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Effectiveness of group-based self-management education for individuals with Type 2 diabetes: a systematic review with meta-analyses and meta-regression

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What's new?

- We present a comprehensive up-to-date review of the evidence for the effectiveness of Type 2 diabetes group-based interventions. This is the first review in the area to complete a meta-regression.
- We report statistically significant results for improving HbA_{1c}, fasting blood glucose, body weight, waist circumference, triglycerides and diabetes knowledge, but clinical improvement is more nuanced.
- Group-based interventions facilitated by a single discipline, multidisciplinary teams or health professionals with peer supporters appear to be more effective at improving HbA_{1c} than peer-led interventions.

Abstract

Aims Patient education for the management of Type 2 diabetes can be delivered in various forms, with the goal of promoting and supporting positive self-management behaviours. This systematic review aimed to determine the effectiveness of group-based interventions compared with individual interventions or usual care for improving clinical, lifestyle and psychosocial outcomes in people with Type 2 diabetes.

Methods Six electronic databases were searched. Group-based education programmes for adults with Type 2 diabetes that measured HbA_{1c} and followed participants for ≥ 6 months were included. The primary outcome was HbA_{1c}, and secondary outcomes included fasting blood glucose, weight, BMI, waist circumference, blood pressure, blood lipid profiles, diabetes knowledge and self-efficacy.

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Results Fifty-three publications describing 47 studies were included (n = 8533 participants). Greater reductions in HbA_{1c} occurred in group-based education compared with controls at 6–10 months [n = 30 studies; mean difference (MD) = 3 mmol/mol (0.3%); 95% confidence interval (CI): –0.48, –0.15; P = 0.0002], 12–14 months [n = 27 studies; MD = 4 mmol/mol (0.3%); 95% CI: –0.49, –0.17; P < 0.0001], 18 months [n = 3 studies; MD = 8 mmol/mol (0.7%); 95% CI: –1.26, –0.18; P = 0.009] and 36–48 months [n = 5 studies; MD = 10 mmol/mol (0.9%); 95% CI: –1.52, –0.34; P = 0.002], but not at 24 months. Outcomes also favoured group-based education for fasting blood glucose, body weight, waist circumference, triglyceride levels and diabetes knowledge, but not at all time points. Interventions facilitated by a single discipline, multidisciplinary teams or health professionals with peer supporters resulted in improved outcomes in HbA_{1c} when compared with peer-led interventions.

Conclusions Group-based education interventions are more effective than usual care, waiting list control and individual education at improving clinical, lifestyle and psychosocial outcomes in people with Type 2 diabetes.

Introduction

Patient education is an integral and vital component of successful diabetes care [1–3]. The main goal of diabetes patient education is to promote and support positive self-management behaviours to optimize metabolic control, improve long-term diabetes outcomes and quality of life (QOL), prevent complications, and reduce morbidity and mortality, while remaining cost-efficient [1,4]. Group-based education for individuals with Type 2 diabetes mellitus may be more cost-effective and efficient than individual education, due to the reduced time and funding required to educate numerous people in one sitting [5]. The potential advantages of

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group-based education interventions over individual visits include time for the provision of more detailed information, decreased time demands on health workers, easily incorporating families and carers, and facilitating discussions and support from others facing the same challenges [6,7]. Clearly, the use of group-based education warrants further investigation.

Three previous systematic reviews included group education for Type 2 diabetes. A Cochrane systematic review assessed the effects of group-based training on clinical, lifestyle and psychosocial outcomes in people with Type 2 diabetes compared with routine treatment, waiting list control or no intervention [8]. The review favoured group-based education, finding significant improvements in HbA_{1c} levels, body weight and systolic blood pressure (BP), fasting blood glucose (FBG), a decreased need for diabetes medication and increased diabetes knowledge [8]. A subsequent publication in 2012, updating the original Cochrane review, supported the findings of the former, favouring group-based education, with significant reductions in HbA_{1c}, FBG and body weight, and improvements in diabetes knowledge compared with controls [6]. Another recent systematic review [9] assessed the effect of diabetes self-management education and support methods, providers, duration and contact time on glycaemic control in adults diagnosed with Type 2 diabetes. The review included individual, group-based, combination and remote interventions for the management of Type 2 diabetes, with results suggesting that a combination of individual and group-based education was most effective at improving HbA_{1c} (median 9.6 mmol/mol; 0.88%) when compared with controls [9].

These previous reviews had limitations. First, the searches are outdated and the number of published studies for group-based diabetes interventions has increased substantially since their completion. High heterogeneity precluded meta-analyses for several of the main outcomes, which were completed for just two studies [6,8]. Although both reviews found clinical and statistically significant changes in health outcomes, the exact mechanism or

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'active ingredient(s)' of these complex interventions were not identified [6,8]. Both reviews only conducted follow-up analyses of the primary outcome up to 2 years from baseline [6,8]. The quality of the previous reviews was assessed using 'A Measurement Tool to Assess Systematic Reviews' (AMSTAR), a reliable and valid method for assessing the methodological quality of systematic reviews [10]. The AMSTAR scores were categorized in line with previous research [11,12], with scores of 0–4 classified as 'low quality', 5–8 classified as 'moderate quality', and 9–11 classified as 'high quality'. The Cochrane review [8] was assessed as a high-quality review (score: 9/11). This review lacked an assessment of publication bias and conflict of interest for the included studies. The review by Steinsbekk *et al.* [6] was assessed as a moderate quality review (score: 5/11); no protocol was available, grey literature and publication bias were not considered, a list of excluded studies was not provided, an assessment of conflict of interest for included studies was not explored and the scientific quality of the included studies was not used appropriately in formatting conclusions. The review by Chrvala *et al*. [9] was assessed as a moderate quality review (score: 7/11); grey literature and publication bias were not considered, a list of excluded studies was not provided and conflict of interest for included studies was not explored. The review had various limitations including: restricting included studies to English-language publications, including only randomized controlled trials, including interventions for individuals with either/both Type 1 and/or Type 2 diabetes, and an inability to conduct meta-analyses [9].

Despite these systematic reviews providing evidence of effectiveness, group-based education interventions are often complex and the characteristics of the interventions vary greatly, for example, in the number of contact hours, number of sessions, number and characteristics of participants, group facilitator(s) qualifications, facilitator training, theoretical framework, and whether family, friends or carers can attend [6,8]. Health professionals may deter from

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group-based education because the essential attributes for a successful group-based education programme are unknown. Furthermore, no specific evidence-based practice guidelines for group-based education in Type 2 diabetes have been identified internationally, inevitably resulting in wide variations in the programmes offered, and creating difficulty in the interpretation of evidence and its translation to a practice setting.

This systematic review builds upon two of the previous reviews [6,8] and seeks to update the evidence for the effectiveness of group-based interventions for Type 2 diabetes management and investigate key attributes for successful group programs. It was hypothesized that:

- group-based interventions for Type 2 diabetes would have greater reductions in HbA_{1c} compared with controls in the short (6 months) and long (> 12 months) term;
- group-based interventions for Type 2 diabetes would improve body weight, waist circumference, FBG, BP, lipid profiles, diabetes knowledge and self-efficacy, compared with controls;
- variations in effect sizes could be attributed to study design (i.e. setting, control group, educator), and intervention characteristics (i.e. number of participants, intervention length, number of contact hours).

Methods

The study was registered with the International Prospective Register of Systematic Reviews PROSPERO (CRD42015027785).

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Data sources and search strategy

A systematic literature search was performed to retrieve publications on group-based education for the management of Type 2 diabetes in adults. The search was completed in three parts. First, electronic databases, including PubMed, the Cochrane Central Register of Controlled Trials (CENTRAL), Embase, CINAHL, PsycINFO and ERIC, were searched from commencement of records to 22 September 2015 (File S1). Second, hand searches of reference lists from previous reviews were completed [6,8]. Finally, the included studies were cross-referenced with the results of an updated search by the authors of the most recent review including studies up to May 2012 (email correspondence). No language or date restrictions were applied. Abstract-only publications were excluded and duplicate articles were removed prior to title and abstract screening.

Inclusion criteria and study selection

Group-based education intervention studies for participants diagnosed with Type 2 diabetes that reported randomized controlled trials, cluster randomized trial or controlled clinical trial study designs were included. Studies were included if the described intervention met the following criteria: adults aged ≥ 18 years; face-to-face, educative group-based interventions (including those with occasional adjunct individual consultations) for people with Type 2 diabetes; a minimum of four participants and may include family and friends for support; a minimum of one session lasting for 1 h; groups delivered in primary or secondary care compared with a control or comparison group (usual care, waiting list control or individual intervention); and studies that measured HbA_{1c} at both baseline and 6 or more months from baseline. Studies were excluded if participants were pregnant women or were diagnosed with

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Type 1 diabetes, or interventions provided education in individual consultations, included only exercise prescriptions without education or were not conducted face-to-face.

All studies were screened against the eligibility criteria by two independent reviewers (KOJ and LEB) using reference manager software EndNote (Thomson Reuters, New York, NY, USA). Conflicts were resolved by discussion between them. Studies that met the inclusion criteria or did not include sufficient information for screening in the title and abstract, were included for full-text review. Full-text versions of these articles were obtained and screened independently. Authors were contacted for missing data up to three times by email if the missing data affected assessment of the study's eligibility, and were excluded if contact could not be made.

Data extraction and quality assessment

Data extraction was completed by the first author (KOJ) and confirmed for accuracy by an independent reviewer (JTK). Data extracted included: general information on the study design, trial characteristics, intervention details, participant characteristics, outcome measures, results and information for appraising the risk of bias. Study quality was assessed using the Cochrane risk of bias tool [13] by two independent reviewers (KOJ and LEB). Disagreements were resolved through discussion. Risk of bias was ranked as low, unclear or high depending on whether a study had any element of bias (e.g. selection, performance, detection, attrition, reporting and other bias).

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Data synthesis and analysis

Descriptive data from the included studies were summarized. Data were meta-analysed if the same measurement was used across three or more studies at the same time point. The primary outcome measure was change in HbA_{1c} in group-based education vs. control. The secondary outcome measures were changes in FBG, weight, BMI, waist circumference, BP, total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides, diabetes knowledge and self-efficacy. Prior to the meta-analyses, studies reporting FBG or lipid profile measures in mg/dl were converted to mmol/l; those reporting weight in lb were converted to kg.

Summaries of effect estimates were calculated by meta-analysis using the DerSimonian and Laird random effects model in Review Manager (RevMan, v. 5.3) [14]. Continuous data using the same measures were analysed with a weighted mean difference in outcomes between the intervention and control groups, whereas continuous data collected using a variety of measures were assessed using the standard mean difference (SMD). Heterogeneity was assessed using the *I*-squared statistic and reported following the Cochrane Handbook [13].

Mean differences (MD) and 95% confidence intervals (CI) were calculated in RevMan and standard error was calculated in Microsoft® Excel using the 95% CIs for the meta-regression. Separate analyses for the effect of group-based interventions on HbA_{1c} were performed for the following subgroups: control groups, delivery setting, insulin therapy, type of educator(s), training of educator(s), baseline HbA_{1c} levels, theoretical model and intervention content, materials, length, number of sessions, contact time, number of participants and the inclusion/exclusion of family and/or friends.

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Sensitivity analyses were conducted to explore the influence of study quality (overall risk of bias and reporting bias), on HbA_{1c} outcomes (as measured closest to intervention completion) and heterogeneity. Reporting bias and selective outcome reporting were chosen for the sensitivity analysis because studies that did not report the pre-specified outcomes or failed to include the results for an expected outcome may be reporting only results supporting the studies' aims or hypotheses. We also examined potential influences on the primary outcome for studies that had differences in HbA_{1c} at baseline, large (defined as > 10%) compared with small attrition (defined as < 10%), and studies published in non-English journals due to potential publication bias.

Subgroup analyses were also conducted to examine the effects of different educators (health professionals, health professionals with peer support, peer or lay-persons), disciplines (single discipline compared with multidiscipline) and studies that included participants taking (and not taking) insulin on the primary outcome HbA_{1c}.

In addition, a univariate meta-regression was completed to explore potential associations between the size of effect and varying study and intervention characteristics [15]. Variables were similar to those explored in the subgroup analyses. A meta-regression was performed using Stata statistical software [16].

Results

Study selection

The search identified 14 016 results, from which 9764 publications were screened against the selection criteria, leaving 298 studies for full-text review (Fig. 1). Forty-seven studies reported in 53 publications were included in the systematic review (references provided in File S2).

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A total of 8533 participants were included in the 47 studies (intervention group $n = 4416$, control group $n = 4117$). The mean age of participants was 60 years. Men made up 44% of participants in the both the intervention (1917 of 4383) and control (1799 of 4086) groups. Three of the 47 included studies (6%) recruited only women. Known duration of diabetes was reported by 29 of the 47 studies (62%). Mean duration of diabetes was 8.9 years for participants in the intervention group, and 9.4 years in the control group. Mean HbA_{1c} level at baseline was 67 mmol/mol (8.3%) for both groups and ranged between 39 and 111 mmol/mol (5.7%–12.3%) for the intervention group and between 40 and 115 mmol/mol (5.8%–12.7%) for the control group. In 38 (81%) studies, the mean HbA_{1c} was > 53 mmol/mol (7%) for both the intervention and control groups.

Study characteristics

Study characteristics are detailed in Table S1. Of the 47 studies included, 40 reported the results of randomized controlled trials, four reported results of controlled clinical trials and three reported the results of cluster randomized controlled trials. Most of the studies were carried out in the USA (18; 38%), the UK (6; 13%) and Italy (5; 11%). Forty-two of the studies were published in English, two in Spanish [17,18], two in Italian [19,20] and one in Dutch [21]. The studies were published between 1988 and 2015, and the length of follow-up was 6–60 months from baseline. Intervention characteristics varied in materials provided, discipline(s) of group educators and theoretical model used, as summarized in Table S2. Studies were conducted predominantly in primary care settings (32; 68%), with 15 (32%) of the studies delivered in secondary or tertiary care settings, for example, hospital diabetes centres or tertiary hospitals. Four publications [22–25] reported on multiple arm studies.

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Study quality

Most studies were classified as having a moderate (31) or high (12) risk of bias, with four studies classified as having a low risk of bias (Table S3). Of the six risk of bias items, allocation concealment (selection bias), blinding of participants and personnel (performance bias), and blinding of outcome assessment (detection bias) were the least consistently described or were generally poorly conducted in the included studies (Fig. S1).

Overall effects of group-based interventions for HbA_{1c}

A meta-analysis was conducted to assess the effect of group-based education compared with control for all 47 included studies (n = 7055) using the measure of HbA_{1c} at the time point closest to the completion of each group-based education intervention (Fig. 2). Overall, compared with control, group-based intervention was effective in reducing HbA_{1c} by 4 mmol/mol (0.3%) (95% CI: –0.51, –0.17; $P < 0.0001$; $I^2 = 84\%$). Heterogeneity was statistically significant and potential reasons for this were explored with sensitivity analyses.

The results of the meta-analyses for HbA_{1c} and secondary outcome measures at various time points are provided in Table 1.

