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# Effectiveness of lifestyle interventions/culturally bespoke programmes in South Asian ethnic groups targeting weight loss for prevention and/or remission of type 2 diabetes: a systematic review and meta-analysis of intervention trials

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## Abstract

**Background:** People from South Asian heritage are at high risk of type 2 diabetes, but there are limited specific strategies to prevent and manage this condition. The aim was to assess the effectiveness of culturally bespoke lifestyle programmes in South Asians that target weight loss for the prevention or remission of type 2 diabetes mellitus (T2DM).

**Methods:** We performed a systematic review and meta-analysis of intervention trials. PubMed, Scopus, MEDLINE (EBSCOhost), CINAHL, PsycINFO and CENTRAL were searched. Human intervention trials (randomised controlled trials and quasi-experimental) investigating the effect of lifestyle interventions on the prevention and remission of T2DM in South Asians were included. Studies including participants at risk of T2DM (prevention trials) and having the disease (remission trials) with duration ≥12 weeks were eligible. For prevention trials, the primary outcome was change in weight (kg) from baseline; for remission trials, it was decrease in HbA1c to non-diabetic levels (HbA1c ≤ 6.5%) without diabetes medications. Prevention trials were separated into (i) lifestyle modification advice and (ii) lifestyle modification advice including a supervised physical activity programme.

**Results:** Twenty-four trials were eligible (21 prevention trials and 3 remission trials). In T2DM prevention trials involving only lifestyle modification advice, the mean postintervention difference in weight between intervention and control groups was −0.65 kg (95% confidence interval [CI]: −1.04, −0.26; $p = 0.01$). Lifestyle modification advice including a physical activity programme was associated with greater decreases in weight: −1.13 kg (95% CI: −2.04, −0.21; $p = 0.02$). Fasting blood glucose levels were slightly lower in intervention groups for both intervention subtypes, although there was no significant change in HbA1c levels or 2-h plasma glucose levels.

Diabetes remission trials showed potential acceptability but were limited in number and involved a small sample size, and some did not include a control group.

**Conclusions:** In South Asians, lifestyle interventions for prevention of T2DM offer only modest impacts on weight and glucose control and will unlikely reduce diabetes incidence. Alternative lifestyle interventions co-designed with members of the communities and aimed at both prevention and remission of

T2DM must be urgently considered. Systematic review registration number: PROSPERO CRD42022385174 https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=385174

**KEYWORDS**
diabetes remission, diet, lifestyle intervention, obesity, South Asian population, type 2 diabetes

**Key points**

- People from South Asian heritage are at high risk of type 2 diabetes.
- Weight loss is the cornerstone of type 2 diabetes prevention and remission.
- There are limited specific strategies to prevent and manage type 2 diabetes in South Asians.
- Lifestyle interventions that aimed to prevent type 2 diabetes in South Asians produced modest effects on weight and glycaemic control and will unlikely reduce diabetes incidence in this population.
- Diabetes remission trials could potentially be effective and acceptable although they are to date limited in number.
- Our results can help clinicians and researchers consider alternative lifestyle interventions to reduce diabetes risk and develop further trials of diabetes remission in South Asians.

## INTRODUCTION

Recent years have witnessed a further escalation in the prevalence of people living with obesity and type 2 diabetes mellitus (T2DM) worldwide, exceeding the projections for both conditions.[1] Excess body weight is a major contributor to T2DM risk, with about 2 billion people living with higher body weight and obesity, and 422 million people live with T2DM worldwide.[1,2] This increasing prevalence extends to the South Asian population (SAP), which includes people with heritage from India, Pakistan, Bangladesh, Nepal, Bhutan and the Maldives[3] and whose people make up a quarter of the world's population.[4] People with SAP heritage have a significantly higher risk of developing T2DM compared with White populations,[5,6] with T2DM also occurring at a younger age and a lower body mass index (BMI).[4,7] In the United Kingdom, people with a South Asian heritage are the second-largest ethnic group (7% of the UK population) and yet constitute 20% of people living with diabetes.[7] This higher risk is likely to be attributed to genetic differences associated with a higher liver fat deposition[8] and a lower β cell function.[9] Lifestyle differences, including diet (high in carbohydrates and potentially high in saturated fats), and lower levels of physical activity along with societal inequities, including poverty, are potentially additionally involved in exacerbating the risk of diabetes in South Asians.[7]

Weight loss is the cornerstone of diabetes prevention and remission; the latter is defined as HbA1c levels below the diabetes threshold (HbA1c ≤ 6.5%) for at least 3 months without diabetes medications.[10] Small amounts of weight loss can reduce diabetes risk,[11] yet T2DM remission, initially shown to be achieved through bariatric surgery[12] and later through very low-calorie diets,[13,14] requires larger amounts of weight loss. This substantial weight loss reduces liver and pancreatic fat, which are potential mechanisms by which T2DM prevention and remission can be achieved.[14,15]

Despite the significant research interest in addressing weight management and diabetes risk in the SAP, there are limited specific strategies to prevent and manage the condition. This is primarily due to a low uptake or inclusion of people of SAP heritage in research trials,[13,16] which has been attributed to cultural barriers, low perception of disease risk, lack of knowledge and reluctance to change lifestyle due to the perceived associations between diet and cultural identity. The importance of participating in cultural celebrations can also hinder adherence to recommended diets.[7,17,18] Additionally, the subethnic differences in people of SAP heritage, including cultural and language differences, are often overlooked, and this can affect the development of culturally tailored interventions for different people of SAP heritage ethnic subgroups.[19]

Recent reports highlighted that lifestyle interventions produce modest or no significant weight changes in populations of SAP heritage,[20,21] suggesting the need to test specific interventions that can support weight loss and maintenance.[22] This systematic review aimed to examine the effectiveness of interventions in South Asians designed to prevent and/or reverse T2DM. Our aims were to assess the potential of lifestyle programmes (focusing on diet and/or physical activity) in reducing body weight and glucose parameters (fasting blood glucose [FBG], 2-h plasma glucose during oral glucose

tolerance testing and HbA1c levels) for the prevention and remission of T2DM.

