**Multiple risk behaviour interventions: meta-analyses of randomised controlled trials**

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**Abstract**

**Context:** Systematic review, meta-analysis, and meta-regression of the effectiveness of multiple risk behaviour interventions.

**Evidence acquisition:** Six electronic databases including MEDLINE, EMBASE and PsycINFO searched to August 2016.

Study selection:RCTs of non-pharmacological interventions in general adult populations. Studies targeting specific at risk groups (such as people screened for cardiovascular risk factors, or obesity) were excluded.

Study appraisal:Studies were screened independently. Study characteristics and outcomes were extracted and risk of bias assessed by one researcher and checked by another. The Behaviour Change Wheel and Oxford Implementation Index were used to code intervention content and context.

 **Evidence synthesis:** Random effects meta-analyses were conducted. Sixty-nine trials involving 73,873 individuals were included. Interventions mainly comprised education and skills training and were associated with modest improvements in most risk behaviours: increased fruit and vegetable intake (0.31 portions; 95% CI 0.17 to 0.45), and physical activity (SMD 0.25; 95% CI 0.13 to 0.38) and reduced fat intake (SMD -0.24; 95% CI -0.36 to -0.12). Although reductions in smoking were found (OR 0.78; 95% CI 0.68 to 0.90), they appeared to be negatively associated with improvement in other behaviours (such as diet and physical activity). Preliminary evidence suggests that sequentially changing smoking alongside other risk behaviours was more effective than simultaneous change.

But most studies assessed simultaneous rather than sequential change in risk behaviours therefore comparisons are sparse. Follow-up period and intervention characteristics impacted on effectiveness for some outcomes.

**Conclusions:** Interventions comprising education (e.g. providing information about behaviours associated with health risks) and skills training (e.g. teaching skills that equip participants to engage in less risky behaviour) and targeting multiple risk behaviours concurrently are associated with small changes in diet and physical activity. Although on average smoking was reduced, it appeared changes in smoking were negatively associated with changes in other behaviours suggesting it may not be optimal to target smoking simultaneously with other risk behaviours.

**Systematic Review registration:** PROSPERO number CRD42013005248

**Context**

Physical inactivity, eating an unhealthy diet, smoking and excessive alcohol consumption are associated with greater risk of developing cancers, cardiovascular diseases and type 2 diabetes[1](#_ENREF_1) and, together, these conditions are estimated to account for more than 50% of preventable premature deaths globally.[2](#_ENREF_2) Studies suggest the majority of adults report two or more risk behaviours and approximately 25% of the adult population report three or more risk behaviours.[3](#_ENREF_3),[4](#_ENREF_4),[5](#_ENREF_5)Engaging in multiple risk behaviours is associated with greater risk of chronic disease and mortality compared to engaging in one or no risk behaviours.[6](#_ENREF_6)Multiple risk behaviours are associated with health inequalities, people in unskilled work or with no qualifications are more likely to engage in two or more risk behaviours.[7](#_ENREF_7) [8](#_ENREF_8) [9](#_ENREF_9)

High blood pressure and tobacco smoke were among the three leading risk factors for global disease burden, and unhealthy diet and physical inactivity accounted for 10% of all disease burden.[10](#_ENREF_10) Interventions supporting people to make healthy choices receive high priority in most high-income countries because of potential to improve population health and reduce future demand on health care. Given risk behaviours rarely occur in isolation tackling multiple rather than single behaviours may be a more effective approach. Since 2000 there has been a steady increase in studies evaluating multiple risk behaviour interventions, with a sharp rise from 2010 onwards. Between 2010 and 2013, over 100 studies were published.[11](#_ENREF_11) Findings from these studies have not yet been synthesised and to our knowledge this is the first systematic review to evaluate which interventions are effective in changing which behaviours in adult, non-clinical populations. Which behaviours were targeted, by what type of intervention and the outcomes achieved were investigated. It was also explored which factors were associated with improved outcomes.

**Evidence acquisition**

*Eligibility criteria*

An iterative approach was used to determine inclusion criteria. This involved conducting a mapping exercise appraising the scope of the multiple risk behaviour literature. No evidence was found suggesting restriction of studies to RCTs would limit types of eligible interventions.[11](#_ENREF_11) Studies with the following characteristics were included:

Population:General adult (aged 16 years or older) or non-targeted subgroups of general adult populations (e.g., pregnant women, older adults, students). Studies of targeted subgroups, where screening takes place to determine eligibility (e.g., to identify obesity, or those at risk of type 2 diabetes) were excluded.