Group-based interventions significantly reduced HbA_{1c} post intervention at most time points compared with controls. HbA_{1c} was significantly reduced at 6–10 months post baseline [n = 30 studies; MD = 3 mmol/mol (0.3%); 95% CI: –0.48, –0.15; $P = 0.0002$; $I^2 = 65\%$], 12–14 months post baseline [n = 27 studies; MD = 4 mmol/mol (0.3%); 95% CI: –0.49, –0.17; $P < 0.0001$; $I^2 = 64\%$], 18 months [n = 3 studies; MD = 8 mmol/mol (0.7%); 95% CI: –1.26, –0.18; $P = 0.009$; $I^2 = 50\%$] and at 36–48 months [n = 5 studies; MD = 10 mmol/mol (0.9%); 95% CI: –1.52, –0.34; $P = 0.002$; $I^2 = 93\%$]. By contrast, when eight studies comparing

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group-based interventions with controls measured HbA_{1c} at 24 months post baseline, there was no significant difference between the groups. This time point also had the highest heterogeneity (I^2 = 94%).

There was variation in effectiveness in reducing FBG when comparing group-based interventions with controls. Group-based education was significantly more effective at reducing FBG compared with controls at 12–14 months post baseline (n = 8 studies; MD = 0.68 mmol/l; 95% CI: –1.25, –0.11; P = 0.02; I^2 = 55%). However, this was not the case for FBG when measured at 6–10 or 24 months post baseline. All time points were assessed as having significant heterogeneity.

Group-based education was significantly more effective at reducing body weight compared with controls at both 6–10 months (n = 17 studies; MD = 1.22 kg; 95% CI: –2.22, –0.23; P = 0.02; I^2 = 62%) and 12–14 months (n = 9 studies; MD = 1.43 kg; 95% CI: –2.09, –0.77; P < 0.0001; I^2 = 0%). Despite the statistically significant improvements in body weight at two time points, group-based education was not effective at significantly reducing BMI. Group-based education was significantly more effective at reducing waist circumference at 6–10 months (n = 5 studies; MD = 1.19 cm; 95% CI: –2.34, –0.05; P = 0.04; I^2 = 58%). However, although waist circumference showed a trend for improvement with group-based education at 12–14 months, the difference between groups was not significant (n = 3 studies; MD = 0.79 cm; 95% CI: –1.96, 0.38; P = 0.19; I^2 = 38%).

Both systolic and diastolic BP were measured at five time points (6–10, 12–14 and 24 months post baseline). When pooled, changes in systolic and diastolic BP were not statistically different between groups for any of these intervals. In addition, there were no significant differences in total cholesterol between group-based interventions and controls at any time point.

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There were no statistically significant differences in HDL-cholesterol between groups at any time point. Heterogeneity was significant at all time points. There were mixed results for LDL-cholesterol when measured at two time points, 6–10 and 12–14 months (Table 1). At 6–10 months, the meta-analysis resulted in no significant differences between groups for LDL-cholesterol (n = 12 studies; MD = 0.03 mmol/l; 95% CI: –0.13, 0.07; P = 0.59; I^2 = 49%). The studies assessing LDL-cholesterol at 12–14 months showed a significant decrease in LDL favouring the control group (n = 5 studies; MD = 0.08 mmol/l; 95% CI: 0.01, 0.15; P = 0.04; I^2 = 0%). Group-based education was significantly more effective at reducing triglycerides at 6–10 months (n = 14 studies; MD = 0.13 mmol/l; 95% CI: –0.24, –0.01; P = 0.03; I^2 = 4%) and 24 months (n = 3 studies; MD = 0.32 mmol/l; 95% CI: –0.58, –0.06; P = 0.01; I^2 = 8%). At 12–14 months, the difference between groups for triglycerides were not significant (n = 11 studies; MD = 0.04; 95% CI: –0.22, 0.14; P = 0.66; I^2 = 68%).

Diabetes knowledge was reported by 16 studies and measured using a range of validated questionnaires. Group-based education was significantly associated with improved diabetes knowledge at two time points: 6–10 months (n = 7 studies; SMD = 0.61; 95% CI: 0.14, 1.08; P = 0.01; I^2 = 83%) and 12–14 months (n = 7 studies; SMD = 0.58; 95% CI: 0.08, 0.97; P = 0.02; I^2 = 93%). Self-efficacy was reported by five studies at three time points (6, 12 and 24 months). Group-based education showed a trend to improved self-efficacy at 12 months post baseline (n = 3 studies; SMD = 0.15; 95% CI: –0.02, 0.33; P = 0.08; I^2 = 0%), however, these measures were not significant. In addition, QOL, depression, energy intake and physical activity levels were assessed (Table S4).

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Subgroup analyses

Analyses were completed for 13 subgroups using HbA_{1c} at the point closest to the end of each of the group-based education interventions as the outcome measure (Table 2).

The type of educator subgroup analysis resulted in a significant subgroup difference ($P = 0.002$), with peer- and/or lay-led group-based interventions having no significant influence on improving HbA_{1c} ($P = 0.80$). Interventions facilitated by single disciplines ($P = 0.0003$), multidisciplinary teams ($P = 0.02$) or health professionals with peer supporters ($P = 0.01$) were effective at significantly improving HbA_{1c} (Table 2 and Fig. S2). Types of educators were further analysed to individual disciplines included in the 'single discipline' group, finding that physician-, dietitian- and nurse-led group-based education interventions were effective ($P < 0.00001$) at improving HbA_{1c} (Fig. S3). Heterogeneity for both subgroup analyses was significant ($I^2 = 79.1\%$ and 89.2%, respectively). In addition, subgroup analysis of studies with regards to insulin therapy resulted in a significant subgroup difference ($P < 0.00001$), with interventions that excluded participants on insulin therapy resulting in greater reductions in HbA_{1c} (Fig. S4). Heterogeneity for both subgroup analyses was significant ($I^2 = 69\%$ and 88%, respectively).

Sensitivity analyses

Sensitivity analyses were performed to explore the influence of study quality and characteristics on post-baseline HbA_{1c} outcomes (Table 3) and heterogeneity. Forest plots for sensitivity analyses are reported in Figs S5–S9.

There were no significant differences in HbA_{1c} outcomes when study quality and attrition were explored; all subgroups showed statistically significant improvements in HbA_{1c} ($P \leq 0.05$). However, subgroups of studies assessed as being at high risk of reporting bias

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(Fig. S6), having baseline differences between groups (Fig. S7) and studies published in non-English journals (Fig. S9) did not show significant improvements in HbA_{1c}.

Meta-regression

We used study variables and intervention characteristics including theoretical model, discipline(s) of educator(s), educator training, materials provided, delivery in primary care, both groups $HbA_{1c} < 7\%$ at baseline, intervention length, contact time, number of participants, number of sessions, and the inclusion of family and friends in a meta-regression to explore potential associations between the size of effect and study and intervention characteristics on HbA_{1c} at post intervention. None of these variables explained significant portions of heterogeneity among the studies (Table S5).

Discussion

This study systematically evaluated the effectiveness of group-based education for the management of Type 2 diabetes in adults. Given the high prevalence of Type 2 diabetes and the need for effective intervention, a synthesis of the most up-to-date literature is required. A previous review included only studies published prior to January 2008 [6]. This study fills this important gap and attempted to expand our understanding of effective intervention components.

Meta-analyses of the primary outcome measure, HbA_{1c}, resulted in statistically significant improvements at 6–10, 12–14, 18 and 36–48 months, but unexpectedly, not at 24 months post intervention. The meta-analysis at this time point had the highest heterogeneity ($I^2 = 94\%$). One study [26], in which contact with intervention participants decreased after 6 months,

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favoured the control group and appeared to be an outlier, with a mean difference increase in HbA_{1c} of 0.60% (95% CI: 0.52, 0.68). When this, and three other studies [18,20,27] assessed as high risk, were excluded from the meta-analysis, heterogeneity decreased substantially ($I^2 = 0\%$) and HbA_{1c} lowered in favour of the intervention group [$n = 4$ studies; MD = 6 mmol/mol (0.6%); 95% CI: –0.86, –0.32; $P < 0.0001$] at the 24-month time point. Statistically significant reductions ranged from 3 mmol/mol (0.3%) at 6–10 months when pooled for 30 studies to 10 mmol/mol (0.9%) at 36–48 months when pooled for five studies. Although these reductions did not reach 11 mmol/mol (1%), suggested as the level necessary to achieve clinical importance [28,29], similar-sized reductions in HbA_{1c} are known to mediate the risk of Type 2 diabetes complications [30].

Variability in outcomes was found for some secondary outcome measures, specifically FBG, body weight, waist circumference, triglyceride levels and diabetes knowledge. For example, FBG was improved statistically by mean reductions of 0.68 mmol/l at 12–14 months, but not at other time points. Previous research suggests that improving FBG in people with Type 2 diabetes can reduce the development or progression of microvascular complications and can improve QOL [31]. Ideally, FBG should be maintained < 7.2 mmol/l in individuals with Type 2 diabetes [32]. Although the data suggest statistical improvements, only two of the eight studies included in the meta-analysis of FBG at 12–14 months resulted in reductions of FBG to < 7.2 mmol/l, suggesting that the improvements in FBG may be less clinically important. This may indicate that group-based education programmes are not effective at improving various secondary outcome measures when compared with controls, or that further consideration of these measures is required.

Body weight and waist circumference were statistically improved by group-based interventions at time points closer to intervention completion, indicating that interventions were effective at improving these measures; however, maintenance of these improvements

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requires further consideration. Weight control is recognized as a central strategy in diabetes care [31], however, the reductions in body weight (range 0.62–1.43 kg) and waist circumference (range 0.79–1.19 cm) in this review are unlikely to be clinically important. It has been demonstrated that a sustained weight loss (> 12 months) of 5 kg in people with Type 2 diabetes is associated with a reduction in HbA_{1c} of 6–11 mmol/mol (0.5%–1%) [33]. Furthermore, for overweight or obese individuals with Type 2 diabetes, a weight loss of at least 5% seems necessary to improve blood glucose, lipid profiles and blood pressure [34]. However, it is unclear whether the participants in the included studies were overweight or obese, and a recent study found that intensive lifestyle interventions focusing on weight loss in adults with Type 2 diabetes did not reduce the rate of cardiovascular events despite significant weight loss [35]. Waist circumference is a commonly utilized measure of total body fat, a useful predictor of visceral fat [36], and can be a better predictor of cardiovascular risk [37] than BMI. It is likely that the reductions in weight were not great enough to influence BMI measures. These results are in line with previous systematic reviews, which found no statistically significant differences in BMI between groups [6,8].

Despite improvement in various blood lipid (excepting LDL-cholesterol) and BP measures, statistical significance was not reached at most time points. There may be several reasons for this: the limited number of studies assessing or providing education on these measures, the lack of intervention focus on blood lipids or BP, the widespread and early use of pharmacological interventions, the inclusion of participants on cholesterol-reducing or hypotensive medications, and underpowered studies to detect changes in blood lipids or BP. The results highlight an important area for future research, given that improvements in lipid measures and BP control in Type 2 diabetes can reduce the risk of death related to diabetes, macrovascular and microvascular complications and myocardial infarction [29].

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The meta-analyses indicate that group-based interventions are effective at improving diabetes knowledge, but no differences in self-efficacy were evident. Perceived self-efficacy describes a person's confidence or belief about his or her personal capabilities to accomplish a task or change a behaviour [38]. The found improvement in diabetes knowledge is consistent with two previous systematic reviews [6,8]. Successful self-management of Type 2 diabetes requires sufficient knowledge of the condition and its treatment, and the performance of self-management activities and skills [39], and knowledge is an essential prerequisite [1].

The subgroup analyses revealed that peer- or lay-led group-based interventions did not significantly reduce HbA_{1c}; however, interventions facilitated by single disciplines, multidisciplinary teams or health professionals with peer supporters resulted in statistical improvements in HbA_{1c}. Furthermore, subgroup analysis of single educator studies indicated that physician-, dietitian- and nurse-led group-based education interventions were equally effective at improving HbA_{1c} levels. The International Diabetes Federation guideline recommends that an appropriately trained multidisciplinary team provides education to groups of people with diabetes [40]. It defines limited care as group education by a smaller team, for example, with a physician and diabetes educator or, in very limited situations, an appropriately skilled individual [40]. By contrast, and similar to the previous review [6], the results of this review indicate that educators from a single discipline providing group-based education to persons with Type 2 diabetes can be more effective than multidisciplinary teams. Multidisciplinary teams may result in reduced contact time with each educator, thus limiting the participant's development of relationships and level of perceived support. Support from group educators can enhance the development of self-management skills in people with Type 2 diabetes [41–43], with researchers suggesting that this support can influence an individual's motivation to self-manage their condition [44,45].

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Our results support the use of peer facilitators complementing health professionals, rather than replacing them [7]. Peer support can enhance and complement other healthcare services, can provide role-modelling and practical, emotional and ongoing support, and can assist individuals to follow management plans, cope with the stressors of chronic disease and remain motivated [46,47]. The benefits of peer support include the establishment of a non-hierarchical, reciprocal relationship with the individual, and the ability to share knowledge, life experience and common illness experiences, which many health workers would not have [7].

Although HbA_{1c} did improve statistically in both groups as expected, studies that excluded participants that used insulin showed greater improvements in HbA_{1c} than studies that included them. This was an expected result, because insulin therapy lowers blood glucose and HbA_{1c}, resulting in tighter glycaemic control [32].

Despite the lack of statistically significant differences between subgroups, some subgroup analyses resulted in significant improvements, whereas others did not. To improve HbA_{1c} outcomes for individuals with Type 2 diabetes, the following characteristics of group-based interventions may be associated with greater effects: conducted in primary care settings; provide materials to participants; have < 10 sessions provided either in < 1 month, or over 7–12 or 13–60 months; provide < 8, 8–12, 19–30 or 31 h or more of contact time; include < 20 participants in each group; and include individuals with HbA_{1c} levels > 53 mmol/mol (7%). Although not directly comparable because we did not reach a pooled reduction of HbA_{1c} of 11 mmol/mol (1%), these results differed from the findings from a previous systematic review which found that the only predictor of a reduction in HbA_{1c} of 11 mmol/mol (1%) was contact time of 23.6 h [4]. Furthermore, a previous systematic review found that group-based interventions delivered in < 10 months, with > 12 h of contact time over 6–10 sessions were

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most efficacious in improving HbA_{1c} [6]. The reasons for the different results relative to the contact time are likely due to other intervention factors, such as intervention content, facilitators or intervention length.

Finally, studies in which the content was facilitator-directed resulted in significant improvements in HbA_{1c}, whereas patient-directed interventions did not. These results contradict the findings from previous studies, which support the use of a patient-centred approach, suggesting that engaging individuals in their healthcare decisions can enhance their adherence to therapy [32]. Patient-directed interventions, in which participants decide on the content covered in the intervention and can therefore explore their own agenda, interests and needs, have been suggested to be effective in improving participant knowledge, blood glucose levels, weight and medication usage, as well as assisting the development of self-management behaviours [48,49]. Facilitator-directed programmes contain lesson plans with clearly defined content selected by intervention facilitators. This allows programmes to be replicated by multiple facilitators; however, they may be more likely to utilize a didactic facilitation style, which could reduce time for group interactions and discussion [48]. The subgroup analysis in the current study, however, was underpowered, with only four studies utilizing a patient-centred approach, compared with 43 studies utilizing a facilitator-directed approach. Furthermore, studies that compared group-based interventions to usual care were effective at improving HbA_{1c}, whereas those compared with other comparators (e.g. individual education, waiting list control), did not significantly improve HbA_{1c}. However, this analysis did not result in a significant difference between groups, and was underpowered, with 28 (65%) of the studies comparing to usual care controls.

