	No	No	Do not know	No
Parra-Medina et al. (2011)	Trans-theoretical model and social cognitive theory	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No	Yes	No	No	A	Do not know	No	No	Do not know	No
Drevenhorn et al. (2012)	Stages of changes model	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	No	N/A	A	Do not know	No	No	Do not know	No
Brett et al. (2012)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Harris et al. (2012)	Stages of changes model	Yes	Yes	Yes	No	No	Yes	No	No	No	No	No	No	N/A	A and B	No	No	No	No	No
Mendis et al. (2010)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Koelewijn-van Loon et al. (2009)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eriksson et al. (2009)	Stages of change model	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	N/A	No	No	No	No	No	No
Phelan et al. (2007)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Harting et al. (2006)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Korhonen et al. (2003)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Baron et al. (1990)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Knutsen and Knutsen (1991)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nilsson et al. (1992)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wood et al. (1994)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OXCHECK Study group (1995)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Lindholm et al. (1995)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meland et al. (1997)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Avram et al. (2011)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Steptoe et al. (1999)	Stages of change model	Yes	Yes	Yes	No	No	No	No	No	No	No	No	Yes	C and F	N/A	N/A	N/A	N/A	N/A	N/A
Sartorelli et al. (2005)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ma et al. (2009)	Social cognitive theory and trans-theoretical model	Yes	No	No	No	No	No	No	No	No	No	No	No	N/A	N/A	N/A	N/A	No	No	No
Åberg and Tibblin (1989)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gomez-Huelgas et al. (2015)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wennehorst et al. (2016)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Salisbury et al. (2016)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Duncan et al. (2016)	Theory use is not reported	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Item 1) Theory/ model of behaviour mentioned

Item 2) Targeted construct mentioned

Item 3) Intervention based on single theory

Item 4) Theory used to select recipients

Item 5) Theory used to select intervention techniques

Item 6) Theory used to tailor intervention techniques to recipients

Item 7) All intervention techniques are explicitly linked to theory construct

Item 8) At least one of the intervention techniques are explicitly linked to theory construct

Item 9) Group of techniques are linked to a group of constructs

Item 10) All theory relevant constructs are explicitly linked to at least one intervention technique.

Item 11) At least one of the theory relevant constructs are explicitly linked to at least one intervention technique.

Item 12) theory-relevant constructs are measured

Item 13) Quality of measures

Item 14) Randomization of participants' condition

Item 15) Changes in measured theory-relevant constructs

Item 16) Mediational analysis of constructs

Item 17) Results discussed in relation to theory

Item 18) Appropriate support for theory

Item 19) Results used to refine theory

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5 & 6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	7
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	8 & 9
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix A
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	9 & 10
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	10
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	10 & 11
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	10

Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	11 & 12
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	11 & 12
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	11 & 12
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	11 & 12
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	13 and figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Supplementary table 1 & 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplementary table 3
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Appendix B
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	20
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	21 - 26
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	21 - 26
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	29
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	32
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	33
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	33

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