## METHODS

We registered our study on PROSPERO CRD42022385174 and performed a systematic review using the methodology outlined in the *Cochrane Handbook for Systematic Reviews*.[23] Our protocol was revised to include those at high risk of diabetes regardless of weight status. Trials designed to lower cardiovascular risk were considered as they often assessed weight and glycaemic markers. Our search strategy was also extended to include two more databases (CINHAL and PsycINFO) given the lifestyle intervention elements of this review. We report our findings based on PRISMA guidelines.[24,25]

### Search strategy

One author (G.F.) conducted a systematic literature search between 12 December 2022 and 10 January 2023 in PubMed, Scopus, MEDLINE (EBSCOhost), CINAHL, PsycINFO and Cochrane Central Register of Controlled Trials from the date of inception to 10 January 2023, using the following keywords: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet). No MeSH (Medical Subject Headings) terms were used in the searches. We included human randomised controlled trials (RCT) and quasi-experimental studies (with no control group) investigating the effect of lifestyle interventions on the prevention and remission of T2DM in South Asians. For trials to be considered eligible, our operational definition of a lifestyle intervention was any intervention including a diet and/or physical activity element. The reference lists of selected trials and recent systematic reviews[26,27] were additionally searched for more relevant research.

### Study selection and data extraction

Duplicate records, records deemed ineligible by automation tools and protocols, were excluded before screening. References were then screened by two authors (G.F. and D.D.M.) who independently screened study titles, abstracts and full texts. Disagreements in the assessment of data were resolved by discussion, and consensus was reached in all cases. Trials were first stratified into diabetes prevention trials and diabetes remission trials. Prevention trials were then separated into (i) lifestyle modification advice on diet and physical activity and (ii) lifestyle modification advice including a supervised physical activity programme. Data on study design, participant information (BMI, age, gender and subethnicity), study setting, study location, attrition rate and outcome measures (body weight, BMI, HbA1c, FBG and 2-h plasma glucose levels) were extracted by G.F. Baseline and postintervention values and mean difference from baseline data were collected. We contacted authors for missing data and further information.[12,19,22,28–34] Four authors responded and provided requested data.[28,30,31,34]

### Eligibility criteria

Trials included were human intervention trials investigating the effects of lifestyle and/or behavioural interventions on weight and markers of glycaemia (through at least two measurements of HbA1c, FBG and/or 2-h plasma glucose levels taken from oral glucose tolerance testing) for the prevention and remission of T2DM. Eligible trials included only people of SAP heritage with/at risk of T2DM. Eligibility of trials was restricted to those with a duration of no less than 12 weeks and those published in the English language. Control groups included people receiving either a general lifestyle advice (on healthy diet and physical activity recommendations) or no intervention. The inclusion and exclusion criteria are presented in Table 1.

### Outcome measures

For diabetes prevention trials, the primary outcome was change in body weight (kg) or BMI ($kg/m^2$) from baseline. Secondary outcomes included any measure of glycaemic control (FBG (mmol/L), HbA1c (%) or 2-h plasma glucose levels (mmol/L). With respect to diabetes remission trials, the primary outcome was a decrease in HbA1c to non-diabetic levels (HbA1c ≤ 6.5%) at the end of the intervention without the use of diabetes medications. Secondary outcomes included change in weight, BMI and/or any other measure of glycaemic control (FBG or 2-h plasma glucose levels).

### Risk of bias

Risk of bias was assessed by one author (G.F.) and moderated by a second author (D.D.M.) using the Cochrane risk of bias tool.[35] The tool includes five domains for the assessment of the risk of selection bias, performance bias, detection bias, attrition bias and reporting bias. We rated each domain as high, low or unclear risk of bias. A high risk of attrition bias was defined as dropout rate ≥20%.[36] If any of the domains was determined to have a high risk of bias in a trial, then the overall risk of bias was considered to be high, as specified in the *Cochrane Handbook for Systematic Reviews* for assessing the risk of bias.[35]

TABLE 1 Review inclusion and exclusion criteria.

| | Inclusion criteria | Exclusion criteria |
|---|---|---|
| Language | English language | |
| Population | People of South Asian heritage defined as being Indian, Nepali, Pakistani, Bangladeshi, Sri Lankan, Maldives (Dhivehi) (adults ≥18 years) with T2DM (HbA1c ≥ 6.5%) or at risk of T2DM (BMI ≥ 23 kg/m$^2$ and/or impaired glycaemic control[a]) | Children and adolescents<br>Pregnant women<br>Trials including non-South Asians (multiethnic trials in which data on South Asians were not separately reported) |
| Setting | Any setting | |
| Interventions | Lifestyle interventions for obesity or type 2 diabetes | Lifestyle interventions for cancer<br>Pharmacological/surgical interventions<br>Dietary supplementation trials |
| Comparator | No intervention or general lifestyle advice (healthy diet and physical activity recommendations) | Intake of diabetes medications |
| Outcomes | BMI, body weight, HbA1c, fasting blood glucose, 2-h plasma glucose[b] | |
| Study duration | ≥3 months | |

Abbreviations: BMI, body mass index; T2DM, type 2 diabetes mellitus.

[a]Impaired glycaemic control includes impaired fasting glucose, impaired glucose tolerance, HbA1c in the prediabetes range or any other suitable measurements for assessing impaired glycaemic control.

[b]Two-hour plasma glucose levels are based on the oral glucose tolerance test results.