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Limitations

Although our study has many strengths, there are several limitations. Using the AMSTAR quality assessment tool, our review is of high quality (10/11). A search of the grey literature in the area was not completed and may have resulted in publication bias. However, we conducted sensitivity analysis to consider the influence of publication bias when studies were published in non-English journals and found no differences in the primary outcome. Most studies included in the review were assessed as having a moderate (31 of 47 studies) or high (12 of 47 studies) risk of bias. As such, the results should be interpreted with caution. Thirteen studies were assessed as having a potential conflict of interest either due to partial funding or equipment donations by pharmaceutical companies, or possible financial gains to the authors from commercially available materials and training courses (Table S1). Only 5 of the 47 included studies measured hypoglycaemia, an important end point, unwanted consequence of therapy and commonly feared acute complication in Type 2 diabetes [31]. Furthermore, the authors were unable to explore the barriers and enablers regarding the implementation of education programmes because this information was not commonly provided in published reports.

Numerous meta-analyses resulted in high heterogeneity between studies; however, this is common in allied health research, particularly in complex interventions, and was assessed comprehensively through sensitivity analyses, subgroup analyses and a univariate meta-regression. Furthermore, the two previous systematic reviews also had high heterogeneity, with the Cochrane review reporting I^2 scores between 0% and 96.4% [8] and a review by Steinsbekk *et al.* [6] reporting I^2 scores between 0% and 85.5%.

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Conclusions

The 47 studies included in this systematic review provide evidence supporting the use of group-based education for the management of Type 2 diabetes to significantly improve HbA_{1c}, FBG, body weight, waist circumference, triglycerides and diabetes knowledge. However, the results may not be clinically important and were complex, with most outcomes improving at time points proximal to the intervention, but others improving at more distal time points. In addition, the results should be interpreted with caution due to the high heterogeneity of some of the meta-analyses, as well as assessment of most of the included studies as having a moderate or high risk of bias. Group-based education interventions facilitated by single disciplines, multidisciplinary teams or health professionals with peer supporters result in improved outcomes in HbA_{1c} when compared with peer-led interventions. The lack of statistical significance in all but two of the subgroup analyses may indicate that other factors such as peer identification, normalization and group interactions are the 'active ingredient(s)' and, as such, substantially influence the effectiveness of group-based education interventions for the management of Type 2 diabetes. Future research should explore these factors, as well as the cost-effectiveness of, and barriers and facilitators to implementing group-based education programmes for the management of Type 2 diabetes. Finally, future interventions should consider hypoglycaemia as an important end point.

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Competing interests

None declared.

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Author contributions

KOJ undertook this project as part of her PhD and had a principal role in study conception and design, screening, data extraction, risk of bias, data analysis and interpretation, and wrote the first draft of the manuscript. LEB assisted with the study conception and design, screening and risk of bias. JTK assisted with screening, data extraction, and data analysis. RT assisted with the study conception and design, data analysis and interpretation. EAI and DPR assisted with the study conception and design. All six authors commented critically on the manuscript and approved it for submission.

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FIGURE 1 Stages of study identification

FIGURE 2 Effectiveness of group-based interventions compared with controls for Type 2 diabetes for HbA_{1c} (%). Risk of bias: A, random sequence generation (selection bias); B, allocation concealment (selection bias); C, blinding of participants and personnel (performance bias); D, blinding of outcome assessment (detection bias); E, incomplete outcome data (attrition bias); F, selective reporting (reporting bias); G, other bias.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1 Overall risk of bias for the included studies.

Figure S2 Forest plot – subgroup analysis of group educators.

Figure S3 Forest plot – subgroup analysis of group educators by individual discipline.

Figure S4 Forest plot – subgroup analysis of insulin therapy.

Figure S5 Forest plot – sensitivity analysis: overall risk of bias.

Figure S6 Forest plot – sensitivity analysis: reporting bias.

Figure S7 Forest plot – sensitivity analysis: baseline differences.

Figure S8 Forest plot – sensitivity analysis: attrition.

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Figure S9 Forest plot – sensitivity analysis: published in non-English journals.

Table S1 Characteristics of the included studies.

Table S2 Intervention characteristics of the included studies.

Table S3 Risk of bias summary of studies included in the systematic review.

Table S4 Summary of meta-analysis results of secondary outcomes assessed using standard mean difference at various time points.

Table S5 Meta-regression: association between study variables and primary outcome measure (HbA_{1c}).

File S1 Search strategy for PubMed.

File S2 References for included studies.

Table 1 Summary of meta-analysis results for primary and secondary outcome measures at various time points

Outcome	Time point (months)	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	*P*-value	Heterogeneity (%) (I^2)	Heterogeneity (*P*-value)
HbA_{1c} (%)	6–10	30	2155/1952	–0.31 (–0.48, –0.15)	0.0002	65	< 0.00001
	12–14	27	2233/2151	–0.33 (–0.49, –0.17)	< 0.0001	64	< 0.00001
	18	3	98/96	–0.72 (–1.26, –0.18)	0.009	50	0.13
	24	8	551/555	–0.33 (–0.82, 0.17)	0.20	94	< 0.00001
	36–48	5	747/689	–0.93 (–1.52, –0.34)	0.002	93	< 0.00001
Fasting blood glucose (mmol/l)	6–10	10	454/461	–0.24 (–0.95, 0.47)	0.51	79	< 0.00001

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Outcome	Time point (months)	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	*P*-value	Heterogeneity (%) (I^2)	Heterogeneity (*P*-value)
	12–14	8	496/575	–0.68 (–1.25, –0.11)	0.02	55	0.03
	24	4	204/209	–0.10 (–1.60, 1.39)	0.89	88	< 0.0001
Weight (kg)	6–10	17	1341/1172	–1.22 (–2.22, –0.23)	0.02	62	0.0003
	12–14	9	804/760	–1.43 (–2.09, –0.77)	< 0.0001	0	0.88
	36–48	4	714/605	–0.62 (–1.69, 0.45)	0.25	0	0.77
BMI (kg/m^2)	6–10	18	1019/1016	–0.00 (–0.44, 0.44)	0.99	36	0.07
	12–14	13	962/1082	0.19 (–0.37, 0.75)	0.51	55	0.009
	24	6	496/502	0.80 (–0.93, 2.54)	0.36	89	< 0.00001
Waist circumference (cm)	6–10	5	520/466	–1.19 (–2.34, –0.05)	0.04	58	0.05
	12–14	3	579/509	–0.79 (–1.96, 0.38)	0.19	38	0.20
Systolic blood pressure (mmHg)	6–10	17	1359/1218	0.12 (–1.44, 1.67)	0.88	38	0.05
	12–14	11	1087/1083	–0.49 (–1.90, 0.92)	0.49	0	0.45
	24	4	263/265	–0.68 (–5.43, 4.07)	0.78	40	0.17
	36–48	4	714/605	–1.71 (–5.76, 2.34)	0.41	66	0.03
Diastolic blood pressure (mmHg)	6–10	17	1435/1261	–1.77 (–3.73, 0.20)	0.08	92	< 0.00001
	12–14	11	1087/1083	–0.80 (–1.71, 0.12)	0.09	0	0.46

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Outcome	Time point (months)	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	*P*-value	Heterogeneity (%) (I^2)	Heterogeneity (*P*-value)
	24	3	97/94	1.12 (–1.77, 4)	0.45	17	0.30
	36–48	4	714/605	–1.13 (–2.70, 0.43)	0.16	40	0.17
Total cholesterol (mmol/l)	6–10	15	1153/1117	–0.01 (–0.16, 0.14)	0.87	75	< 0.00001
	12–14	9	891/928	0.01 (–0.12, 0.15)	0.84	44	0.07
	24	3	241/243	–0.10 (–0.56, 0.36)	0.67	81	0.005
	36–48	3	692/583	–0.23 (–0.65, 0.18)	0.27	88	0.0003
HDL cholesterol (mmol/l)	6–10	13	967/906	0.16 (–0.09, 0.41)	0.22	99	< 0.00001
	12–14	10	915/943	0.02 (–0.02, 0.07)	0.28	74	< 0.0001
	36–48	3	692/583	0.04 (–0.10, 0.18)	0.59	94	< 0.00001
LDL cholesterol (mmol/l)	6–10	12	571/560	–0.03 (–0.13, 0.07)	0.59	49	0.03
	12–14	5	333/398	0.08 (0.01, 0.15)	0.04	0	0.44
Triglycerides (mmol/l)	6–10	14	1105/1045	–0.13 (–0.24, –0.01)	0.03	4	0.41
	12–14	11	1045/1069	–0.04 (–0.22, 0.14)	0.66	68	0.0005
	24	3	118/119	–0.32 (–0.58, –0.06)	0.01	8	0.34

Outcome	Time point (months)	No. studies	No. participants (IG/CG)	Standard mean difference (95% CI)	*P*-value	Heterogeneity (%) (I^2)	Heterogeneity (*P*-value)
Diabetes knowledge	6–10	7	239/240	0.61 (0.14, 1.08)	0.01	83	< 0.00001

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Outcome	Time point (months)	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	*P*-value	Heterogeneity (%) (I^2)	Heterogeneity (*P*-value)
	12–14	7	609/682	0.58 (0.08, 0.97)	0.02	93	< 0.00001
Self-efficacy	12	3	256/272	0.15 (–0.02, 0.33)	0.08	0	0.92

IG, intervention group; CG, control group; CI, confidence interval.

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Table 2 Subgroup analysis results for primary outcome measure (HbA_{1c}; %)

Analysis outcome	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	Overall effect: *P*-value	Heterogeneity (%)	Subgroup differences: *P*-value
Control group	47	3579/3476	–	–	–	0.60
Usual care	28	2414/2322	–0.42 (–0.66, –0.18)	0.0007	88	
Waiting list control	4	243/251	–0.34 (–0.85, 0.18)	0.20	70	
Individual intervention	6	542/532	–0.05 (–0.50, 0.40)	0.82	81	
Usual care with written materials	6	315/412	–0.21 (–0.54, 0.12)	0.21	61	
Group education prior to usual care	3	65/63	–0.48 (–1.03, 0.07)	0.09	34	
Delivery setting	47	3579/3476	–	–	–	0.38
Primary care	34	2858/2808	–0.28 (–0.41, –0.16)	< 0.0001	59	
Other	13	721/668	–0.52 (–1.02, –0.01)	0.05	93	
Type of educators	47	3579/3476	–	–	–	0.002
Peer or lay led	5	530/536	0.02 (–0.12, 0.16)	0.80	0	
Health professional led with peer support	5	517/502	–0.27 (–0.48, –0.06)	0.01	0	
Single discipline	17	1054/1080	–0.56 (–0.86, –0.26)	0.0003	86	
Multidisciplinary	20	1478/1358	–0.24 (–0.43, –0.04)	0.02	61	
Training:	47	3579/3476	–	–	–	0.82
Yes	34	2915/2814	–0.33 (–0.53, –0.13)	0.001	87	
No	13	664/662	–0.38 (–0.70, –0.05)	0.02	69	
Baseline HbA_{1c} levels	47	3579/3476	–	–	–	0.52
> 7 in both groups	38	3043/2937	–0.37 (–0.56, –0.17)	0.002	85	
< 7 in both groups	9	536/539	–0.24 (–0.60, 0.13)	0.21	82	
Insulin therapy	38	2978/2893	–	–	–	< 0.0001
Yes	20	1809/1661	–0.19 (–0.28, –0.10)	< 0.0001	69	
No	18	1169/1232	–0.81 (–0.92, –0.70)	< 0.00001	88	
Theoretical model	47	3579/3476	–	–	–	0.48
Yes	24	2227/2089	–0.39 (–0.65, –0.12)	0.004	89	
No	23	1352/1387	–0.27 (–0.46, –0.09)	0.003	62	
Intervention content	47	3579/3476	–	–	–	0.75
Facilitator–directed	43	3306/3226	–0.34 (–0.52, –0.15)	0.0003	85	
Patient–directed	4	273/250	–0.42 (–0.94, 0.09)	0.11	73	
Materials	47	3579/3476	–	–	–	0.90
Yes	40	3182/3100	–0.34 (–0.53, –0.15)	0.0004	85	
No	7	397/376	–0.37 (–0.83, 0.09)	0.12	84	

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Analysis outcome	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	Overall effect: *P*-value	Heterogeneity (%)	Subgroup differences: *P*-value
Intervention length (months)	47	3579/3476	–	–	–	0.53
< 1	6	875/790	–0.33 (–0.64, –0.02)	0.04	56	
1–3	8	585/546	–0.20 (–0.50, 0.10)	0.19	71	
4–6	11	501/486	–0.19 (–0.48, 0.10)	0.20	67	
7–12	13	824/850	–0.32 (–0.55, –0.09)	0.007	54	
13–60	9	794/804	–0.66 (–1.14, –0.18)	0.007	93	
Number of sessions	47	3579/3476	–	–	–	0.34
< 5	13	1223/1208	–0.46 (–0.70, –0.23)	< 0.0001	68	
6–10	21	1360/1294	–0.20 (–0.39, –0.01)	0.04	71	
11–20	8	707/678	–0.48 (–1.04, 0.09)	0.10	92	
> 21	5	289/296	–0.31 (–0.71, 0.09)	0.13	41	
Contact time (h)	47	3579/3476	–	–	–	0.72
≤ 8	13	1168/1033	–0.45 (–0.74, –0.17)	0.002	72	
9–12	7	536/557	–0.35 (–0.59, –0.11)	0.004	55	
13–18	10	909/909	–0.19 (–0.74, 0.35)	0.48	96	
19–30	9	348/352	–0.42 (–0.77, –0.08)	0.02	58	
≥ 31	8	618/625	–0.25 (–0.42, –0.09)	0.003	0	
Number of participants	47	3579/3476	–	–	–	0.40
4–10	32	2563/2426	–0.39 (–0.16, –0.17)	0.0006	87	
11–20	15	1016/1050	–0.25 (–0.48, –0.02)	0.03	64	
Family and friends	47	3579/3476	–	–	–	0.70
Yes	29	2841/2700	–0.36 (–0.59, –0.13)	0.002	88	
No	18	738/776	–0.30 (–0.52, –0.08)	0.008	67	

IG, intervention group; CG, control group; CI, confidence interval.

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Table 3 Sensitivity analysis results for primary outcome measure (HbA_{1c}; %)

Analysis outcome	No. studies	No. participants (IG/CG)	Mean difference (95% CI)	*P*-value	Heterogeneity (%)	Subgroup differences: *P*-value
Overall risk of bias	47	3579/3476	–	–	–	0.92
Low	4	409/375	–0.40 (–0.75, –0.06)	0.02	52	
Moderate	31	2011/1963	–0.35 (–0.59, –0.12)	0.003	88	
High	12	1159/1138	–0.31 (–0.59, –0.02)	0.03	74	
Reporting bias	47	3579/3476	–	–	–	0.38
Low	38	2792/2734	–0.38 (–0.58, –0.18)	0.0002	86	
High	9	787/742	–0.22 (–0.52, 0.08)	0.16	69	
Baseline differences	47	3579/3476	–	–	–	0.68
Yes	10	737/695	–0.27 (–0.62, 0.07)	0.12	70	
No	37	2842/2781	–0.36 (–0.55, –0.16)	0.0004	86	
Dropout	47	3579/3476	–	–	–	0.09
< 10% attrition	14	1043/949	–0.53 (–0.72, –0.34)	< 0.00001	41	
> 10% attrition	33	2536/2527	–0.27 (–0.49, –0.05)	0.02	88	
Translated publication	47	3579/3476	–	–	–	0.48
Yes	42	3313/3206	–0.36 (–0.55, –0.18)	< 0.0001	85	
No	5	409/375	–0.15 (–0.72, 0.42)	0.61	74	

IG, intervention group; CG, control group; CI, confidence interval.