Intervention: Any non-pharmacological intervention aiming to change at least two risk behaviours (risk behaviours were not determined a priori). Studies of school or family-based interventions were excluded to avoid duplication with registered protocol for a Cochrane systematic review.[12](#_ENREF_12)

Comparator: any comparator (such as attention control, single risk behaviour nonpharmacological intervention).

Outcomes: The primary outcome was change in risk behaviours. This included any behaviour that entailed potential risk to participants’ health. Secondary outcomes were changes in weight, BMI, blood pressure and cholesterol; intermediate outcomes included self-efficacy, attitudes, beliefs and knowledge. Process related outcomes were collected.

Study design: RCTs.

*Information sources*

MEDLINE, EMBASE, PsycINFO, Science Citation Index, Cochrane Central Register for Controlled Trials, Applied Social Sciences and Index and Abstracts were searched from January 1990 to August 2016 with no language restrictions (online appendices). Citation searches were carried out using Google Scholar, Scopus, Web of Science, and OVIDSP MEDLINE.[13](#_ENREF_13)

*Selection of studies, data collection process and risk of bias assessment*

Final selection of studies, data extraction and assessment of risk of bias was conducted by one reviewer and checked by a second. A modified version of the *Cochrane Public Health Group’s* data extraction template was used (piloted on five studies to ensure consistency) and the *Behaviour Change Whee*l (Table 1)to classify intervention content according to nine functions: education; persuasion; incentivisation; coercion; training; enablement; modelling; environmental restructuring and restrictions (no policy level interventions were found).[14](#_ENREF_14)

The *Oxford Implementation Index* was utilized to assess intervention characteristics and contextual factors.[15](#_ENREF_15) Both were adapted for the purposes of this review. The *Cochrane Risk of Bias Tool* was used to critically appraise included studies.[16](#_ENREF_16)

For dichotomous outcomes, ORs and their 95% CI were calculated with values less than one favouring the intervention group. For continuous outcomes, standardised mean differences were calculated using Hedges’ g.[17](#_ENREF_17) Where a sufficient number of studies were available, mean differences were calculated on original scales (e.g., portions of fruit and vegetables).

**Evidence Synthesis**

*Methods*

Meta-analyses: Random effects meta-analyses using Review Manager 5 software were calculated. Control conditions were grouped into three categories (minimal intervention, information provision, active control) to examine differences in effect estimates across these conditions.

Heterogeneity assessment was based on visual inspection of forest plots and the I2 statistic.[18](#_ENREF_18) A Q-value (approximating Χ2 distribution) of p<0.1 indicated statistically significant heterogeneity. Statistical heterogeneity was explored using meta-regression.

Meta-regression analyses: Mixed-effects meta-regression analyses (where there were at least 10 studies for an outcome) were conducted to examine the influence of implementation factors on effectiveness based on criteria from the *Oxford Implementation Index* [15](#_ENREF_15) and the *Behaviour Change Wheel*.[14](#_ENREF_14) A permutation test adjusted p-values to reduce risk of false positives.[19](#_ENREF_19) Although meta-regression analyses were planned in advance the findings should be considered exploratory given the large number of covariates examined.

Covariates relating to intervention characteristics included number of intervention functions, specific intervention functions (as defined by the *Behaviour Change Wheel*), method of delivery, intervention duration, staff characteristics, participant characteristics, intervention setting, publication period, and duration of follow up.

Additional analyses: Multivariate meta-analyses of correlated outcomes were compared with standard univariate meta-analyses. Subgroup analyses according to socio-economic position (SEP) (studies with predominantly low SEP versus mixed SEP), and ethnicity (participants were predominantly from a Black and Minority Ethnic population versus participants from Majority and Minority Ethnic populations) were conducted.

*Results*

Sixty-nine RCTs (comprising 73,873 participants) were included (Figure 1).

Risk of bias: Study quality was variable (online appendices). Blinding of participants and personnel was not included in the risk of bias assessment because it was not feasible given the nature of the interventions. Just over half of the studies had high risk of bias for at least one domain: incomplete outcome data (attrition bias) (n=27); other bias (n=8); blinding of outcome assessors (n=6); selective reporting (n=5); and allocation concealment (n=3).

Summary of contextual factors and population characteristics: Contextual factors, participant characteristics and intervention characteristics were extracted according to the *Oxford Implementation Index* (online appendices). Most studies were conducted in US (n=34), UK (n=9), Netherlands (n=6) and Australia (n=5). Settings varied including homes, community centres, churches, universities, primary care clinics, hospitals and prisons. Few studies reported information about the wider environment in which the intervention took place or characteristics of the delivering organisation. Data on other contextual factors such as occurrence of important external events at the time of intervention were limited.