## Data analysis

Meta-analyses were conducted using Review Manager 5.4 software. Data for change in weight (kg), BMI (kg/m$^2$), HbA1c (%), FBG (mmol/l) and 2-h plasma glucose (mmol/L) were expressed as mean differences and 95% confidence intervals (CI), which were calculated as changes from baseline levels. Due to the unavailability of original data, it was not possible to convert HbA1c values (%) to the International Federation of Clinical Chemistry unit (mmol/mol), therefore the adoption of the Diabetes Control and Complications Trial unit. When standard deviation (SD) of change was not available, it was estimated by using baseline and end-of-treatment SD and a correlation coefficient (between baseline and final measurements) imputed from another study in the meta-analysis,[21] as described in the *Cochrane Handbook for Systematic Reviews* on including variants in randomised trials.[37]

As it was expected that the treatment effects would vary across trials, pooled mean differences were estimated using a random effects model. Funnel plots were produced to examine small study effects. Where possible, subgroup analyses were conducted based on study duration (<12 or ≥12 months), type of advice (general vs. personalised advice), study location (inside or outside the Indian subcontinent) and study setting (community, research setting or primary care). Studies with no control groups were excluded from the meta-analysis. Sensitivity analysis was performed to examine the impact of risk of bias on the outcomes. Heterogeneity of studies was assessed using $I^2$ statistic. Publication bias was assessed by visual examination of asymmetry in funnel plots and Egger's regression-based test using SPSS software (version 28).

## Patient and public involvement

The research question was developed following a recent patient and public engagement activity carried out in the north of England,[38] which aimed to assess the acceptability of total diet replacement among a group of people of SAP heritage. When this intervention was deemed largely unacceptable by this group, we aimed to assess the effectiveness of previous interventions and, when possible, to identify the more successful trial elements that could assist in the development of more effective and acceptable interventions in this population.

# RESULTS

Our study selection process is summarised in Figure 1. The search identified 24 eligible trials (21 diabetes prevention trials and 3 diabetes remission trials), of which 16 were RCTs and 8 were quasi-experimental, with no control group. Prevention trials looked at the effects of lifestyle interventions on weight (16 trials, number of participants $n = 8283$), BMI (18 trials, $n = 8673$), FBG (15 trials, $n = 2873$), HbA1c (8 trials, $n = 7672$) and 2-h plasma glucose levels (6 trials, $n = 2016$). Six of the prevention trials did not include a control group and were therefore excluded from the meta-analyses but were still included in the review, as they could potentially provide insights in relation to successful intervention