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Figure 1: Stages of Study Identification

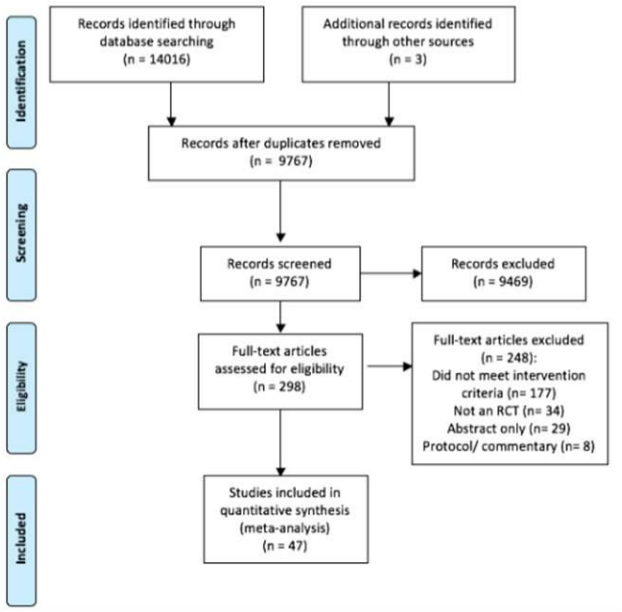
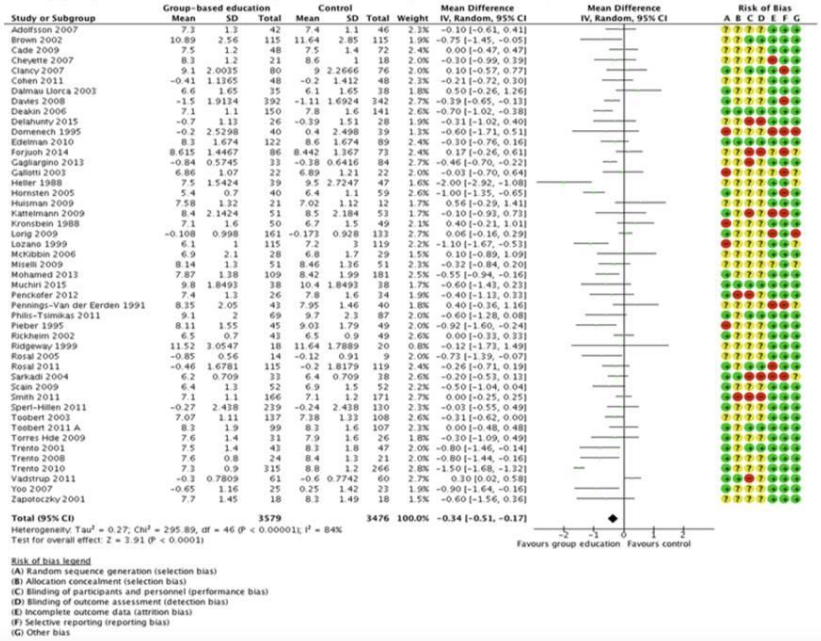


Figure 2: Effectiveness of group-based interventions compared with controls for Type 2 diabetes for HbA1c[%]



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Supplemental Data

Supplemental Item S1: Search Strategy for PubMed

We used the following search strategy to search Pubmed. The search strategy was adapted to search the Cochrane Central Register of Controlled Trials (CENTRAL), EMBASE, CINAHL, PsycINFO, and ERIC. There were no language or date restrictions.

Pubmed

"Patient Education as Topic"[Mesh] OR "Self Care"[Mesh] OR "Behavior Therapy"[Mesh] OR "Group Processes"[Mesh] OR "Psychotherapy, Group"[Mesh] OR "Self-Help Groups"[Mesh] OR Patient education[tiab] or Self care[tiab] OR Self-care[tiab] OR Self management[tiab] OR Self-management[tiab] OR Behavior therapy[tiab] OR Behaviour therapy[tiab] OR Group process[tiab] OR Group processes[tiab] OR Group psychotherapy[tiab]

AND

"Diabetes Mellitus, Type 2"[Mesh] OR MODY[tiab] OR NIDDM[tiab] OR T2DM[tiab] OR ((non insulin[tiab] OR noninsulin[tiab] OR “Type 2”[tiab] OR “Type II”[tiab] OR Ketosis-Resistant[tiab] OR Ketosis resistant[tiab] OR Maturity-Onset[tiab] OR Maturity onset[tiab] OR Mature-onset[tiab] OR Mature onset[tiab] OR Adult-onset[tiab] OR Adult onset[tiab] OR Slow-onset[tiab] OR Slow onset[tiab] OR Stable[tiab]) AND Diabetes)

AND

Group[tiab] OR Groups[tiab]

NOT

"Diabetes Insipidus"[Mesh] OR Diabetes Insipidus[tiab]

AND

randomized controlled trial[Publication Type] OR controlled clinical trial[Publication Type] OR randomized[Title/Abstract] OR randomised[Title/Abstract] OR placebo[Title/Abstract] OR "drug therapy"[MeSH Terms] OR randomly[Title/Abstract] OR trial[Title/Abstract] OR groups[Title/Abstract]

Supplemental Table S1: Study characteristics of included studies*

Author, Year, Country	Study design	Length of follow up in months	Setting	No. at recruitment	No. at follow up	Mean baseline age (SD)	Gender: % Male	Mean baseline HbA1c	Conflict of interest
Adolfsson 2007, Sweden[1]	RCT	12	Primary care	IG: 42; CG: 46	IG: 42; CG: 46	IG: 62.4 (8.9); CG: 63.7 (9.0)	IG: 57%; CG: 61%	IG: 7.4; CG: 7.1	No
Brown 2002, USA[2]	RCT	12	Primary care	IG: 128; CG: 128	IG: 115; CG: 115	IG: 54.7 (8.2), CG: 53.3 (8.3)	IG: 40%; CG: 32%	IG: 11.8; CG: 11.8	No
Cade 2009, UK[3]	RCT	12	Primary care	IG: 122; CG: 127	IG: 86; CG: 108	IG: 65.8 (11), CG: 66.6 (11)	IG: 62%; CG: 58%	IG: 7.3; CG: 7.5	No
Cheyette 2007, UK[4]	RCT	12	Secondary care	IG: 29; CG: 20	IG: 21; CG: 18	IG: 56.7 (9.7); CG: 58 (10.7)	IG: 48%; CG: 60%	IG: 8.2; CG: 8.2	No
Clancy 2007, USA[5]	RCT	12	Primary care	IG: 96; CG: 90	IG: 80; CG: 76	IG: 55; CG: 57	IG: 26%; CG: 30%	IG: 9.3; CG: 8.9	Yes
Cohen 2011, USA[6]	RCT	6	Primary care	IG: 50; CG: 49	IG: 48; CG: 48	IG: 69.8 (10.7); CG: 67.2 (9.4)	IG: 100%; CG: 96%	IG: 7.8; CG: 8.1	No
Dalmau Llorca 2003, Spain[7]	RCT	12	Primary care	IG: 33; CG: 35	IG: 35; CG: 38	IG: 64.9 (8.2); CG: 65.6 (8.1)	IG: 64.7%, CG: 35.3%	IG: 7.2; CG: 6.6	Unclear
Davies 2008[8]/ Khunti 2012, UK[9]	Cluster RCT	12/ 36	Primary care	IG: 437; CG: 387	IG: 404; CG: 345/ IG: 332; CG: 272	IG: 59.4 (11.6), CG: 61.01 (12.1)	IG: 53%; CG: 57%	IG: 8.3; CG: 7.9	No
Deakin 2006, UK[10]	RCT	14	Primary care	IG: 157; CG: 157	IG: 150; CG: 141	IG: 61.3 (9.7); CG: 61.8 (11)	IG: 52% CG: 52%	IG: 7.7; CG: 7.7	Yes
Delahanty 2015, USA[11]	RCT	6	Primary care	IG: 28, CG: 29	IG: 26; CG: 28	IG: 62 (9.6), CG: 61 (11.4)	IG: 61%; CG: 59%	IG: 8.1; CG: 8.3	No
Domenech 1995, Argentina[12]	CCT	12	Primary care	IG: 40; CG: 39	IG: 40; CG: 39	IG: 52.7 (3.1); CG: 53.1 (1.1)	IG: 55%; CG: 56%	IG: 9; CG: 9	Yes
Edelman 2010, USA[13]	RCT	12.8	Primary care	IG: 133; CG: 106	IG: 122; CG: 89	IG: 63 (9.4); CG: 60.8 (10)	IG: 95.5%; CG: 96.2%	IG: 9.2; CG: 9.2	Unclear
Forjuoh 2014, USA[14]	RCT	12	Primary care	IG: 101; CG: 95	IG: 86; CG: 73	IG: 57.6 (10.9) CG: 57.6 (10.9)	IG 46.5%, CG 44.2%	IG: 9.2; CG: 9.0	Unclear
Gagliardino 2013, Argentina[15]	RCT	42	Primary care	G1: 117; G3: 117; G4: 117	G1: 84; G3: 86; G4: 33	G1 62 (8.4); G3 62.2 (8.4); G4 62.2 (8.4)	G1 32.5%, G3 33.3%, G4 37.6%	IG: 7.7; CG: 7.8	No
Gallotti 2003, Italy[16]	CCT	36	Primary care	IG: 22; CG: 22	IG: 22; CG: 22	IG & CG: 56-73 yrs	IG: 55%; CG: 55%	IG: 6.9; CG: 6.8	Unclear

Heller 1988, UK[17]	RCT	12	Secondary care	IG: 36; CG: 39	IG: 35; CG: 39	IG 56.5 (55-58); CG 56.4 (53-59.9)	IG 55%, CG 41%	IG: 12.3; CG: 12.7	Yes
Hornsten 2005& 2008, Sweden[18, 19]	Cluster RCT	12/ 60	Primary care	IG 44; CG: 60	IG: 40; CG: 59/ IG: 39; CG: 50	IG: 63.6 (9.3); CG: 63.4 (9.1)	IG: 52%; CG: 55%	IG: 5.7; CG: 5.8	No
Huisman 2009, Netherlands[20]	RCT	6	Secondary care	IG: 53; CG: 38	IG: 21; CG: 12; CG+ manual: 7	IG: 60.07 (6.76); CG: 56.69 (9.88); CG + manual: 56.74 (10.30)	IG: 52%; CG: 46%; CG + manual: 42%	IG: 7.3; CG: 7.2	Unclear
Kattelmann 2009, USA[21]	RCT	6	Primary care	IG: 57; CG: 57	IG: 51; CG: 53	Unclear	Unclear	IG: 8.9; CG: 8.6	No
Kronsbein 1988, Germany[22]	CCT	12	Primary care	IG: 50; CG: 49	IG: 50; CG: 49	IG: 65 (9); CG: 63 (8)	IG: 42%; CG: 39%	IG: 7.1; CG: 6.5	Unclear
Lorig 2009, USA[23]	RCT	12	Primary care	IG: 186; CG: 159	IG: 161; CG: 133	IG: 67.7 (11.9); CG: 65.4 (11.4)	IG: 37.6%, CG: 33.8%	IG: 6.7; CG: 6.7	Yes
Lozano 1999, Spain[24]	RCT	24	Primary care	IG: 120; CG: 123	IG: 115; CG: 119	IG: 63.8; CG: 64.7	IG: 48%, CG: 48%	IG: 6.6; CG: 6.7	Unclear
McKibbin 2006, USA[25]	RCT	6	Secondary care	IG: 32; CG: 32	IG: 28; CG: 29	IG: 53.1 (10.4); CG: 54.8 (8.2)	IG: 68%; CG: 62%	IG: 7.4; CG: 6.7	Unclear
Miselli 2009, Italy[26]	RCT	24	Primary care	IG: 51; CG: 51	IG: 51; CG: 51	IG: 63.38 (9.68); CG: 63.70 (6.99)	IG: 45.1%; CG: 66.7%	IG: 8.7; CG: 8.8	No
Mohamed 2013, Qatar[27]	RCT	12	Primary care	IG: 215; CG: 215	IG: 109; CG: 181	IG: 52 (8.9); CG: 55 (10.7)	IG: 37%; CG: 28%	IG: 8.7; CG: 8.6	No
Muchiri 2015, South Africa[28]	RCT	12	Primary care	IG: 41; CG: 41	IG: 38; CG: 38	IG: 59.4 (6.9), CG: 58.2 (8.0)	IG: 12.2%; CG: 14.6%	IG: 10.8; CG: 11.4	No
Penckofer 2012, USA[29]	RCT	6	Primary care	IG: 38, CG: 36	IG: 26; CG: 34	IG: 54.8 (8.8), CG: 54 (8.4)	IG: 0%; CG: 0%	IG: 7.8; CG: 7.9	No
Pennings-Van der Eerden 1991, Netherlands[30]	RCT	6	Primary care	IG: 61; CG: 57	IG: 43; CG: 40	IG: 64.9 (9.77); CG: 63.86 (9.34)	IG: 39.3%; CG: 52.6%	IG: 8.0; CG: 7.7	Yes
Philis-Tsimikas 2011, USA[31]	RCT	10	Primary care	IG: 104; CG: 103	IG: 69; CG: 87	IG: 52.2 (9.6); CG: 49.2 (11.8)	IG: 33.7%; CG: 25.2%	IG: 10.5; CG: 10.3	Yes
Pieber 1995, Austria[32]	CCT	6	Primary care	IG: 45; CG: 49	IG: 45; CG: 49	IG: 63.9 (8.2); CG: 65.4 (11.2)	IG: 42%; CG: 47%	IG: 8.6; CG: 8.8	Unclear