General adult populations were the focus in most studies (n=32). Others targeted students (n=13), older adults (n=8), pregnant women (n=4), and prisoners (n=1). Some specifically targeted those on low incomes (n=8) or black and minority ethnic groups (n=5). There is some overlap in categories therefore summing the totals exceeds the number of included studies.

Risk behaviours: Most studies targeted two risk behaviours (n=32). Fewer studies targeted three (n=17), four (n=13), or five behaviours (n=2) (online appendices). Most (72%) targeted diet and physical activity with 46% focusing exclusively on these behaviours; 35% targeted diet and smoking but few focused exclusively on these behaviours; 23% targeted alcohol and smoking but few focused exclusively on these behaviours.

Summary of intervention characteristics:

Number of intervention functions ranged from one (n=8) to five (n=4), with most including three functions (n=28). Coercion and restriction were not included as part of any intervention and incentives and environmental restructuring were rarely used. Most (n=66) included an education function and just over half included education with training (n=39). Persuasion was also used in a number of studies (n=21). These functions are consistent with the mostly commonly adopted theoretical approaches, including Social Cognitive Theory,[20](#_ENREF_20) the Health Belief Model,[21](#_ENREF_21) and the Theory of Planned Behaviour[22](#_ENREF_22) (online appendices summarise intervention functions classified using the *Behaviour Change Wheel*,[14](#_ENREF_14) theoretical approaches reported, and risk behaviours targeted).

No clear patterns between particular risk behaviour combinations and use of specific intervention functions were detected. Studies targeting a larger number of behaviours did not appear to adopt more intervention functions than studies targeting two behaviours.

Although most studies (n=47) reported the theoretical basis of interventions, few reported examining changes in intermediate outcomes (e.g., attitudes, beliefs, and knowledge) predicted by theory to mediate behaviour change (online appendices).

Summary of participant uptake, fidelity of intervention and challenges to implementation:

Twenty-three studies provided process evaluation data (online appendices). These data were mostly related to participant uptake of materials such as pedometers, resistance bands, exercise calendars and written/online materials. Only four studies reported analyses of intervention fidelity or challenges to implementation.[23-26](#_ENREF_23)

Most studies that requested participant feedback found high levels of satisfaction both with materials provided (e.g. pedometers, exercise calendars, educational materials) and content of the intervention.[27-33](#_ENREF_27) While some studies did not find differences in satisfaction between participants in the intervention group compared with controls [34-36](#_ENREF_34) these interventions were compared with relatively active control groups.

Participant’s perceived effectiveness of interventions and engagement in behaviour change were less positive. Only 55% of participants in one study[27](#_ENREF_27) felt the intervention helped them to improve their diet. Similarly, another study[29](#_ENREF_29) found less than 50% of the participants considered the intervention effective in improving their diet and physical activity, with only 25% engaging in new activities. Although participants in another study [31](#_ENREF_31) were satisfied with their motivational interviewing session most provided neutral responses concerning perceived relevance. In another study[37](#_ENREF_37) several themes were identified in relation to participants’ perception of the intervention and subsequent impact on behaviour change: the importance of group interaction (such as accountability, but also disappointment when group members stop attending), encouragement provided by advisors, (such as improved motivation), and specific helpful aspects of the intervention (such as use of pedometers, goal-setting).

Summary of effectiveness data: Summary estimates from the meta-analyses are presented in Tables 2 and 3. Subgroup analyses according to control group category (minimal intervention/information provision/active control) did not substantially change the pooled results and are not discussed further.

Compared with control groups the intervention groups demonstrated a small increase in fruit and vegetable intake (0.31 portions; 95% CI 0.17 to 0.45), a small reduction in calorie intake (KCal -83.37, 95% CI -148.54 to -18.20) and fat intake (SMD -0.24; 95% CI -0.36 to -0.12) and a small increase in physical activity (SMD 0.25; 95% CI 0.13 to 0.38). However, the findings for physical activity were sensitive to an individual study[38](#_ENREF_38) where the intervention was more effective than in other studies (SMD=2.94). When this study was removed from the analysis the effect estimate (SMD 0.15, 95% CI 0.09 to 0.21) and heterogeneity (I2=61% compared with I2=93% when considering all studies) were substantially reduced.

Small-to-moderate improvements were found in overall diet score, fibre intake, calorie intake, sodium intake, alcohol use and reduction of sexual risk behaviours but there were few studies and some results lacked precision (i.e. wide CIs). There was also a statistically significant reduction in smoking (OR 0.78; 95% CI 0.68 to 0.90).