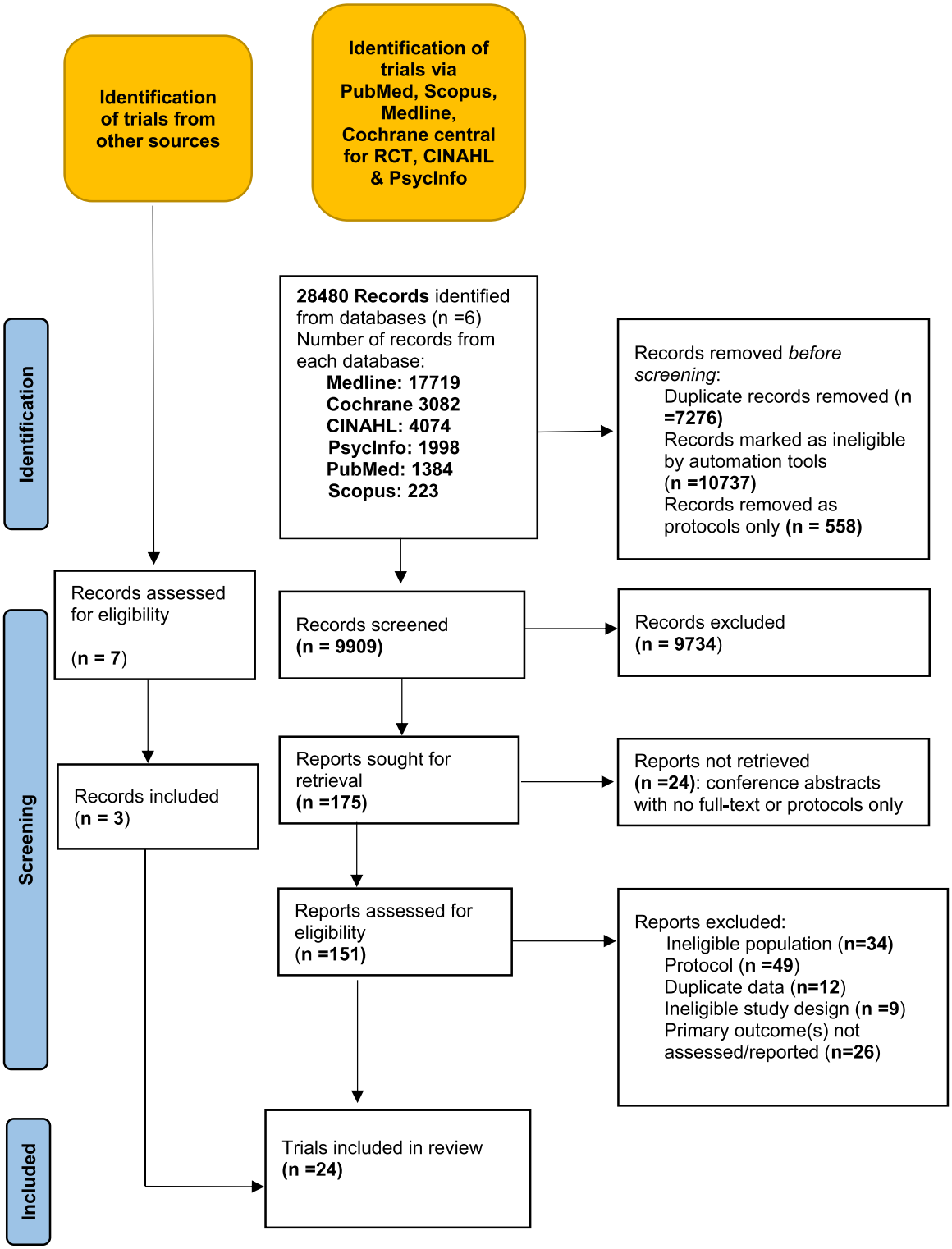


**FIGURE 1** PRISMA flow diagram of included trials. Search algorithm for each of the databases was as follows: PubMed search: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet); no filters; sort by: most recent. Medline search: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet); filters: English language, academic journals; sort by: most recent. CINAHL search: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet); filters: English language, academic journals, age (all adults 18 years and older); sort by: most recent. PsycINFO search: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet); filters: English language, academic journals; sort by: most recent. Cochrane search: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet); filters: English language; sort by: most recent. Scopus search: (Asian OR Indian OR Pakistani OR Bangladeshi OR Sri Lanka OR Nepal OR Maldives) AND (Obesity OR Type 2 diabetes OR Lifestyle OR Diet); sort by: most recent.

elements. Three trials looking at the effects of lifestyle intervention on T2DM remission ($n = 69$) were not eligible for meta-analysis because two of them did not include a control group.

The characteristics of the included trials are presented in Supporting Information: 1. Prevention trials were conducted in India ($n = 9$),[31,33,39–45] the United Kingdom ($n = 5$),[15,34,46–48] the United States ($n = 3$),[20,22,30] Norway ($n = 2$),[29,49] the Netherlands ($n = 1$),[21] New Zealand ($n = 1$),[32] Australia ($n = 1$),[50] both India and the United Kingdom,[11] and one trial took place in India, Pakistan, Sri Lanka and the United Kingdom.[28] Two trials included only men,[29,39] whereas four trials included only women.[34,47,49,51] Trial duration ranged from 3 to 36 months. Trials were carried out in community settings ($n = 13$),[20,22,28–31,34,39,41,43,47,49,51] primary care settings ($n = 4$)[11,15,21,52] or research settings ($n = 6$).[32,33,42,44–46] For diabetes prevention trials, we categorised them as (i) lifestyle modification advice on diet and physical activity ($n = 18$),[11,20,22,28,30–34,39–42,46,47,49,51,52] which included general or personalised advice on healthy eating and following physical activity recommendations; or (ii) lifestyle modification advice (general or personalised), including a supervised physical activity programme[21,29,43] ($n = 3$). The risk of diabetes at entry was assessed differently across trials but was predominately examined through participants having excess weight with or without impaired glycaemic control (defined as impaired fasting glucose, impaired glucose tolerance, HbA1c in the prediabetes range, elevated homeostasis modelling assessment-insulin resistance) or through an Indian diabetes risk score (≥50[30] or ≥60[31]). In diabetes remission trials, daily energy intake ranged between 850 and 1500 kcal in the form of either foods or meal replacement.[15,44,45]

The risk of bias for the included trials is presented in Figure 2. Due to the nature of the interventions, most trials were unblinded, and whereas some trials took measures that mitigated bias, others remained at high risk of detection and performance bias. Six trials presented a high risk of attrition bias. For prevention studies included in the meta-analysis, details of the percentage of trials that were at high, low or unclear risk of bias are presented in Figure 3.

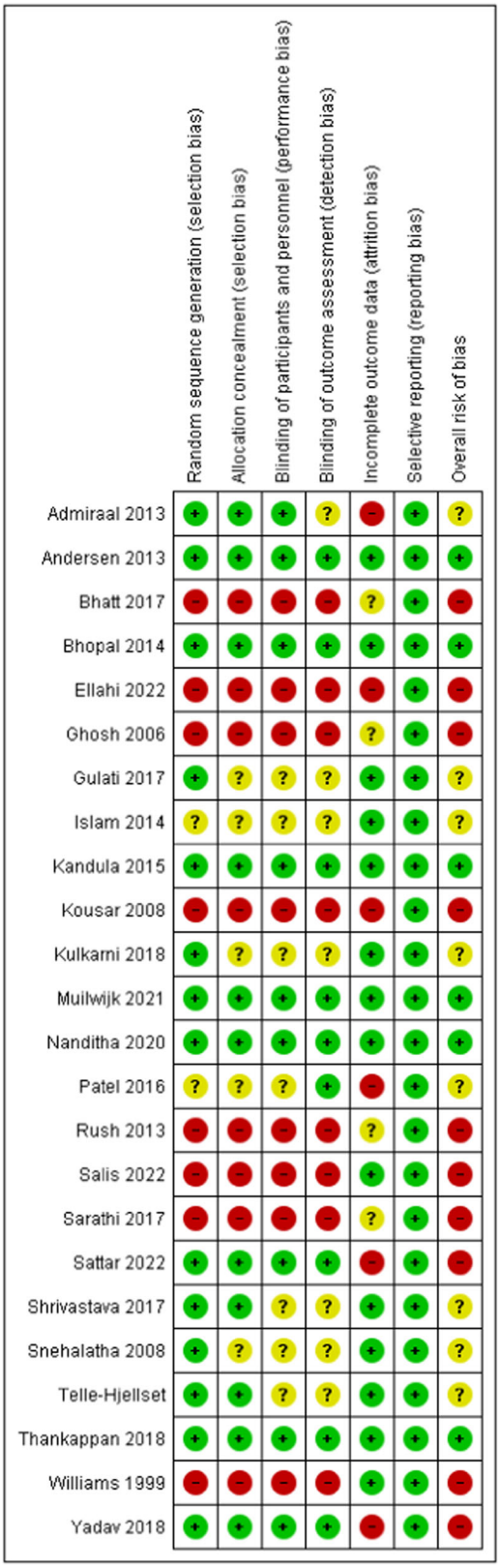


FIGURE 2 Risk of bias in all trials included in the review. +, low risk; –, high risk; ?, unclear risk.