Rickheim 2002, USA[33]	RCT	6	Secondary care	IG: 87, CG: 83	IG: 43; CG: 49	IG: 51.6 (9.2); CG: 52.9 (12.8)	IG: 35.6%; CG: 32.5%	IG: 8.9; CG: 8.0	Yes
Ridgeway 1999, USA[34]	RCT	12	Primary care	IG: 28; CG: 28	IG: 18; CG: 20	IG: 62; CG: 65	IG: 33%; CG: 25%	IG: 12.3; CG: 12.3	Unclear
Rosal 2005, USA[35]	RCT	6	Primary care	IG: 15; CG: 10	IG: 14; CG: 9	IG: 62.7 (8.1); CG: 62.4 (9.7)	IG: 20%; CG: 20%	IG: 7.7; CG: 9.3	Yes
Rosal 2011, USA[36]	RCT	12	Primary care	IG: 124; CG: 128	IG: 115; CG: 119	IG: 45-54 (32.3%), 55-64 (29%); CG: 45-54 (27.3%), 55-64 (36.7%)	IG: 21.8%, CG: 25%	IG: 8.9; CG: 9.1	Yes
Sarkadi 2004, Sweden[37]	RCT	24	Primary care	IG: 33; CG: 31	IG: 33; CG: 31	IG: 66.5 (10.7), CG: 66.4 (7.9)	Unclear	IG: 6.5; CG: 6.4	Yes
Scain 2009, Brazil[38]	RCT	12	Tertiary care	IG: 52; CG: 52	IG: 52; CG: 52;	IG: 59.3 (8.8); CG: 59.5 (10.2)	IG: 44.2%; CG: 50%	IG: 6.8; CG: 6.7	Unclear
Smith 2011, UK[39]	Cluster RCT	24	Primary care	IG: 192; CG: 203	IG: 166; CG: 171	IG: 66.1 (11.11); CG: 63.2 (11.04)	IG: 54%; CG: 54%	IG: 7.2; CG: 7.2	No
Sperl-Hillen 2011/ 2013, USA[40, 41]	RCT	6.8/ 12.8	Primary care	IG: 243; IE: 246; CG: 134	IG: 239; CG: 130; IE: 239/ IG: 227; CG: 124; IE: 239	IG: 61.2 (11.8); CG: 63.3 (11.5); IE: 61.6 (10.9)	IG: 49%; CG: 53.7%; IE: 50.4%	IG: 8.1; CG: 8.0	Yes
Toobert, 2003, USA[42]	RCT	6	Primary care	IG: 163; CG: 116	IG: 137; CG: 108	IG: 61.1 (8); CG: 60.7 (7.8)	IG: 0%; CG: 0%	IG: 7.4; CG: 7.4	No
Toobert 2011A& 2011B, USA[43, 44]	RCT	12/ 24	Primary care	IG: 142; CG: 138	IG: 99; CG: 107/ IG: 97; CG: 93	IG: 55.6 (9.7); CG: 58.7 (10.3)	IG: 0%; CG: 0%	IG: 8.4; CG: 8.2	No
Torres Hde 2009, Brazil[45]	RCT	6	Secondary care	IG: 54; CG: 50	IG: 31; CG: 26	IG: 61.7 (10.5); CG: 59.4 (10.4);	IG: 24.1%; CG: 26%	IG: 9.3; CG: 9.3	Unclear
Trento 2001/ 2002/ 2004, Italy[46-48]	RCT	24/ 48/ 60	Secondary care	IG: 56; CG: 56	IG: 43; CG: 47/ IG: 45; CG: 45/ IG: 42; CG: 42	IG: 63 (37-82); CG: 64 (45-80)	IG: 51%; CG: 64%	IG: 7.4; CG: 7.4	No
Trento 2008, Italy[49]	RCT	24	Secondary care	IG: 25; CG: 24	IG: 24; CG: 21	IG: 64.6 (9.3); CG 68.1 (7.1)	IG: 52%; CG: 67%	IG: 7.8; CG: 7.8	No

Trento 2010, Italy[50]	RCT	48	Secondary care	IG: 421; CG: 394	IG: 315; CG: 266	IG: 69 (8.4); CG: 69.6 (8.4)	IG: 48%; CG: 54%	IG: 8; CG: 8	No
Vadstrup 2011, Denmark[51]	RCT	6	Secondary care	IG: 70; CG: 73	IG: 61; CG: 60	IG: 58.5 (9), CG: 58 (10.3)	IG: 59%; CG: 60%	IG: 7.9; CG: 7.8	Yes
Yoo 2007, Korea[52]	RCT	18	Secondary care	IG: 25; CG: 23	IG: 25; CG: 23	IG: 55.32 (7.56); CG: 55.08 (7.175)	IG: 32%; CG: 34.8%	IG: 8.3; CG: 8.7	No
Zapotoczky 2001, Austria[53]	RCT	12	Secondary care	IG: 18; CG: 18	IG: 18; CG: 18	IG: 62 (8.2); CG: 53 (11.4)	IG: 44%; CG: 28%	IG: 8.6; CG: 8.0	Unclear

No.= number; RCT= Randomised controlled trial; CCT= Controlled clinical trial; IG= Intervention group; CG= Control group; IE= Individual intervention; SD= standard deviation; HbA1c= glycated haemoglobin

* A list of excluded studies is available on request from the first author.

Supplemental Table S2: Intervention characteristics of included studies

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Adolfsson 2007, Sweden[1]	7	Empowerment group education	Usual care	5-8	12.5- 15	4-5	No	Empowerment, motivation, learning principles	Yes (document and guidelines for facilitators)	Physicians, diabetes specialist nurses	Yes
Brown 2002, USA[2]	12	Group education program	Waiting list	8	52	26	Yes	Not stated	Yes (videos, lab results)	Bilingual Mexican American nurses, dietitians, community workers	Yes
Cade 2009, UK[3]	1.75	Expert Patient Program (EPP) (adapted for Type 2 diabetes)	Usual care	12-16	14	7	Yes	Not stated	Yes (written materials plus booklet)	Peer or lay led	Yes
Cheyette 2007, UK[4]	4	Weight No More program	Usual care	8-10	12	8	No	Not stated	Yes (visual teaching aids, food diaries)	Dietitian, physio, diabetes nurse specialist	Not stated
Clancy 2007, USA[5]	12	Group visits	Usual care	14-17	24	12	Yes	Not stated	No	Primary care internal medicine physicians, registered nurses	Yes

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Cohen 2011, USA[6]	6	VA MEDIC-E (Veterans Affairs Multidisciplinary Education and Diabetes Intervention for Cardiac Risk Reduction-Extended)	Usual care	4-6	15.5	9	Yes	Not stated	Yes (cardiovascular report card, videos; Powerpoint slides; food log; Pedometers)	Pharmacist led, dietitian, nurse, physical therapist	Not stated
Dalmau Llorca 2003, Spain[7]	12	Group education	Individual education	5	3	6	Yes	Not stated	Yes (food photographs, written information; blackboards, transparencies and slides)	Medical resident, nurse	Not stated
Davies 2008[8]/ Khunti 2012, UK[9]	1 day/ 2 half days	Structured group education program	Usual care	8 (4 to 16)	6	1 to 2	Yes	Leventhal's common sense theory, dual process theory, social learning theory; Patient empowerment	Yes (patient resources)	Registered dietitians, practice nurses or nurse specialists	Yes
Deakin 2006, UK[10]	1.5	X-PERT program	Individual education	Average 16	12	6	Yes	Patient empowerment, discovery learning	Yes (patient manual)	Diabetes research dietitian	Not stated
Delahanty 2015, USA[11]	4.75	Group lifestyle intervention (GLI) adapted 'Look Ahead'	Individual education	8-10	28.5	19	Not stated	Not stated	Yes (Look AHEAD group materials)	Dietitians	Yes

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Domenech 1995, Argentina[12]	1	Group-based structured teaching/ treatment program	Usual care	5-8	6-8	4	Yes	Not stated	Yes (flip-charts, food photographs, question cards, individual log books, patient booklet)	Physicians	Yes
Edelman 2010, USA[13]	12	Group Medical Clinics	Usual care	7-9	10.5-14	7	Yes	Not stated	No	Primary care general internist, pharmacist, nurse or certified diabetes educator	Yes
Forjuoh 2014, USA[14]	1.5	Intervention: Group program (Stanford CDSMP)	Usual care (with written materials)	7-17	15	6	Yes	Not stated	Yes (companion book, audio relaxation tape)	Stanford-certified CDSMP lay leaders and master trainers	Yes
Gagliardino 2013, Argentina[15]	6	Patient education-Diabetes Structured Education Courses for Type 2 diabetes	Usual care (with written materials)	6-10	7.5- 10	5	Yes	Not stated	Yes (Illustrated materials, programme book, questionnaire cards, individual log-book, patient book)	Physicians	Yes (G4 only)
Gallotti 2003, Italy[16]	36	Group program	Usual care	11	54	36	No	Not stated	Yes (manual)	Medical doctors	Yes

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Heller 1988, UK[17]	6	Intervention: Group program	Usual care	4-6	7.5	5	Yes	Not stated	Yes (video tape, simple explanatory book)	Diabetes nurses, dietitian	Not stated
Hornsten 2005 & 2008, Sweden[18, 19]	9	Educational intervention (focus on personal understanding of their illness)	Usual care	5-8	20	10	No	Patient-directed, patient-centred, model of chronic illness	No	Diabetes nurses, nurse as moderator	Yes
Huisman 2009, Netherlands[20]	6	Self-regulation weight reduction intervention	Usual care, or usual care (with written materials)	10-15	16	8	Yes	Self-regulation principles, motivational interviewing	Yes (workbook, pedometer)	Health psychologist	Not stated
Kattelmann 2009, USA[21]	6	The Medicine Nutrition Wheel Nutrition Model education lessons	Usual care	5-9	18-21	6	Yes	Empowerment	Yes (Medicine Wheel Model for Native Nutrition, Powerpoint Presentations, individualized meal plan)	Registered dietitian, tribal member	Yes
Kronsbein 1988, Germany[22]	1	Group structured treatment and teaching program (DTTP)	Waiting list	4-6	6-8	4	Not stated	Not stated	Yes (flip-charts, food photographs, diabetes-related question cards, patients' log-books)	Physicians, physician assistants	Yes
Lorig 2009, USA[23]	1.5	Diabetes self-management program (DSMP)	Usual care	10-15	15	6	Yes	Not stated	Yes (book)	Peer leaders	Yes

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Lozano 1999, Spain[24]	24	Health educational workshops	Usual care	12-14	6	4	Yes	Not stated	Yes (handouts, food photographs, self-care devices, insulin pen)	Nurses	No
McKibbin 2006, USA[25]	6	Diabetes Awareness and Rehabilitation Training (DART)	Usual care (with written materials)	32	36	24	Not stated	Social cognitive theory	Yes (handouts, educational materials, pedometers, mnemonic aids, printed materials)	Diabetes educators, dietitians	Not stated
Miselli 2009, Italy[26]	24	ROMEO	Usual care	6-10	7	7	No	Not stated	Not stated	Doctor, dietitian, nurse	Not stated
Mohamed 2013, Qatar[27]	1	Group-based intervention	Usual care (with written materials)	10-20	12- 16	4	Yes	Empowerment, health belief models	Yes (educational booklet for self-management, pictorial materials, questionnaires)	Physicians	Yes
Muchiri 2015, South Africa[28]	9	Structured nutrition education (NE) program	Usual care (with written materials)	6-10	25- 29	14	Yes	Social Cognitive Theory, Health Belief Model, Knowledge Attitude Behaviour model	Yes (education materials, diabetes education flip charts, hands on activities, demonstrations, food displays and vegetable gardening)	Sub-district dietitian, final-year nutrition and food science student, experienced dietitian, sub-district horticulture officer	Yes

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Penckofer 2012, USA[29]	5.5	Study of Women's Emotions and Evaluation of a Psycho educational (SWEEP) program	Usual care	10-12	10	10	No	Cognitive behavioural theory (CBT)	Yes (progressive muscle relaxation CD, video, workbook, log book)	Nurse	Yes
Pennings-Van der Eerden 1991, Netherlands[30]	1.75	Education program	Usual care	8-10	21-28	7	Yes	Not stated	Yes (written information, audio-visual aids, demonstration materials)	Physicians, dietitians, diabetologist, diabetes nurse	Not stated
Philis-Tsimikas 2011, USA[31]	10	Project Dulce diabetes self-management classes	Usual care	6-12	32	16	Yes	Not stated	Yes (handouts)	Lay community health workers	Yes
Pieber 1995, Austria[32]	1	Diabetes treatment and teaching program (DTTP)	Waiting list	4-8	6-8	4	No	Not stated	Yes	GP's, office staff	Yes
Rickheim 2002, USA[33]	6	Group intervention	Usual care	4-8	7	4	Yes	Adult learning model, public health nursing model, health belief model, transtheoretical model	Yes	Nurse, dietitian	Yes
Ridgeway 1999, USA[34]	12	Education/ behaviour modification	Usual care	14	10.5	7	Not stated	Not stated	Yes (teaching slides, handouts)	Registered nurse, registered dietitian, diabetes educators, physicians	Not stated

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Rosal 2005, USA[35]	2.5	Group based intervention	Usual care	15	25 to 30	10	No	CBT, patient-centred counselling, social cognitive theory	Yes (log book, glucose meter, step counter, large visuals depicting traffic light system, dietary guidelines, soap opera drama)	Diabetes nurse, nutritionist, assistant	Yes
Rosal 2011, USA[36]	11	The Latinos en Control intervention	Usual care	Up to 15	30	20	Yes	Social cognitive theory	Yes (log book, glucose meter, step counter, visuals of traffic light system, dietary guidelines, soap opera drama)	Nutritionist or health educator, assistant (trained lay individuals)	Yes
Sarkadi 2004, Sweden[37]	12	Experience-based group educational program	Waiting-list	8-10	36	12	Not stated	Not stated	Yes (video, game, booklet)	Pharmacists	Yes
Scain 2009, Brazil[38]	1	Structured group education program based on the Latin American Diabetes Association program for health care providers	Usual care	8-10	8	4	No	Not stated	Yes (brochure, log book, leaflet with anthropometric data and test results, recipes, cooking suggestions)	Nurse educator	No

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Smith 2011, UK[39]	24	Peer support meetings	Usual care	10	9- 13.5	9	No	Social support theory	Yes (educational resources; target card, video/ DVD, pedometer, laminated topic sheets)	Trained peer supporters	Yes
Sperl-Hillen 2011/ 2013, USA[40, 41]	1	Group education using the US Diabetes Conversation Map program: IDEA study	Usual care; and individual education	8-10	8	4	Yes	Patient-centred, non-didactic approach using the US Diabetes Conversation Map	Yes (Conversation Map support materials)	Certified diabetes educators (nurses, dietitians)	Yes
Toobert, 2003, USA [42]	6	Mediterranean Lifestyle Program (MLP)	Usual care	5-10	116	6	Not stated	Social Cognitive Theory, Goal Systems, Social Ecological Theory	Yes (program materials)	Registered dietitian, exercise physiologist, stress-management instructor, professional, lay support group leaders	Yes
Toobert 2011A & 2011B, USA[43, 44]	12/ 24	Viva Bien! Group education program	Usual care	5-10	164/ 200	36/ 45	Yes	Behaviour change theory	Yes (stress management CDs, recipes, pamphlets)	Physician, dietitian, exercise physiologist, yoga/ meditation instructor, support group leaders	Yes

Author, Year, Country	INT duration (mths)	INT	Control Group	No. per group	Contact time (hrs)	No. of sessions	Family/ friends included	Theory	Materials (type)	Facilitator/s	Training
Torres Hde 2009, Brazil[45]	3	Group meetings	Individual intervention	Average 13	22	11	Yes	Social learning theory, health belief model	Yes (educational pamphlets, videos)	Nurse-led, doctor, nutritionist, physio, OT	Yes
Trento 2001/ 2002/ 2004, Italy[46-48]	24/ 48/ 60	Structured education programme	Usual care	9-10	8 / 15/ 19	8/ 15/ 19	Yes	Systemic education approach	Yes (visual aids, food, graduated containers, flip chart)	Hospital physicians	Not stated
Trento 2008, Italy[49]	24	Group education sessions	Usual care	8-9	4-6.5 hrs	4-6	Yes	Adult learning theory	Yes (operational manual, brochures)	Nurses, dietitian	Yes
Trento 2010, Italy[50]	48	Structured education programme	Usual care	10	14 hours	14	Yes	Systemic education approach	Yes (as per Trento 2001)	Physicians	Yes
Vadstrup 2011, Denmark[51]	6	Group-based rehabilitation programme	Individual education	8	17 hrs education	9	Not stated	Motivational interviewing; empowerment approach	Not stated	Nurse, physio, podiatrist, dietitian	Yes
Yoo 2007, Korea[52]	13	Comprehensive Lifestyle Modification Program (CLMP)	GBE then usual care	5-8	25 hrs	25	Not stated	Self-efficacy	Not stated	Nurse researchers	Yes
Zapotoczky 2001, Austria[53]	10	Psycho educational group training	GBE then usual care	18	15 hrs	10	Not stated	Learning theory	Not stated	Clinical dietitian	Yes