Two studies compared multiple and single risk behaviour interventions.[37](#_ENREF_37)[39](#_ENREF_39) One study [37](#_ENREF_37) compared an intervention targeting two behaviours (smoking and diet) with an intervention targeting a single behaviour (smoking). No statistically significant differences were found between groups for either smoking or diet. Another study compared physical activity alone, fruit and vegetable intake alone, combined physical activity and fruit and vegetable intake, and non-intervention control groups.[39](#_ENREF_39) The diet alone intervention was effective in increasing fruit and vegetable intake there was also supportive evidence for the physical activity intervention improving physical activity. However, it was inconclusive (as it was a relatively small study) whether the combined intervention improved either fruit and vegetable intake or physical activity.

Minimal reductions in weight (-0.59Kg; 95% CI -1.02 to -0.16) and BMI (-0.27 points; 95% CI -0.46 to -0.07) were found, compared with control conditions. Small reductions were also found in systolic blood pressure (SMD -0.11, 95% CI -0.19 to -0.04), diastolic blood pressure (SMD -0.10, 95% CI -0.16 to -0.04), total cholesterol (SMD -0.17, 95% CI -0.27 to -0.06), HDL-cholesterol (SMD -0.13, 95% CI -0.31 to 0.05) and LDL-cholesterol (SMD -0.17, 95% CI -0.34 to 0.00).

Data on intermediate outcomes were very limited. The most commonly reported (eight studies) outcome was self-efficacy where there was no evidence for improvement (SMD -0.06, 95% CI -0.17 to 0.06). Table 3 provides further details on secondary and intermediate outcomes.

Investigating potential moderators of effectiveness: A range of potential moderators of effectiveness were examined: intervention characteristics (e.g. follow up time, intervention characteristics (content), sequential or simultaneous targeting of risk behaviours); contextual factors (e.g. setting, geographic location, significant external events occurring at time of intervention); participant characteristics (e.g. ethnicity, income).

Follow up time

Length of follow up was a statistically significant predictor for meeting recommendations for fruit and vegetable intake explaining all heterogeneity. Longer follow-up was associated with reduced effectiveness compared with post-intervention follow-up (<6 month follow-up: slope=1.68, 95% CI 1.31 to 2.17, p=0.002); 6-12 month follow up: slope 1.54, 95% CI 1.26 to 1.97, p=0.005). Length of follow-up was not associated with any other outcome.

Intervention characteristics

Interventions including education, training and enablement intervention content (slope 0.22, 95% CI 0.07 to 0.38, adjusted r2=70.73%), adjusted p=0.015), and duration of intervention (slope 0.21, 95% CI 0.06 to 0.36, adjusted r2=64.23%, adjusted p=0.009) were associated with increased physical activity.

Enablement was associated with a reduced risk of smoking (slope 0.62, 95% CI 0.47 to 0.81, adjusted p=0.007), and longer duration of intervention was associated with less effectiveness in reducing risk of smoking (slope 1.53, 95% CI 1.71 to 2.01, adjusted p=0.001). Together these factors explained 79.33% of heterogeneity.

Simultaneous versus sequential targeting of risk behaviours

All studies examined simultaneous change of risk behaviours. Three studies [40-42](#_ENREF_40) compared simultaneous change with sequential change of risk behaviours and did not find statistically significant differences between interventions that aimed to changed diet and physical activity simultaneously and those that changed diet and physical activity sequentially. However, one study found that sequential interventions were more likely than simultaneous interventions to be effective in promoting smoking cessation (OR=1.51, p=0.004).41

Impact of contextual factors on effectiveness

There was insufficient evidence to determine whether contextual factors impacted on effectiveness for any outcomes.

Impact of population characteristics

Overall, there were in-sufficient data to conclude whether effectiveness differs between lower and higher income groups, or between Black and minority ethnic groups and majority ethnic groups (table 2).

Multivariate analyses: Comparisons of univariate analyses with the multivariate analyses generally did not reveal substantial differences (online appendices). The exception was the multivariate meta-analysis on smoking, meeting recommendations for fruit and vegetable intake, and meeting recommendations for physical activity. There was statistically significant evidence of improvement in fruit and vegetable intake in the univariate analyses (OR 0.62, 95% CI 0.51 to 0.84, p<.0001). However, in the multivariate meta-analysis effectiveness in improving fruit and vegetable intake reduced substantially (OR 0.84, 95% CI 0.68 to 1.03, p=0.09). This appears to be explained by a strong negative correlation between changes in smoking and fruit and vegetable intake (r=-0.95). In addition, changes in smoking behaviour were negatively associated with improvements in physical activity although less strongly (r=-0.44).