## Diabetes prevention trials

### Weight change

A random effects meta-analysis of mean change in weight (kg) and BMI (kg/m$^2$) showed that participants assigned to intervention groups had modest weight loss when compared with control groups. In T2DM prevention trials that involved lifestyle modification advice only, the mean postintervention difference in weight

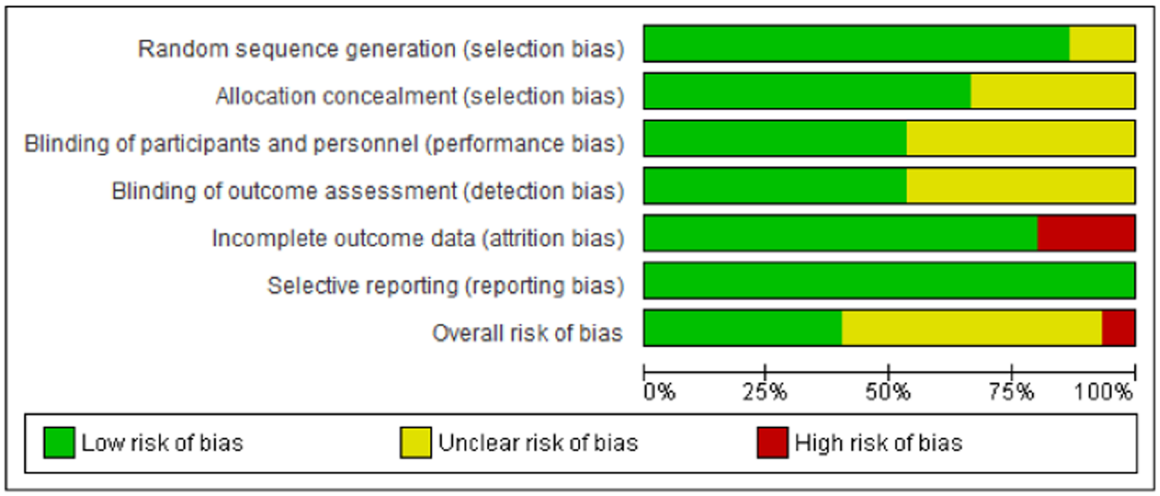


FIGURE 3 Overall risk of bias summary in prevention trials included in the meta-analyses.

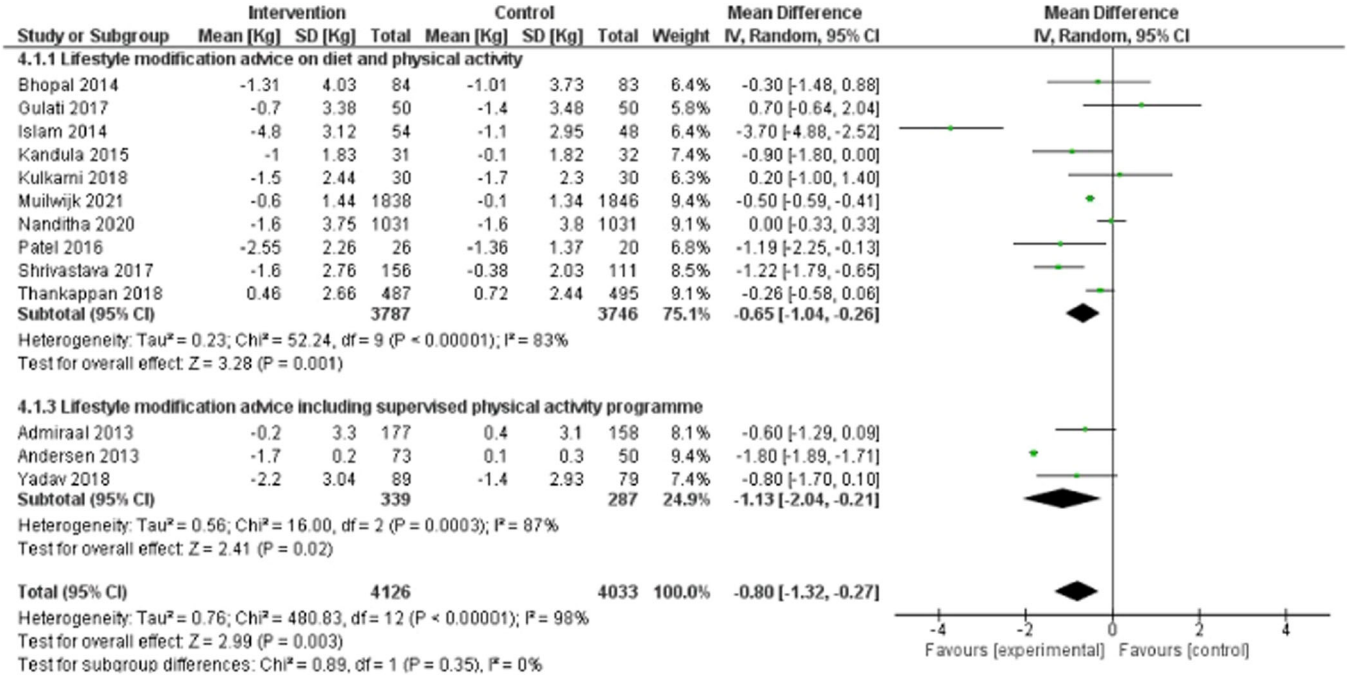


FIGURE 4 Meta-analysis of the mean difference in body weight between intervention and control groups.

between intervention and control groups was −0.65 kg (95% CI: −1.04, −0.26; $p = 0.001$) and the BMI was −0.41 kg/m$^2$ (95% CI: −0.64, −0.18; $p < 0.0001$). However, a high degree of heterogeneity was identified for these parameters ($I^2 = 83\%$ for weight and $I^2 = 91\%$ for BMI).