INT= Intervention; Physio= physiotherapist; OT= occupational therapist; IDEA= Interactive Dialogue to Educate and Activate; US= United States; mths= months; hrs= hours; GBE= group-based education

Supplemental Table S3: Risk of bias summary of studies included in systematic review*

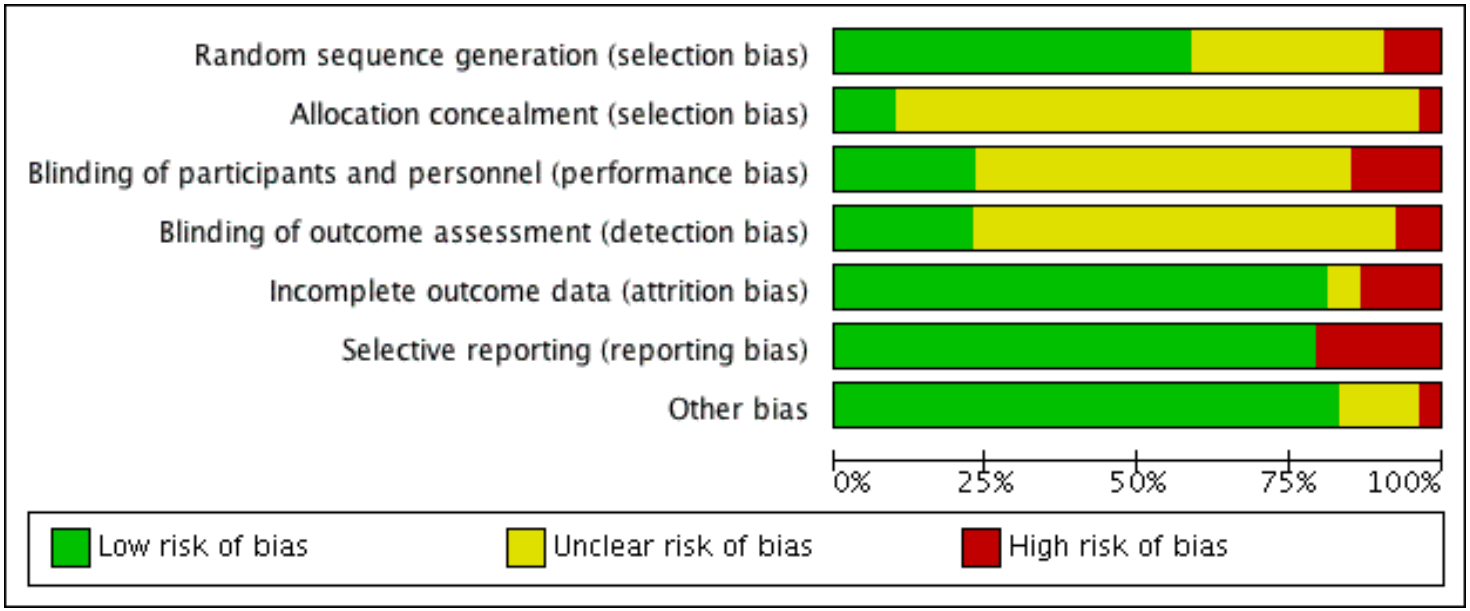
Author, Year, Country	Overall Risk of Bias	Random Sequence Generation	Allocation Concealment	Blinding	Incomplete Outcome Data	Selection Outcome Reporting	Other potential sources of bias
Adolfsson 2007, Sweden[1]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Brown 2002, USA[2]	**Moderate**	Unclear	Unclear	Low	Low	Low	Low
Cade 2009, UK[3]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Cheyette 2007, UK[4]	**Moderate**	Unclear	Unclear	Unclear	High	Low	Low
Clancy 2007, USA[5]	**High**	Low	Unclear	Low	Low	High	Low
Cohen 2011, USA[6]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Dalmau Llorca 2003, Spain[7]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Davies 2008[8]/ Khunti 2012, UK[9]	**High**	Low	Unclear	Unclear	Low	High	Low
Deakin 2006, UK[10]	**Low**	Low	Low	Low	Low	Low	Low
Delahanty 2015, USA[11]	**Moderate**	Unclear	Unclear	High	Low	Low	Low
Domenech 1995, Argentina[12]	**High**	High	Unclear	Unclear	High	High	High
Edelman 2010, USA[13]	**Low**	Low	Low	Low	Low	Low	Low
Forjuoh 2014, USA[14]	**Moderate**	Unclear	Unclear	High	Unclear	High	Unclear
Gagliardino 2013, Argentina[15]	**Moderate**	Unclear	Unclear	High	Low	Low	Low
Gallotti 2003, Italy[16]	**High**	High	Unclear	Unclear	Unclear	High	Unclear
Heller 1988, UK[17]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Unclear
Hornsten 2005 & 2008, Sweden[18, 19]	**High**	Low	Unclear	Unclear	Low	High	Low
Huisman 2009, Netherlands[20]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low

Kattelmann 2009, USA[21]	**High**	Low	Unclear	High	High	High	Low
Kronsbein 1988, Germany[22]	**High**	High	Unclear	Unclear	Low	Low	Low
Lorig 2009, USA[23]	**Moderate**	Low	Unclear	Unclear	High	Low	High
Lozano 1999, Spain[24]	**High**	High	Unclear	Unclear	Low	Low	Unclear
McKibbin 2006, USA[25]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Miselli 2009, Italy[26]	**Moderate**	Unclear	Unclear	Unclear	Unclear	Low	Unclear
Mohamed 2013, Qatar[27]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Muchiri 2015, South Africa[28]	**Low**	Low	Low	Low	Low	Low	Low
Penckofer 2012, USA[29]	**Moderate**	Low	High	High	Low	Low	Low
Pennings-Van der Eerden 1991, Netherlands[30]	**High**	Unclear	Unclear	Unclear	High	High	Unclear
Philis-Tsimikas 2011, USA[31]	**Moderate**	Low	Unclear	Low	Low	Low	Low
Pieber 1995, Austria[32]	**High**	High	Unclear	Unclear	Low	Low	Low
Rickheim 2002, USA[33]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Ridgeway 1999, USA[34]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Rosal 2005, USA[35]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Rosal 2011, USA[36]	**High**	Low	Unclear	Low	High	Low	Low
Sarkadi 2004, Sweden[37]	**Moderate**	Low	Low	High	High	High	Unclear
Scain 2009, Brazil[38]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Smith 2011, UK[39]	**High**	Low	High	High	Low	Low	Low
Sperl-Hillen 2011/ 2013, USA[40, 41]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Toobert, 2003, USA[42]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low
Toobert 2011A & 2011B, USA[43, 44]	**Low**	Low	Unclear	Low	Low	Low	Low
Torres Hde 2009, Brazil[45]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low

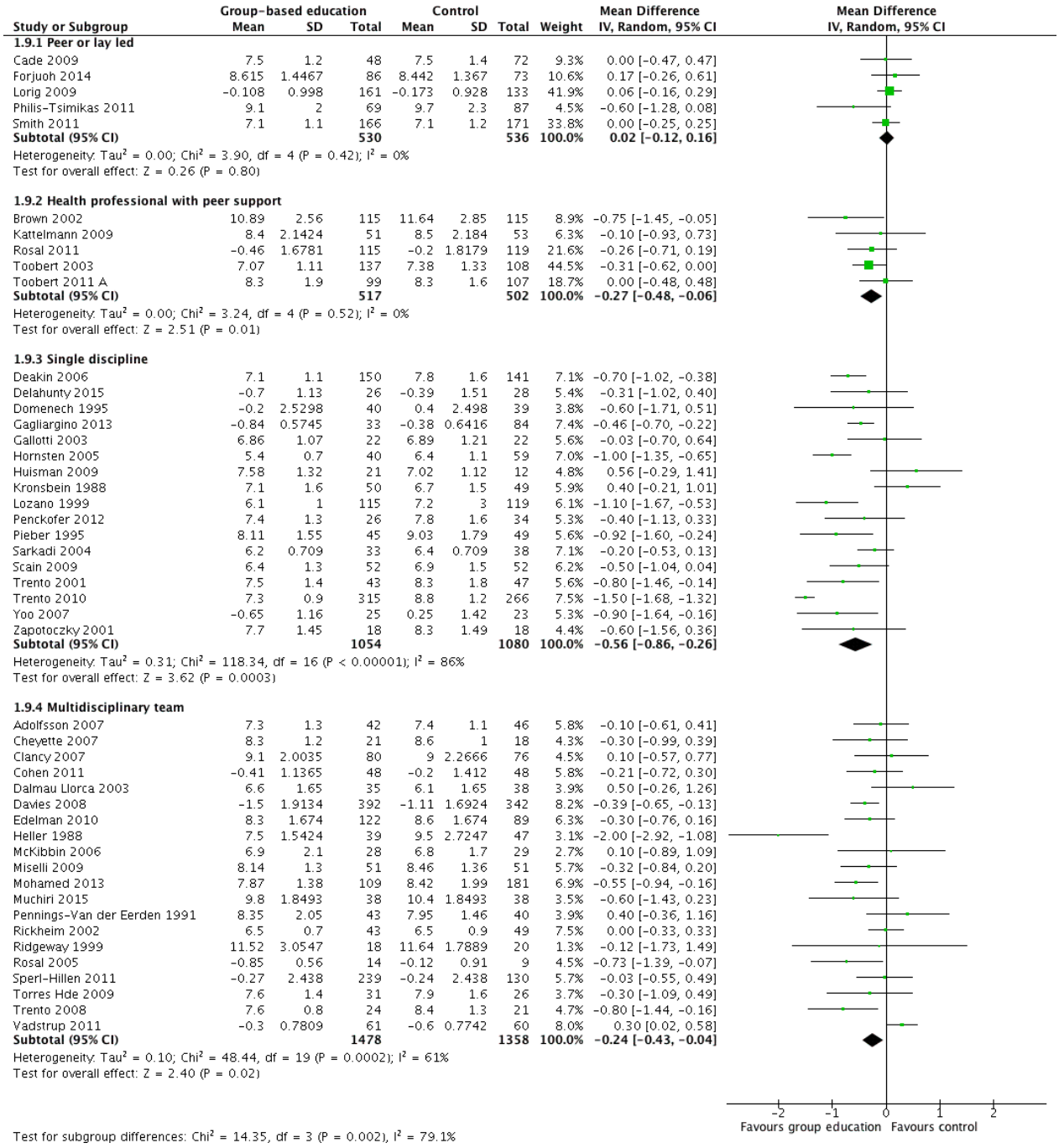
Trento 2001/ 2002/ 2004, Italy[46-48]	**Moderate**	Low	Unclear	Low	Low	Low	Low
Trento 2008, Italy[49]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Trento 2010, Italy[50]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Vadstrup 2011, Denmark[51]	**Moderate**	Low	Low	High	Low	Low	Low
Yoo 2007, Korea[52]	**Moderate**	Low	Unclear	Unclear	Low	Low	Low
Zapotoczky 2001, Austria[53]	**Moderate**	Unclear	Unclear	Unclear	Low	Low	Low

* Studies were ranked into three categories: a. all quality criteria met: low risk of bias; b. one of more of the quality criteria only partly met: moderate risk of bias; c. one or more criteria not met: high risk of bias.

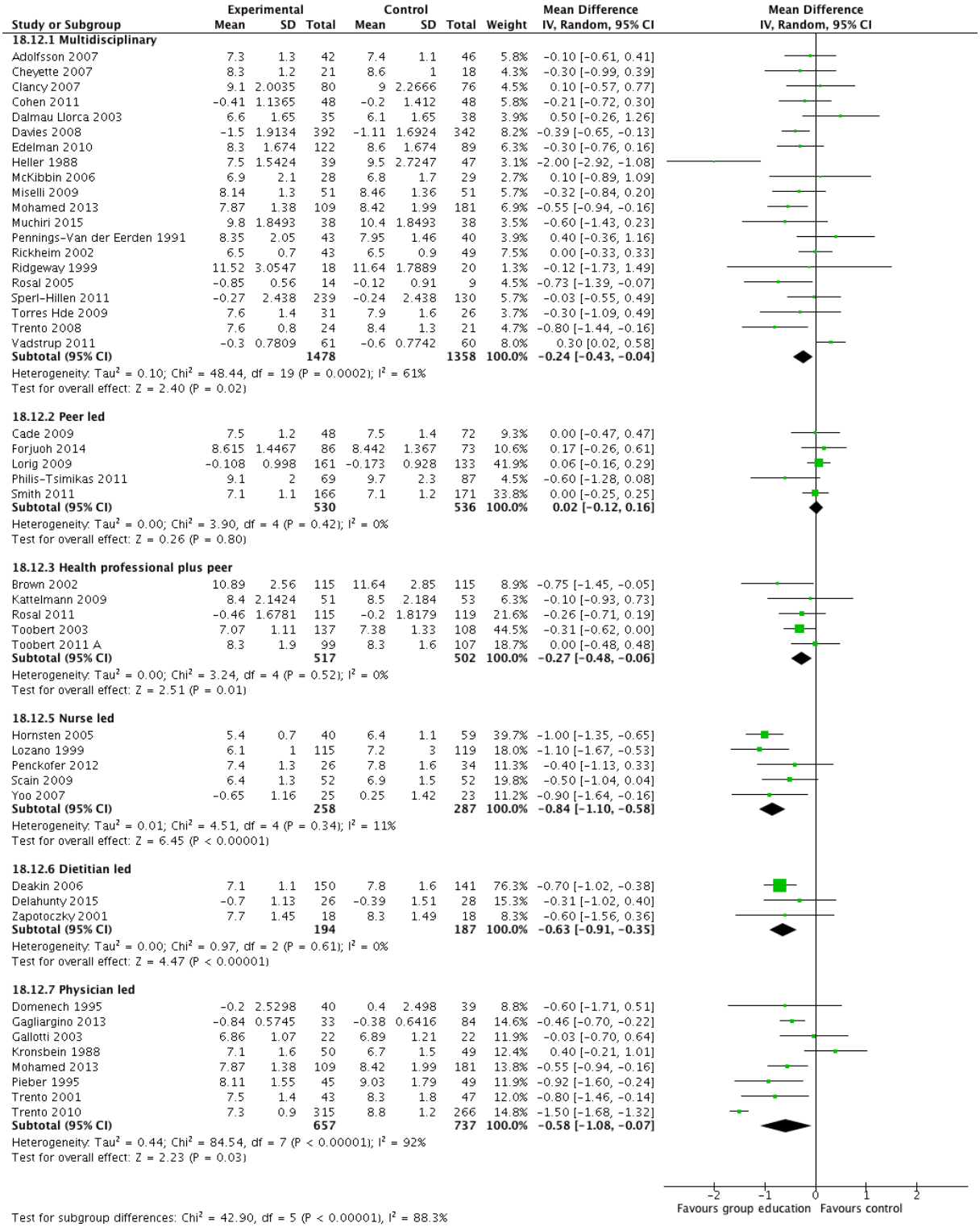
Supplemental Figure S1: Overall Risk of bias for included studies