Moderate sized correlations were found between all of the other behaviours included in the multivariate meta-analyses. Improvements in fruit and vegetable intake (r=0.53), calorie intake (r=0.56), fat intake (r=0.52) and physical activity (r=0.52) were all associated with weight loss in a similar magnitude suggesting that all are important strategies for reducing weight.

A stronger association was found between improvements in fruit and vegetable intake (r=0.56) and changes to total cholesterol than fat intake (r=0.41). Conversely, improvements in fat intake (sBP: r=0.63, dBP: r=0.43) appeared to be more strongly associated with improvements in both systolic blood pressure and diastolic blood pressure than was fruit and vegetable intake (sBP: r=0.52, dBP: r=0.23).

Increased physical activity was strongly associated with changes to total cholesterol (r=0.87), moderately associated with changes in systolic blood pressure (r=0.39), but there was no association with changes to diastolic blood pressure (r=0.05).

**Conclusions**

*Summary of principal findings*

A systematic review was conducted assessing effects of multiple risk behaviour interventions in general adult populations. Studies specifically targeting at risk populations including those at risk of cardiovascular disease or who are obese were excluded. Sixty-nine RCTs were included with a total of 73,873 participants. Diet and physical activity were most frequently targeted and interventions consisted mainly of education combined with skills training. All 69 trials examined the simultaneous change of behaviours, and three[40-42](#_ENREF_40) compared simultaneous with sequential change. Overall, small improvements in diet (e.g., fruit and vegetable, fat, and calorie intake), physical activity and smoking were found, but effects diminished over time for fruit and vegetable intake. Multivariate analyses suggested weight-loss was equally associated with improvements in fruit and vegetable intake, fat intake, calorie intake and physical activity.

Reductions in smoking were negatively associated with improvements in fruit and vegetable intake and physical activity. This is consistent with the finding that interventions that targeted smoking and other risk behaviour sequentially are more effective than those that seek simultaneous change. [41](#_ENREF_41)In contrast, no statistically significant differences were found in the three studies that compared sequential and simultaneous change of diet and physical activity.[40-42](#_ENREF_40)

Most interventions were based on a social cognitive theoretical approach but intermediate outcomes were reported infrequently, which makes it difficult to assess the theoretical assumptions of these interventions. Self-efficacy is a key component of social cognitive theory and was the most commonly reported intermediate outcome. In studies that reported this outcome, interventions did not appear to be effective in improving self-efficacy. More consistent reporting of intermediate outcomes is needed to comprehensively evaluate the effectiveness of multiple risk behaviour interventions and to examine the validity of their theoretical assumptions.

*Findings in context*

This systematic review adds to our knowledge of multiple risk behaviour change by providing a comprehensive evaluation of non-pharmacological interventions targeting two or more risk behaviours in non-clinical adult populations. An earlier Cochrane review on multiple risk factor reduction assessed distal outcomes such as mortality, and fatal and non-fatal coronary heart disease and found limited evidence of benefit from education and counselling interventions on these outcomes.[43](#_ENREF_43) Similarly, a recent review of non-pharmacological multiple risk behaviour interventions delivered in the workplace found small benefits in diet, physical activity and smoking.[44](#_ENREF_44)[45](#_ENREF_45) However, the review did not distinguish between studies targeting multiple and single behaviours.

It was not possible to compare relative effectiveness of multiple and single risk behaviour interventions as only two studies addressed this question. However, other systematic reviews have evaluated the effects of similar (non-pharmacological) interventions on individual behaviours. Overall, the findings are comparable to those from this review. For example, interventions to improve diet in general populations increased servings of fruit and vegetables by a similar amount to the interventions included in this review (0.5 vs 0.31 more servings).[44](#_ENREF_44)[46](#_ENREF_46) Reviews focusing on physical activity[47](#_ENREF_47)[48](#_ENREF_48) [49](#_ENREF_49) reported small improvements (~SMD 0.2) similar to those found in this review (SMD = 0.25).