Lifestyle modification advice that included a physical activity programme was associated with numerically greater decreases in weight, −1.13 kg (95% CI: −2.04, −0.21; $p = 0.02$), and BMI, −0.48 kg/m$^2$ (95% CI: −0.93, −0.03; $p = 0.03$). A high degree of heterogeneity was also noted ($I^2 = 87\%$ for weight and 92% for BMI) (Figures 4 and 5).

## Markers of glycaemic control

Meta-analyses showed a small decrease in FBG in the intervention group in both intervention subtypes for lifestyle modification advice (−0.29 mmol/L [95% CI: −0.49, −0.08], $p < 0.0001$) and for lifestyle modification advice including a supervised physical activity programme (−0.08 mmol/L [95% CI: −0.11, −0.05], $p < 0.0001$). Studies including only lifestyle modification advice demonstrated greater variability in study results ($I^2 = 90\%$) compared with trials involving a supervised physical activity programme ($I^2 = 0\%$); yet the latter was

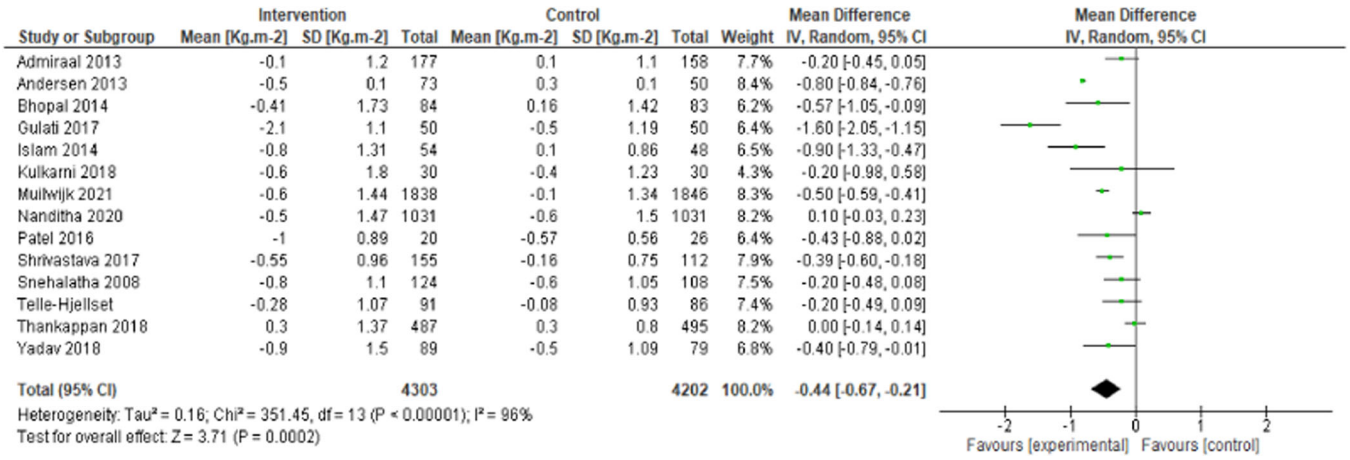


**FIGURE 5** Meta-analysis of the mean difference in BMI (body mass index) between intervention and control groups.

limited by the small number of studies included ($n = 3$) (Supporting Information: 2).

There was no significant mean difference between groups for HbA1c levels in either of the intervention subtypes (overall effect: −0.02% [95% CI: −0.08, 0.04], $p = 0.49$) or 2-h plasma glucose levels (overall effect: −0.16 mmol/L [95% CI: −0.36, 0.05], $p = 0.14$). Supporting Information: 2 provides the forest plot analysis for both HbA1c and 2-h glucose levels for both intervention subtypes.

## Subgroup analyses

Subgroup analyses compared results based on study duration (<12 vs. >12 months), study location (Indian subcontinent vs. other countries), type of advice (general vs. personalised advice) and setting (primary care vs. community vs. research institution). A subgroup analysis based on subethnicity was not undertaken, due to the predominance of trials including either people from the Indian subethnicity or a mix of different subethnicities; only two trials looked at the intervention only in the Pakistani subethnicity. Forest plots representing all subgroup analyses are presented in Supporting Information: 3.

## Trial duration

Trials lasting less than 12 months explained most of the difference in weight (−1.15 kg [95% CI: −1.80, −0.5], $p < 0.0001$), whereas longer-term trials showed less marked weight lowering (−0.32 kg [95% CI: −0.57, −0.08], $p = 0.01$) (Supporting Information: 3.a). Similar results were noted for BMI; trials with duration less than 12 months showed a mean BMI difference of −0.59 kg/m$^2$ (95% CI: −0.92, −0.26), $p < 0.0001$, whereas longer-term trials did not show a statistically significant BMI decrease (−0.31 kg/m$^2$ [95% CI: −0.63, 0.02], $p = 0.07$) (Supporting Information: 3.b).

## Study location and setting

Subgroup analysis showed that the decrease in weight was statistically significant only in trials performed outside the Indian subcontinent (−1.39 kg [95% CI: −2.13, −0.65], $p < 0.0001$) compared with those carried out in the Indian subcontinent (−0.42 kg [95% CI: −1.01, 0.17], $p = 0.16$) (Supporting Information: 3.c). Additionally, the decrease in BMI was numerically larger in studies performed outside the Indian subcontinent (−0.78 kg/m$^2$ [95% CI: −0.81, −0.74], $p < 0.0001$) compared with those performed in India (−0.09 kg/m$^2$ [95% CI: −0.18, −0.01], $p = 0.02$) (Supporting Information: 3.d).

Trials performed in the community reported a statistically significant reduction in both weight (−1.06 kg [95% CI: −1.59, −0.54], $p < 0.0001$) and BMI (−0.45 kg/m$^2$ [95% CI: −0.72, −0.19], $p < 0.0001$) compared with other settings (Supporting Information: 3.e and 3.f).