Supplemental Figure S2: Forest plot- Subgroup analysis of group educators

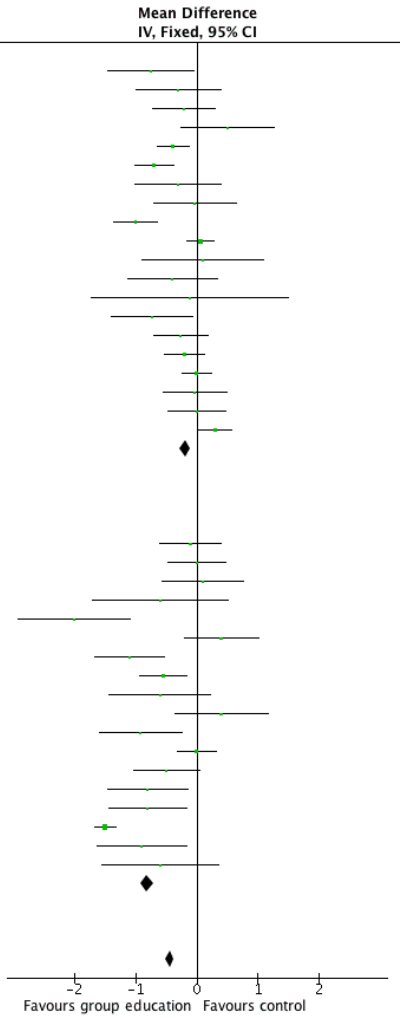


Supplemental Figure S3: Forest plot- Subgroup analysis of group educators by individual discipline

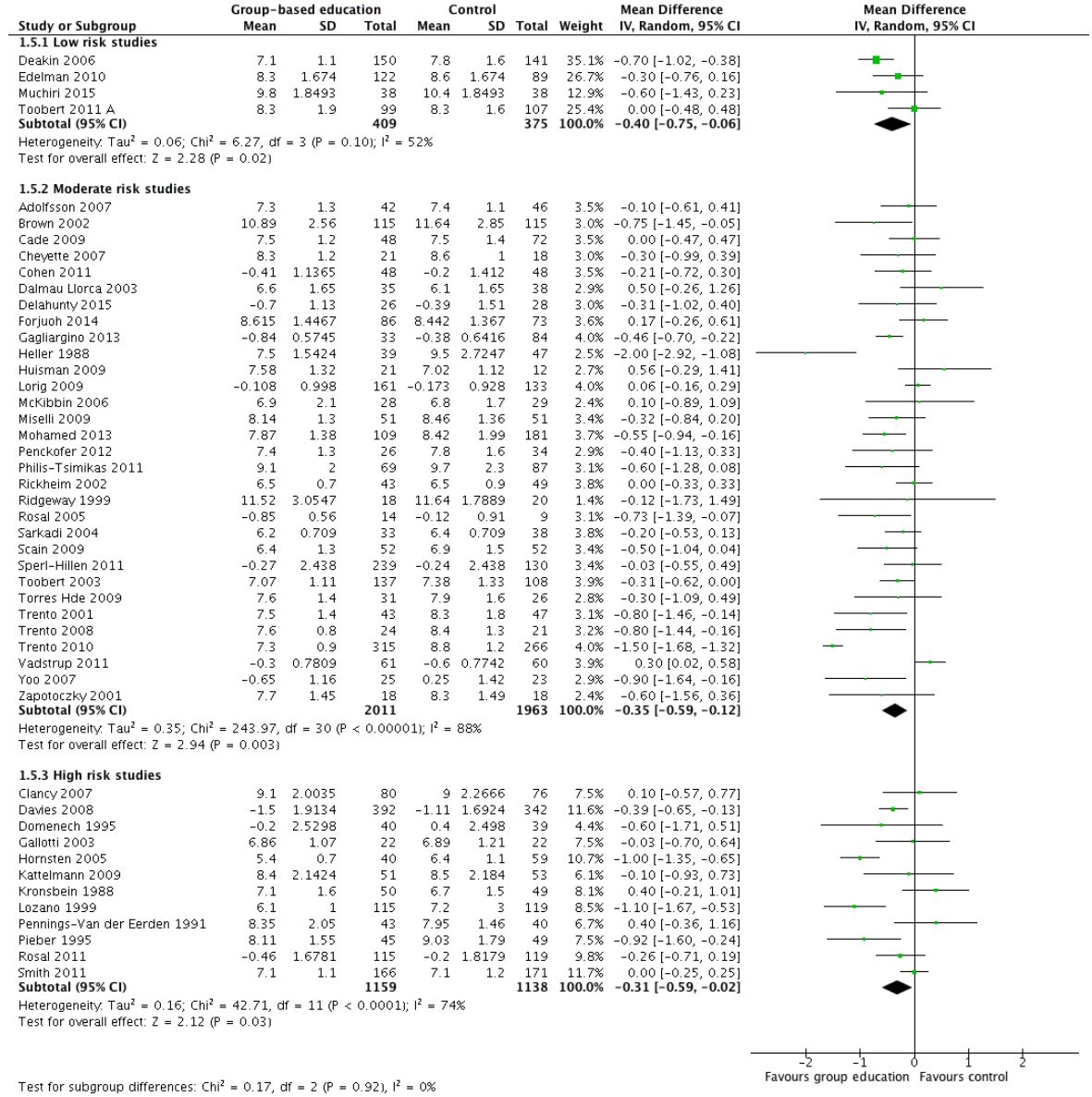


Supplemental Figure S4: Forest plot- Subgroup analysis of insulin therapy

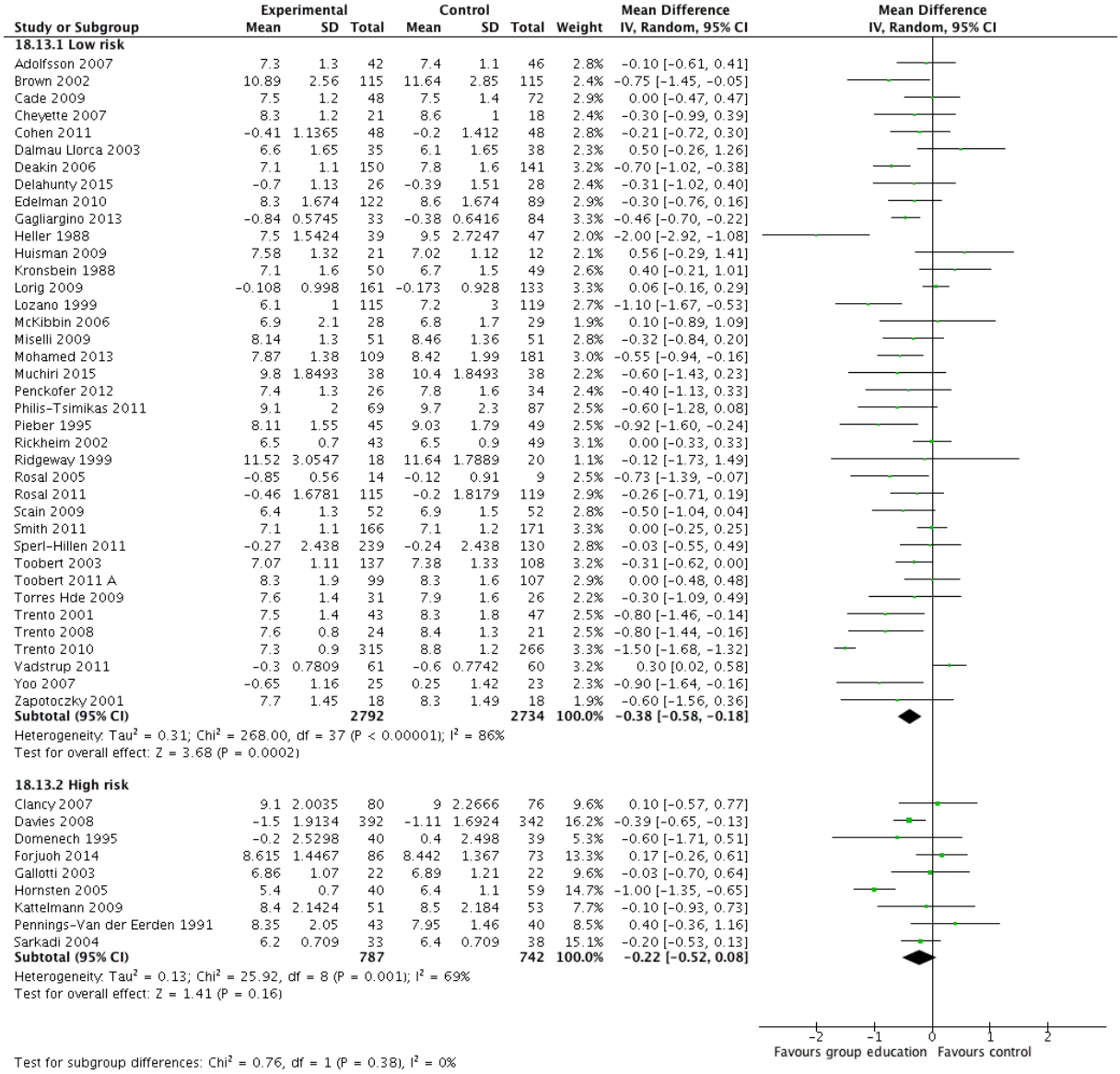
Study or Subgroup	Group-based education Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
1.15.1 Insulin								
Brown 2002	10.89	2.56	115	11.64	2.85	115	1.0%	-0.75 [-1.45, -0.05]
Cheyette 2007	8.3	1.2	21	8.6	1	18	1.0%	-0.30 [-0.99, 0.39]
Cohen 2011	-0.41	1.1365	48	-0.2	1.412	48	1.8%	-0.21 [-0.72, 0.30]
Dalmau Llorca 2003	6.6	1.65	35	6.1	1.65	38	0.8%	0.50 [-0.26, 1.26]
Davies 2008	-1.5	1.9134	392	-1.11	1.6924	342	7.1%	-0.39 [-0.65, -0.13]
Deakin 2006	7.1	1.1	150	7.8	1.6	141	4.8%	-0.70 [-1.02, -0.38]
Delahunty 2015	-0.7	1.13	26	-0.39	1.51	28	1.0%	-0.31 [-1.02, 0.40]
Gallotti 2003	6.86	1.07	22	6.89	1.21	22	1.1%	-0.03 [-0.70, 0.64]
Hornsten 2005	5.4	0.7	40	6.4	1.1	59	3.8%	-1.00 [-1.35, -0.65]
Lorig 2009	-0.108	0.998	161	-0.173	0.928	133	9.9%	0.06 [-0.16, 0.29]
McKibbin 2006	6.9	2.1	28	6.8	1.7	29	0.5%	0.10 [-0.89, 1.09]
Penckofer 2012	7.4	1.3	26	7.8	1.6	34	0.9%	-0.40 [-1.13, 0.33]
Ridgeway 1999	11.52	3.0547	18	11.64	1.7889	20	0.2%	-0.12 [-1.73, 1.49]
Rosal 2005	-0.85	0.56	14	-0.12	0.91	9	1.1%	-0.73 [-1.39, -0.07]
Rosal 2011	-0.46	1.6781	115	-0.2	1.8179	119	2.4%	-0.26 [-0.71, 0.19]
Sarkadi 2004	6.2	0.709	33	6.4	0.709	38	4.4%	-0.20 [-0.53, 0.13]
Smith 2011	7.1	1.1	166	7.1	1.2	171	8.0%	0.00 [-0.25, 0.25]
Sperl-Hillen 2011	-0.27	2.438	239	-0.24	2.438	130	1.8%	-0.03 [-0.55, 0.49]
Toobert 2011 A	8.3	1.9	99	8.3	1.6	107	2.1%	0.00 [-0.48, 0.48]
Vadstrup 2011	-0.3	0.7809	61	-0.6	0.7742	60	6.3%	0.30 [0.02, 0.58]
Subtotal (95% CI)			**1809**			**1661**	**59.8%**	**-0.19 [-0.28, -0.10]**
Heterogeneity: Chi² = 61.98, df = 19 (P < 0.00001); I² = 69%								
Test for overall effect: Z = 4.17 (P < 0.0001)								
1.15.2 Non-insulin								
Adolfsson 2007	7.3	1.3	42	7.4	1.1	46	1.9%	-0.10 [-0.61, 0.41]
Cade 2009	7.5	1.2	48	7.5	1.4	72	2.2%	0.00 [-0.47, 0.47]
Clancy 2007	9.1	2.0035	80	9	2.2666	76	1.1%	0.10 [-0.57, 0.77]
Domenech 1995	-0.2	2.5298	40	0.4	2.498	39	0.4%	-0.60 [-1.71, 0.51]
Heller 1988	7.5	1.5424	39	9.5	2.7247	47	0.6%	-2.00 [-2.92, -1.08]
Kronsbein 1988	7.1	1.6	50	6.7	1.5	49	1.3%	0.40 [-0.21, 1.01]
Lozano 1999	6.1	1	115	7.2	3	119	1.5%	-1.10 [-1.67, -0.53]
Mohamed 2013	7.87	1.38	109	8.42	1.99	181	3.2%	-0.55 [-0.94, -0.16]
Muchiri 2015	9.8	1.8493	38	10.4	1.8493	38	0.7%	-0.60 [-1.43, 0.23]
Pennings-Van der Eerden 1991	8.35	2.05	43	7.95	1.46	40	0.8%	0.40 [-0.36, 1.16]
Pieber 1995	8.11	1.55	45	9.03	1.79	49	1.1%	-0.92 [-1.60, -0.24]
Rickheim 2002	6.5	0.7	43	6.5	0.9	49	4.5%	0.00 [-0.33, 0.33]
Scain 2009	6.4	1.3	52	6.9	1.5	52	1.7%	-0.50 [-1.04, 0.04]
Trento 2001	7.5	1.4	43	8.3	1.8	47	1.1%	-0.80 [-1.46, -0.14]
Trento 2008	7.6	0.8	24	8.4	1.3	21	1.2%	-0.80 [-1.44, -0.16]
Trento 2010	7.3	0.9	315	8.8	1.2	266	15.7%	-1.50 [-1.68, -1.32]
Yoo 2007	-0.65	1.16	25	0.25	1.42	23	0.9%	-0.90 [-1.64, -0.16]
Zapotoczky 2001	7.7	1.45	18	8.3	1.49	18	0.5%	-0.60 [-1.56, 0.36]
Subtotal (95% CI)			**1169**			**1232**	**40.2%**	**-0.81 [-0.92, -0.70]**
Heterogeneity: Chi² = 145.14, df = 17 (P < 0.00001); I² = 88%								
Test for overall effect: Z = 14.57 (P < 0.00001)								
Total (95% CI)			**2978**			**2893**	**100.0%**	**-0.44 [-0.51, -0.37]**
Heterogeneity: Chi² = 281.48, df = 37 (P < 0.00001); I² = 87%								
Test for overall effect: Z = 12.46 (P < 0.00001)								
Test for subgroup differences: Chi² = 74.37, df = 1 (P < 0.00001), I² = 98.7%								