*Implications and future direction*

The large number of studies and consistency of findings argues against further trials focusing on the use of education and skills training to target risky behaviours. Similarly, the large number of trials focusing on simultaneous change of multiple behaviours suggests no further evidence is needed. In contrast, a key evidence gap relates to the sequencing of intervention components. Only three studies examined sequential change and therefore our findings are inconclusive. Evidence is lacking on how various intervention components might be ordered to maximise impacts on risk behaviours. Understanding how people approach behaviour change, especially when multiple behaviours are involved, is important. A UK-based qualitative study found that people differ in their strategies for change, with some preferring to make changes simultaneously, viewing each behaviour as part of a healthier lifestyle and others sequentially, seeing behaviours as discrete and easier to change when broken down into manageable chunks.[51](#_ENREF_51)

The present review indicates that interventions comprising education and skills training are associated with modest reductions in risk behaviours. At best, these interventions achieve small changes which may not translate into meaningful reductions in risk of mortality and CVD disease-related mortality.40 Whilst information and skills are important they should be considered alongside other factors that influence behaviour. Lack of social support, cost of adopting healthy behaviours, balancing health behaviours with everyday life (e.g. routines, time management), cultural preferences, and environmental barriers are likely to be equally important.[52](#_ENREF_52) Individuals are influenced not only by their motivation and capability to make behavioural changes but also by opportunities afforded by the social and physical environment. [14](#_ENREF_14) The impact of the physical and social environment on behaviour is increasingly recognised and advocates of the Social-Ecological approach [53](#_ENREF_53) argue that risk behaviours need to be understood within the context of social and physical environmental factors. These include the home and workplace as well as broader societal factors such as income inequality that impact on individuals and groups.[54](#_ENREF_54)

However, the present systematic review identified few studies that incorporated environmental changes as part of the intervention package; where included, the focus was on the social rather than the physical environment. Despite the lack of evidence in support of environmental restructuring for changing health behaviours, findings from field and laboratory experiments suggest that human behaviour is prompted by cues in the environment[55](#_ENREF_55)[56](#_ENREF_56) and such approaches have been explored extensively in the discipline of environmental psychology. This promising approach to large scale behaviour change requires thorough evaluation through good quality observational studies and where feasible RCT’s.

*Strengths and limitations*

Strengths of this review include comprehensive and rigorous searching and the mapping exercise to determine inclusion criteria.[11](#_ENREF_11) It was assessed whether restricting to RCTs would limit type of interventions eligible for inclusion and found this was unlikely to be the case. This is a particular issue with reviews of public health interventions and has been referred to as an “inverse evidence law” whereby least is known about the effects of interventions most likely to influence whole populations because they tend to be evaluated using less rigorous methods.[57](#_ENREF_57)

Other strengths include use of the *Behaviour Change Wheel* to classify intervention components according to a standard set of functions. This enables identification of “active ingredients” across interventions and studies.

Limitations include the variable quality of the RCTs. Just over half of the studies had a high risk of bias for at least one of the domains assessed. Studies varied in the way they measured behaviours, particularly physical activity and alcohol intake, which made comparisons difficult. Reporting of intermediate outcomes such as self-efficacy, attitudes and knowledge was limited and importantly, few studies provided contextual information, for example about important external events occurring at the time of the intervention.

Few studies analyzed their results by subgroup. This is an important evidence gap: public health interventions, particularly those focusing on “downstream” interventions such as education and skills training, have the potential to increase health inequalities by disproportionately benefiting more advantaged groups.[55](#_ENREF_55)[58](#_ENREF_58) Although most studies reported data on income, occupation, education, ethnicity and gender, and a few specifically targeted low income[26](#_ENREF_26)[59-65](#_ENREF_59) or black and ethnic minority groups[25](#_ENREF_25)[33](#_ENREF_33)[64](#_ENREF_64)[66](#_ENREF_66)[67](#_ENREF_67) it was not possible to explore equity effects in a meaningful way.

To ensure homogeneity in our population we focused on non-clinical adult populations which means that a number of studies targeting specific at risk populations, such as those who are obese or at high risk of cardiovascular disease, were excluded. Further systematic reviews are needed to address the effectiveness of multiple risk behaviour interventions in these populations.

*Conclusion*

This is the first systematic review to provide overall estimates of the impact of non-pharmacological interventions on multiple lifestyle risk behaviours in non-clinical, adult populations. Interventions, mainly consisting of education and skills training, targeting multiple risk behaviours resulted in small improvements in diet (e.g., fruit and vegetable intake) and physical activity and smoking. Such approaches result, at best, in small reductions in risk behaviours, which fail to translate into meaningful reduction in risk of overall mortality and CVD disease-related mortality.