## General versus personalised advice

Stratifying the interventions based on whether they included general advice or personalised advice showed that personalised advice had larger effects on reducing BMI (−0.65 kg/m$^2$ [95% CI: −0.86, −0.43], $p < 0.0001$) than general advice (−0.15 kg/m$^2$ [95% CI: −0.33, 0.03], $p = 0.1$) (Supporting Information: 3.g). Meta-analysis of trials including personalised advice also reported greater effects on weight compared with trials with general advice but was limited by having fewer trials providing general advice (Supporting Information: 3.h).

### Publication bias and sensitivity analysis

Egger's regression-based test suggested nominal evidence of publication bias for BMI ($p = 0.02$), and borderline evidence for body weight ($p = 0.07$) and FBG ($p = 0.08$), but not for HbA1c ($p = 0.89$) and 2-h plasma glucose ($p = 0.65$). However, a visual inspection of funnel plots showed that when a degree of asymmetry was present, it mostly favoured the control group (Supporting Information: 4).

In sensitivity analyses, when the study with a high risk of bias[43] was omitted, there was no significant impact on the results of weight and BMI. Limiting meta-analyses to studies having a low risk of bias (studies with unclear and high risk of bias were excluded) rendered some associations insignificant (weight: −0.64 kg [95% CI: −1.39, 0.11], $p = 0.09$, and BMI: −0.35 kg/m$^2$ [95% CI: −0.74, 0.04], $p = 0.08$). This analysis did not however significantly affect the outcomes of FBG (0.05 mmol/L [95% CI: −0.10, −0.00], $p = 0.03$), HbA1c (−0.02% [95% CI: −0.10, 0.05], $p = 0.53$) and 2-h plasma glucose (−0.05 mmol [95% CI: −0.22, 0.12], $p = 0.56$).

### Diabetes remission trials

Of the three included remission trials, only one was an RCT, which showed that T2DM remission was achieved in 5 of 13 patients (38.5%) after 12 weeks of total diet replacement (~850 kcal/day) ($p = 0.04$) and cessation of diabetes medications with an average weight loss of 7.7 kg (7.2%) ($p = 0.005$).[15] The study of Bhatt et al.[44] used a similar protocol but had no control group and reported remission in 6 of 12 (50%) patients with a median weight loss of 6.5 kg ($p = 0.03$). Promising results were shown after using a food-based diet of moderate intensity (1500 kcal/day and daily brisk walking) in 32 Indian patients, of whom 75% and 69% achieved remission at 3 months and 2 years, respectively, with a mean weight loss of 7.4 kg in those who achieved remission ($p < 0.001$).[45] The study was however limited by not including a control group and by the lack of standardisation of medications (participants were given either insulin or metformin or given no medications).

## DISCUSSION

Health services globally have been searching to develop and implement effective interventions to decrease the prevalence of T2DM in people with a SAP heritage. In our meta-analyses of diabetes prevention trials, we have shown statistically significant but small reductions in weight and BMI in intervention groups. Trials including a supervised physical activity programme generated greater weight reduction compared with trials focusing only on lifestyle modification advice. Although trials with such design were limited, they provide insights into the potential effectiveness of physical activity and the importance of overcoming physical activity barriers in South Asians. Shorter-term trials (<12 months) and trials delivered in community settings seemed to have a more pronounced effect on weight. This suggests that strategies that aim to increase long-term adherence beyond the first year of intervention need to be considered. The lack of efficacy or low efficacy of trials delivered in primary care is in line with other trials reporting either modest or no significant effects on weight loss in this setting.[21,50]

Our subgroup analysis also reported that personalised advice generated greater effects on weight and BMI, suggesting the usefulness of considering this element in future research. Trials performed outside the Indian subcontinent showed greater degrees of weight loss. The latter outcome is interesting considering that trials held in the Indian subcontinent might be expected to eliminate language and cultural barriers and therefore contribute to better outcomes. This potentially indicates that challenges may be beyond language and culture, and other challenges (e.g., relating to how South Asians integrate with the environment they live in) may need to be examined.

A small reduction in weight (e.g., 1% of weight) may have modest beneficial effects on cardiometabolic factors,[21] but it is unlikely to reduce diabetes incidence in this population. Weight loss was the strongest predictor of diabetes risk reduction in the American diabetes prevention programme,[53] although other mechanisms are likely to be relevant.[54–56] A minimum weight loss of 2% has been shown to improve glycaemic control, whereas a weight loss of 5%–10% is generally required for the prevention of T2DM.[48] This degree of weight loss can reduce liver fat, a mechanism which is postulated as a primary driver of the development of T2DM.[14] Furthermore, in a recent consensus on the support of people living with obesity in South and Southeast Asia, a weight loss of 5%–10% is recommended to support T2DM prevention.[57,58] We, therefore, believe that these interventions may not be optimal approaches for T2DM prevention in the communities of South Asian heritage and that alternative lifestyle interventions must be considered. Additionally, the small weight changes associated with the interventions were not associated with clinically meaningful reductions in HbA1c or 2-h plasma glucose levels. The slight decrease in FBG (−0.19 mmol/L [95% CI: −0.31, −0.07], $p = 0.002$) is likely to have little or no clinical relevance. Contrary to this evidence, a previous meta-analysis on dietary and physical activity interventions in South Asians reported a similar decrease in body weight to our study, but with a 7.4% absolute risk reduction in diabetes incidence[59]; this meta-analysis was, however, limited by the small number of trials (including those with duration ≥12 months), the considerable loss of participants to follow-up and the lack of consideration of study intensity. Carefully

planned long-term interventions will be able to identify the association between the degree of weight loss and the decrease in diabetes incidence in South Asians.