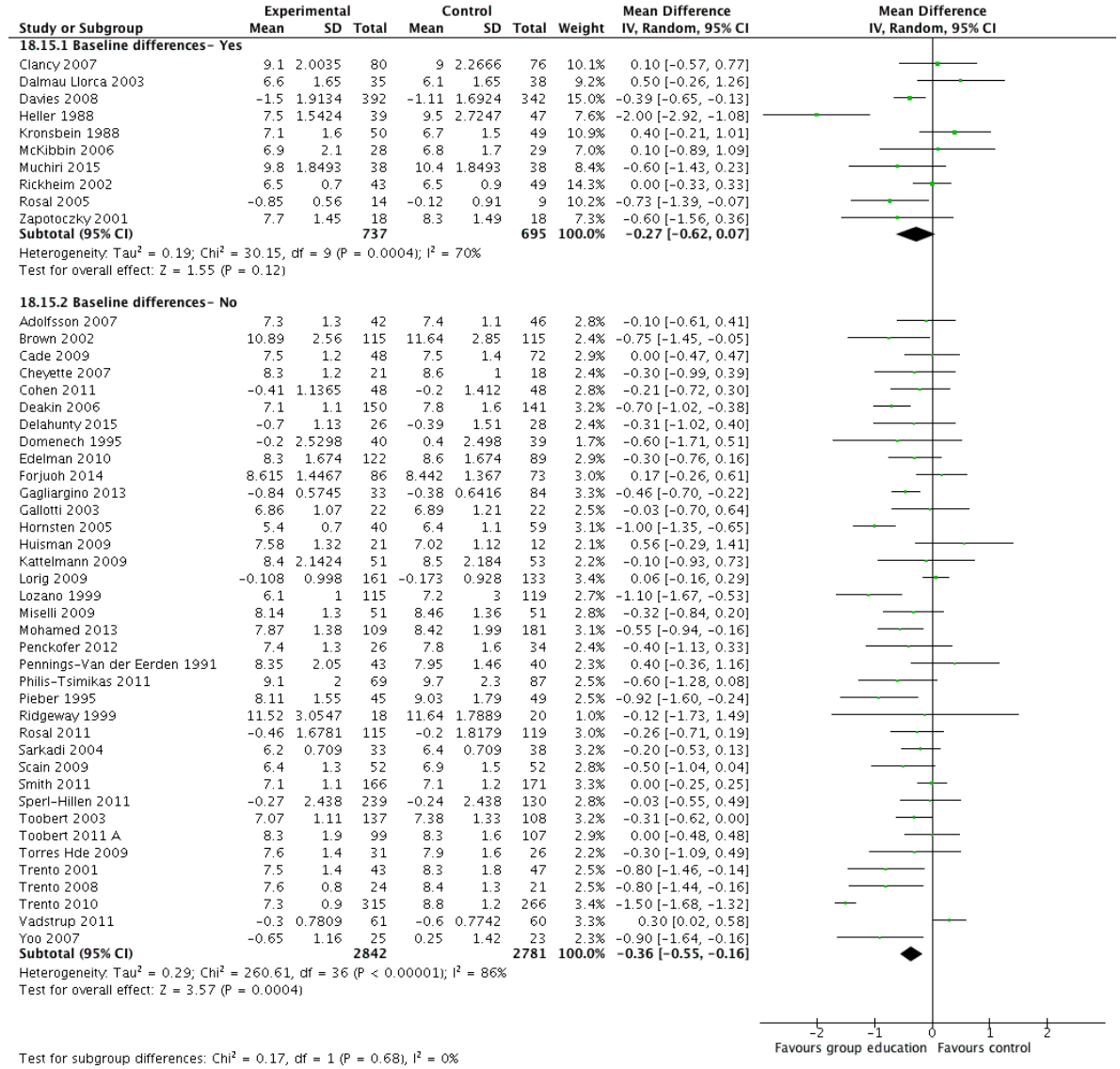
Supplemental Figure S5: Forest plot- Sensitivity analysis: overall risk of bias



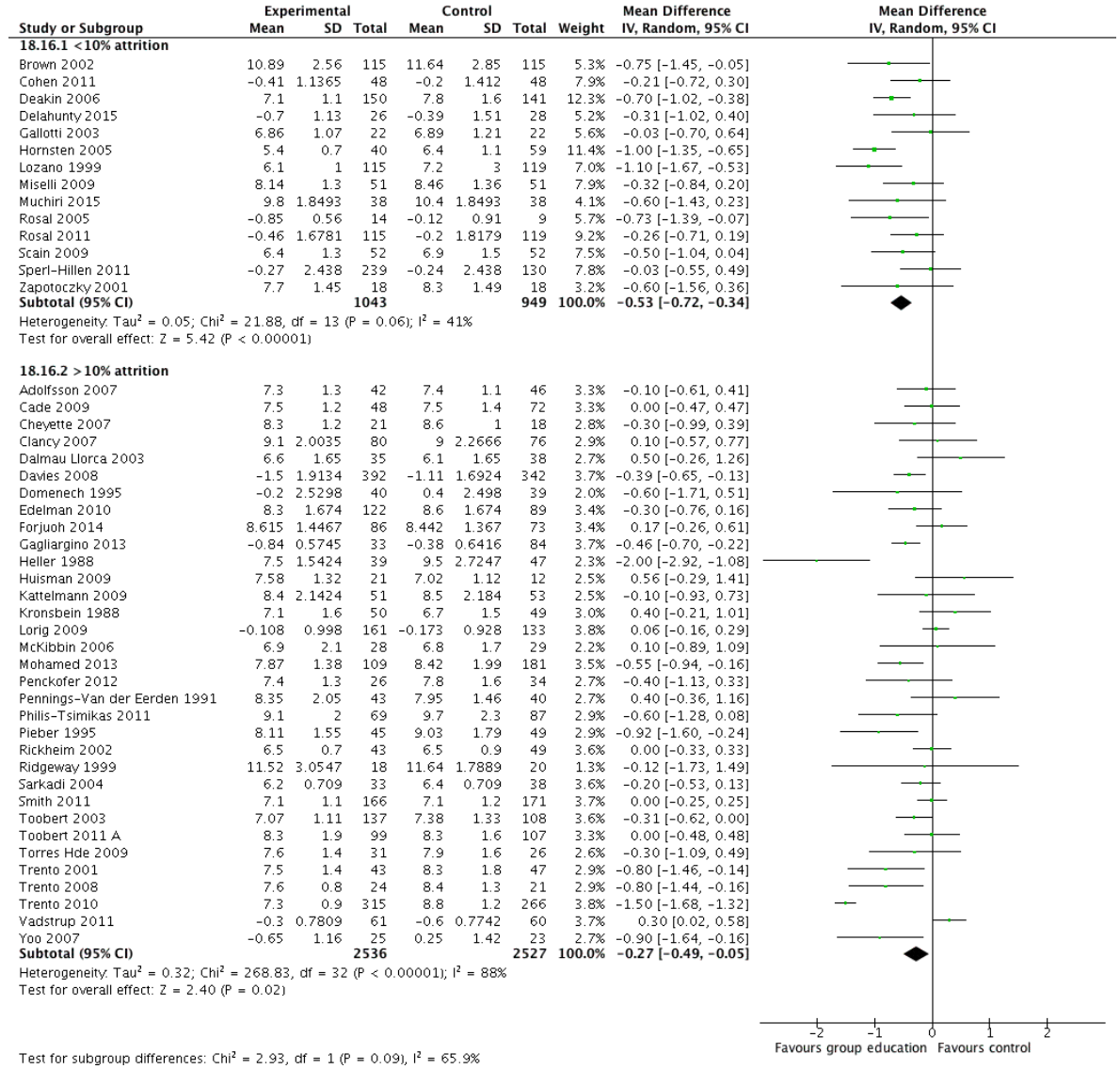
Supplemental Figure S6: Forest plot- Sensitivity analysis: reporting bias



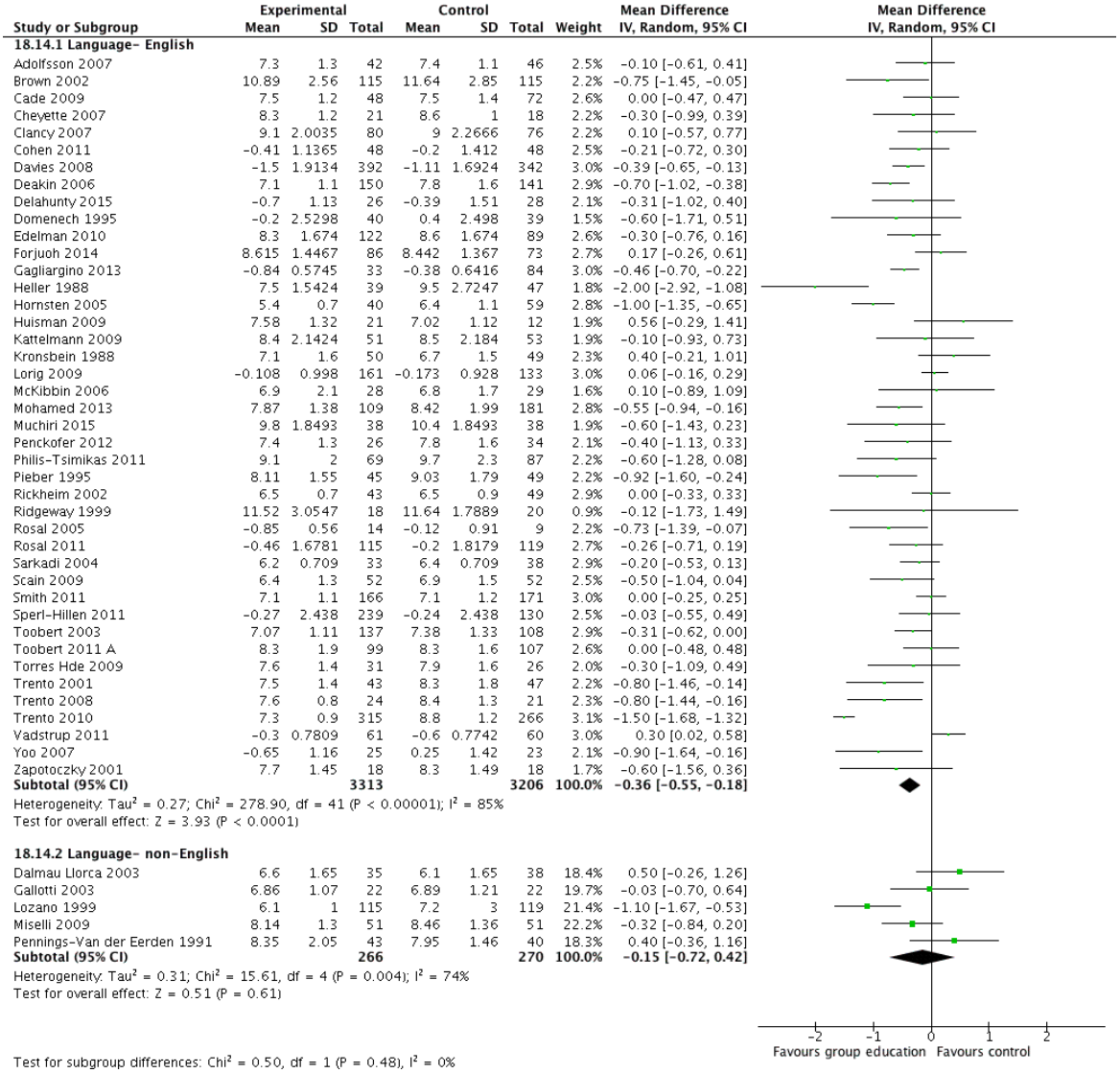
Supplemental Figure S7: Forest plot- Sensitivity analysis: baseline differences



Supplemental Figure S8: Forest plot- Sensitivity analysis: attrition



Supplemental Figure S9: Forest plot- Sensitivity analysis: published in non-English journals



Supplemental Table S4: Summary of meta-analysis results of secondary outcomes assessed using standard mean difference at various time points

Outcome	Time point (mths)	N studies	N participants (IG/ CG)	Standard Mean Difference (95% CI)	P-value	Heterogeneity (I^2)	Heterogeneity (P-value)
QOL	6-10	5	135/ 130	-0.03 (-0.34, 0.29)	0.86	34%	0.19
Depression	6	3	201/ 176	-0.62 (-0.93, -0.31)	0.0001	28%	0.25
Energy intake	6	5	182/ 203	-0.11 (-0.44, 0.22)	0.50	58%	0.05
	12	4	389/ 406	-0.21 (-0.58, 0.16)	0.27	84%	0.0003
Physical activity	6	7	619/ 478	0.23 (0.10, 0.36)	0.0006	9%	0.36
	12-14	3	486/ 376	0.21 (0.06, 0.35)	0.005	11%	0.33

N= number; IG= intervention group; CG= control group; CI= confidence interval; QOL= quality of life; mths= months.

Supplemental Table S5: Meta-regression: association between study variables and primary outcome measure (HbA1c) (n=11)

Study variable	Univariate Analyses		
	Coefficient	**95% CI**	**P-value**
Theoretical model (RC: Yes)			
No	-0.0240	-0.43, 0.38	0.91
Type of educators (RC: Multidisciplinary team)			
Nurse only	-0.4849	-1.16, 0.19	0.15
Dietitian only	-0.2418	-1.10, 0.62	0.57
Physician only	-0.1989	-0.88, 0.48	0.56
Psychologist only	0.8659	-0.66, 2.40	0.26
Peer or lay led	0.2516	-0.40, 0.90	0.44
HP led with peer support	-0.4977	-1.17, 0.17	0.14
Pharmacist only	0.1059	-1.18, 1.40	0.87
Training (RC: Yes)			
No	0.0428	-0.42, 0.51	0.85
Materials (RC: Yes)			
No	0.0349	-0.53, 0.60	0.90
Delivery setting (RC: Primary care)			
Other setting	-0.1574	-0.61, 0.30	0.49
Baseline HbA1c levels (RC: >7% in both groups)			
<7% in both groups	0.2164	-0.29, 0.72	0.39
Intervention length (RC: <1 mth)			
1-3 mths	0.1308	-0.61, 0.87	0.72
4-6 mths	0.1181	-0.59, 0.82	0.74
7-12 mths	-0.1945	-0.88, 0.49	0.57
13-60 mths	-0.3246	-1.04, 0.39	0.37
Number of sessions (RC: < 5 sessions)			
6-10 sessions	0.305	-0.16, 0.77	0.20
11-20 sessions	0.0122	-0.58, 0.61	0.97
> 21 sessions	-0.4054	-1.13, 0.32	0.26
Number of participants (RC: 4-10)			
11-20	0.2290	-0.20, 0.66	0.29
Contact time (RC: 8 or less hrs)			
9-12 hrs	0.1286	-0.53, 0.79	0.70
13-18 hrs	0.2705	-0.31, 0.85	0.35
19-30 hrs	0.0715	-0.55, 0.70	0.82
31 hrs or more	-0.1218	-0.75, 0.51	0.70
Family and friends (RC: Yes)			
No	0.1436	-0.27, 0.56	0.49

RC: reference category; CI= confidence interval; HbA1c= glycated haemoglobin; mths= months; hrs= hours

Supplemental Item S2: References for Included Studies

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