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**Figure 1 Study Flow Diagram**

**Table 1 Summary of Behaviour Change Wheel (adapted from Michie et al)14**

|  |  |  |
| --- | --- | --- |
| **Functions** | **Definition** | **Examples** |
| **Interventions** |
| Education | Seeking to provide or increase knowledge | Educational material provided through lectures, online or written materials |
| Persuasion | Seeking to induce positive or negative feelings that impacts on behaviour | Using motivational interviewing to change behaviour |
| Incentivisation | Providing positive reinforcement to change behaviour | Providing vouchers contingent on engaging in a particular healthy behaviour |
| Coercion | Providing negative reinforcement or punishment to change behaviour | Having to pay a fine for engaging in a risk behaviour |
| Training | Training participants to develop skills that help them to engage in healthy behaviour | Teaching cooking skills to people who have an unhealthy diet |
| Restriction | Using rules to reduce or increase a particular behaviour | Prohibiting the use of novel psychoactive substances |
| Environmental restructuring | Intervening in the social or physical context to promote or reduce particular behaviours | Integrating a health promotion programme within the regular social activities of an African American church to encourage behaviour change in their members |
| Modelling | Providing an example of someone engaging in a behaviour or changing their behaviour  | Recruiting people who inject drugs and train them to promote use of clean needles within their social networks |
| Enablement | Reducing barriers and providing support to help behaviour change | Providing pedometers to help participants monitor their activity levels |
| **Policies** |
| Communication/marketing | Using media (e.g. newspapers, social media, television) to promote healthy behaviour | Conducting mass media campaigns |
| Guidelines | Developing guidance recommending engaging or not engaging in particular behaviours | National guideline programmes such as the National Institute for Health and Care Excellence |
| Fiscal | Taxing unhealthy behaviours or offering subsidies to promote healthy behaviour | Increase taxes on tobacco, high sugar foods |
| Regulation | Rules or principles that encourage healthy behaviour | Voluntary agreements on advertising of unhealthy foods or drinks |
| Legislation | Legislating against unhealthy behaviour | Prohibiting the sale of tobacco to certain age groups |
| Environmental/Social planning | Policies related to the physical or social environment | Town planning to make cycling safer and more accessible to citizens |
| Service provision | Providing a service that promotes healthy behaviour | Local authorities providing affordable and accessible gyms |

**Table 2 Summary point estimates from the meta-analyses of multiple risk behaviour interventions (primary outcomes)**

|  |  |  |
| --- | --- | --- |
| **Risk behaviour outcome** | **Summary point estimate** | **Follow up time** |
| **All**  | **Low SES** | **BME** |
| **Dichotomous data** |  |  |  |  |
| Lack of fruit and vegetable intake: not adhering to F&V recommendations | **OR 0.62 (95% CI 0.51 to 0.76) I2=81% K=11** | **OR 0.65 (95% CI 0.44 to 0.83) I2=48% K=3** | OR 0.65 (95% CI 0.38 to 1.12) I2=N/A K=1 | mean:4monthsrange:endpoint to 12months |
| Intake of fat/meat/dairy: not adhering to recommendations  | **OR 0.70 (95% CI 0.61 to 0.81) I2=0% K=3** | **OR 0.73 (95% CI 0.61 to 0.88) I2=N/A K=1** | N/A | mean:5monthsrange:endpoint to 8months |
| Physical activity: not adhering to physical activity recommendations | **OR 0.73 (95% CI 0.65 to 0.83) I2=64% K=19** | OR 0.85 (95% CI 0.72 to 1.00) I2=0% K=4 | **OR 0.58 (95% CI 0.38 to 0.87) I2=N/A K=1** | mean: 4monthsrange:endpoint to 12months |
| Smoking | **OR 0.78 (95% CI 0.68 to 0.90) I2=63 K=17** | N/A | N/A | mean:4monthsrange:endpoint to 12months |
| Alcohol misuse: not adhering to alcohol intake recommendations | OR 0.84 (95% CI 0.65 to 1.08) I2=60% K=5 | N/A | OR 0.59 (95% CI 0.20 to 1.76) I2=N/A K=1 | mean:5monthsrange:endpoint to 12months |
| **Continuous data** |  |  |  |  |
| Calorie intake  | **MD -83.37 (95% CI -148.54 to** **-18.20) I2=80% K=9** | N/A | N/A | mean:3monthsrange:endpoint to 12months |
| Fruit and vegetable intake (postintervention) | **SMD 0.17 (95% CI 0.11 to 0.23) I2=61% K=22****Portions of fruit and vegetables:** **MD 0.31 (95% CI 0.17 to 0.45) I2=56% K=13** | **SMD 0.22 (95% CI 0.13 to 0.31) I2=0% K=2****Portions of fruit and vegetables:** **MD 0.48 (95% CI 0.32 to 0.64)** **I2=0% K=3** | **SMD 0.14 (95% CI 0.06 to 0.22) I2=0% K=3****Portions of fruit and vegetables: MD 0.37 (95% CI 0.15 to 0.59) I2=0% K=2** | mean:5monthsrange:endpoint to 12months |
| Intake of fat/meat/dairy (postintervention) | **SMD -0.24 (95% CI -0.36 to -0.12) I2=82% K=17** | **SMD -0.14 (95% CI -0.22 to -0.06) I2=0% K=3** | SMD -0.04 (95% CI -0.15 to 0.08) I2=0% K=2 | mean:4monthsrange:endpoint to 12months |
| Physical activity (postintervention) | **SMD 0.25 (95% CI 0.13 to 0.38) I2=93% K=27** | **SMD 0.05 (95% CI 0.18 to 0.29) I2=56% K=3** | **SMD 0.12 (0.01 to 0.23) I2=32% K=3** | mean:5monthsrange:endpoint to 12months |
| Sexual risk behaviours | SMD -0.12 (95% CI -0.49 to 0.24) I2=32% K=3 | N/A | N/A | mean:4monthsrange:1 to 6 months |