T2DM remissions trials have been less common, particularly in the population of individuals from South Asian background. Two proof-of-concept trials held in both the United Kingdom and India assigned participants to receive ~850 kcal in the form of total diet replacement or 1000 kcal of food-based diet, leading to T2DM remission rates of 38.5%[15] and 50%,[44] respectively. However, previous reports highlighted the potential lack of sustainability of very low-calorie diets and low-carbohydrate diets (≤75 g) in people with South Asian heritage.[59] This suggests that tailored interventions that are co-designed with the community may need to be considered. The trial by Sarathi et al.[45] showed some promising results in achieving T2DM remission following a diet with moderate intensity (1500-kcal/day food-based diet; 1 h of brisk walking/day); yet it was limited by its small sample size and the lack of control group. Interestingly, the three trials reported a weight loss of ~7 kg in those who achieved remission. Future trials will be able to determine whether South Asians achieve T2D remission at lower rates than their White counterparts, who attained remission at an average weight loss of 15 kg.[13]

## Strengths and limitations

This review included over 8000 participants and assessed weight status and markers of glycaemic control. Although there was evidence of publication bias for BMI, the effect estimates were interestingly in favour of the control interventions, suggesting that 'negative' studies of active interventions appeared more likely to be published than 'positive' studies. The results were, however, limited by the significant heterogeneity between trials, which could be partly explained by the subgroup analysis. Sensitivity analysis that included only trials with low risk of bias did not suggest significant effects of intervention on body weight, but this observation could be explained by the reduced statistical power of this analysis. Some trials were gender specific, restricting the generalisability of results. There may also be differences in family history or initial prediabetic state that have affected the outcomes. The lack of a control group in some trials limited their inclusion in the meta-analysis. Multiple studies consisted of cointerventions which may have reduced the magnitude of effects of diet and physical activity interventions, despite the effect estimates being small in the control group. Furthermore, we did not find it appropriate to conduct an ethnic subgroup analysis as trials predominantly included participants from the Indian subethnicity. The generalisability of our results may have been influenced by (i) our searches being restricted to trials reported in the English language and (ii) not using Embase or the South Asian Database of Controlled Clinical Trials. Finally, the short duration of prevention trials did not allow the assessment of diabetes incidence as a primary outcome.

## Clinical and research implications

Our data support the idea that current interventions have limited success, thus raising the possibility that prevention of T2DM requires culturally acceptable lifestyle interventions[60] to achieve a weight loss of 5%–10%, and we show that community-based interventions could provide a greater likelihood of success. Previously identified barriers and facilitators such as reinforcing education and dietary knowledge and peer support must also be considered.[61–63] Some intervention elements, such as the provision of portion size control tools[34] and increasing the number of sessions with health professionals, have been shown to positively affect outcomes.[28] With our data suggesting that supervised physical activity programmes could deliver promising results, promoting physical activity while accounting for the barriers to exercise in individuals of South Asian heritage may be beneficial.[64,65]

Most important, considering the subethnic diversity could be crucial in the effectiveness of any future interventions. Randomised controlled clinical trials considering cultural and gender segregation might need to be carefully planned. It has been reported that adapting interventions that are effective in White populations (telephone counselling, accelerometers and technology for improving diet) may not be successful in other ethnicities and communities. Furthermore, reporting diet in the form of diet diaries has been shown to be burdensome,[31,34] suggesting that alternative methods including more visual elements may need to be explored in communities of South Asian heritage. Therefore, co-designing new trial interventions with members of the specific community could increase the chances of success.[22] It is worth noting that communities sharing a similar ethnic background but living in different environments may not necessarily share similar perceptions of what might be a culturally acceptable intervention. For example, British South Asians and Canadian South Asians presented different opinions in relation to suitable interventions to reduce diabetes risk.[66,67] Qualitative and quantitative research will help gain further insights into knowledge, perceptions and motivation in these populations.[22,31] Finally, involving dietitians in the delivery of lifestyle interventions may increase the chances of success.

In relation to the remission of T2DM, future trials should aim to identify the optimal weight loss to induce remission in people of South Asian heritage, together with the evaluation of the effectiveness of multiple tailored dietary options. This could include food-based

diets that create a significant calorie deficit and are adapted around cultural celebrations. Low-carbohydrate diets and intermittent fasting diets for weight loss and T2DM remission have received particular attention over the past few years. Promising results have been reported in the Indian population[40,68] after 3 months of intermittent fasting diet together with qualitative evaluation showing its potential acceptability. Exploring the acceptability and effectiveness of these diets may lead to some of these being presented as suitable options in populations of South Asian heritage. High-protein diets, previously reported to reduce weight and liver fat in South Asians,[42] should also be considered for further investigation.

## CONCLUSIONS

In South Asians, lifestyle interventions for T2DM prevention produced only modest changes in body weight and glycaemic markers and could therefore impact their overall effectiveness. Studies including both lifestyle modification advice and a physical activity programme reported slightly more effective outcomes. Alternative lifestyle interventions co-designed with members of the community and including personalised advice, when possible, should therefore be investigated for reducing diabetes risk in these ethnic groups. Diabetes remission trials showed potential acceptability but have limited effectiveness. Dedicated RCTs of novel and improved diabetes remission interventions in South Asians are called for that assessed effectiveness and acceptability.

### AUTHOR CONTRIBUTIONS

Grace Farhat, Michelle Harvie and Martin K. Rutter conceived the idea for the review. Grace Farhat conducted a systematic literature search, selected eligible trials, extracted data, assessed risk of bias, conducted meta-analyses in RevMan and drafted the manuscript. Duane D. Mellor selected eligible trials and moderated risk of bias. Martin K. Rutter and Naveed Sattar revised the manuscript critically for intellectual content. All authors reviewed and approved the final version of the manuscript.

### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the supplementary material of this article.

### TRANSPARENCY DECLARATION

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The reporting of this work is compliant with PRISMA guidelines. The lead author affirms that no important aspects of the study have been omitted and that any discrepancies from the study as planned (PROSPERO CRD42022385174) has been explained.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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