BME, Black and Minority Ethnic groups; F&V, fruit and vegetable intake; K, number of trials; MD, mean difference; N/A, not applicable; SES, socio-economic status; SMD, standardized mean differences. Results in bold are statistically significant.

**Table 3 Summary point estimates from the meta-analyses of multiple risk behaviour interventions (secondary and intermediate outcomes)**

|  |  |  |
| --- | --- | --- |
| **Outcome** | **Summary point estimates** | **Follow up time** |
| **All** | **Low SES** | **BME** |
| Self-efficacy | SMD -0.06 (95%CI -0.17 to 0.06) I2=71% K=8 | N/A | **SMD 0.16 (0.02 to 0.30)****I2=N/A K=1** | mean: 4 monthsrange: endpoint to 9 months |
| Weight (kg) | **MD -0.59 (95% CI -1.02 to -0.16) I2=57% K=18** | MD -0.76 (95% CI -2.30 to 0.79) I2=41% K=3 | **MD -0.88 (-1.47 to -0.29)** **I2=N/A K=1** | mean:5monthsrange: endpoint to 12months |
| BMI (kg/m2) | **MD -0.27 (95% CI -0.46 to -0.07) I2=65% K=14** | MD -0.58 (95% CI -1.45 to 0.29)I2=7% K=2 | **MD -0.31 (95% CI -0.53 to -0.09)****I2=N/A K=1** | mean:5monthsrange: endpoint to 15months |
| Systolic blood pressure | **SMD -0.11 (95% CI -0.19 to -0.04) I2=56% K=13** | SMD 0.07 (-0.20 to 0.34) I2=N/A K=1 | SMD -0.06 (-0.31 to 0.19) I2=N/A K=1 | mean: 6 monthsrange: endpoint to 24 months |
| Diastolic blood pressure | **SMD -0.11 (95% CI -0.19 to -0.04)** **I2= 51% K=13** | SMD 0.00 (-0.27 to 0.27)I2=N/A K=1 | SMD -0.10 (-0.34 to 0.14)I2=N/A K=1 | mean: 6 monthsrange: endpoint to 24 months |
| Total cholesterol | **SMD -0.17 (95% CI -0.27 to -0.06)** **I2= 81% K=12** | SMD 0.00 (-0.27 to 0.27)I2=N/A K=1 | SMD -0.09 (-0.34 to 0.16)I2=N/A K=1 | mean: 6 monthsrange: endpoint to 24 months |
| HDL cholesterol | SMD -0.13 (95% CI -0.31 to 0.05) I2= 87% K=9 | SMD -0.12 (-0.39 to 0.15)I2=N/A K=1 | SMD -0.11 (-0.35 to 0.13)I2=N/A K=1 | mean: 8 monthsrange: endpoint to 24 months |
| LDL cholesterol | SMD -0.17 (95% CI -0.34 to 0.00) I2= 85% K=9 | SMD -0.04 (-0.31 to 0.23)I2=N/A K=1 | SMD -0.09 (-0.33 to 0.15)I2=N/A K=1 | mean: 8 monthsrange: endpoint to 24 months |

BME, Black and Minority Ethnic groups; K, number of trials; MD, mean difference; N/A, not applicable; SES, socio-economic status; SMD, standardized mean differences. Results in bold are statistically significant.