Dietary interventions to prevent and manage diabetes in worksite settings: a meta-analysis

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Review

Dietary interventions to prevent and manage diabetes in worksite settings: a meta-analysis

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Abstract: Objectives: The translation of lifestyle intervention to improve glucose tolerance into the workplace has been rare. The objective of this meta-analysis is to summarize the evidence for the effectiveness of dietary interventions in worksite settings on lowering blood sugar levels. **Methods:** We searched for studies in PubMed, Embase, Econlit, Ovid, Cochrane, Web of Science, and Cumulative Index to Nursing and Allied Health Literature. Search terms were as follows: (1) Exposure-based: nutrition/diet/dietary intervention/health promotion/primary prevention/health behavior/health education/food /program evaluation; (2) Outcome-based: diabetes/hyperglycemia/glucose/HbA1c/glycated hemoglobin; and (3) Setting-based: workplace/worksite/occupational/industry/job/employee. We manually searched review articles and reference lists of articles identified from 1969 to December 2016. We tested for between-studies heterogeneity and calculated the pooled effect sizes for changes in HbA1c (%) and fasting glucose (mg/d/) using random effect models for meta-analysis in 2016. **Results:** A total of 17 articles out of 1663 initially selected articles were included in the meta-analysis. With a random-effects model, worksite dietary interventions led to a pooled −0.18% (95% CI, −0.29 to −0.06; P<0.001) difference in HbA1c. With the random-effects model, the interventions resulted in 2.60 mg/d/ lower fasting glucose with borderline significance (95% CI: −5.27 to 0.08, P=0.06). In the multivariate meta-regression model, the interventions with high percent of female participants and that used the intervention directly delivered to individuals, rather the environment changes, were associated with more effective interventions. **Conclusion:** Workplace dietary interventions can improve HbA1c. The effects were larger for the interventions with greater number of female participants and with individual-level interventions.

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Supplementary materials (Appendixes) are available in the online version of this article.

Introduction

Diabetes mellitus and elevated blood sugar are among the top ten causes of death worldwide[1)] and is also a major risk factor for blindness, renal failure, and lower limb amputation[2)]. It is estimated that 415 million people were detected with diabetes in 2016; this number is expected to rise to 642 million by 2040[3)].

Efforts to prevent diabetes are necessary because they could make a significant contribution to lowering the diabetes incidence, reducing the complications of this disease, such as blindness, limb amputations, and death. Sedentary lifestyle, poor diet, and excessive body weight are the major risk factors for developing diabetes[4-6)]. Lifestyle interventions addressing diet and exercise have reduced diabetes risk[7-9]. More importantly, lifestyle interventions have a sustained effect on diabetes prevention[10,11], even though weight loss may not be maintained. The quality of the diet, particularly the consumption of low sugar and refined grains intake and high intake of fresh fruits, vegetables, and whole grains, has shown to be inversely associated with the risk of type-2 diabetes[12,13].

Worksites may be a useful platform for scaling up these proven lifestyle interventions because employed adults spend most of their workday waking hours at worksites. Worksites have additional advantages because they have existing social support and formal as well as informal communication networks[14,15]. Worksite health promotion programs for preventing diabetes and weight loss have shown positive effects on employee health[16-20]. Health promotion at the workplace may have additional financial benefits for the company because cardiovascular risk factors are significant predictors of long-term sick leave[21-23] and injuries[24]; improved health could lead to reductions in absenteeism and attrition[25].

Several studies have investigated the effects of diet and other lifestyle-focused interventions in workplace settings. In the past 20 years, systematic reviews and meta-analyses of health promotion at workplaces have been performed and have showed positive impact on physical activity[17,26-30], diet[18,31,32], smoking[33-35], weight loss[19,36,37], or health promotion in general[20,25,38,39]. However, no meta-analysis has been performed to summarize the effect of workplace dietary interventions on diabetes risk. We expect that interventions to improve diet in workplace could potentially prevent diabetes among employees, similar to what has been observed for the other health outcomes. This study aims to summarize the evidence for the effectiveness of dietary interventions at worksites on blood glucose.

Materials and Methods

We followed the recommendations of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)[40] guidelines in all stages of the design, implementation, and reporting of this meta-analysis.

Primary Exposure, Outcome and Setting

The primary outcome was change in blood glucose level, measured by fasting glucose (mg/d*l*) and glycated hemoglobin (HbA1c, %). The primary exposure was interventions targeting dietary modifications that encourage and facilitate changes to healthier diets and that discourage unhealthy diets.

The setting of interest was worksites.

Search Strategy

We searched multiple online databases including PubMed (www.ncbi.nlm.nih.gov/pubmed), Econlit (www.aeaweb.org/econlit), Embase (www.embase.com), Ovid (www.ovid.com), Cochrane Library (www.thecochranelibrary.com), Web of Science (www.wokinfo.com), and Cumulative Index to Nursing and Allied Health Literature (www.ebscohost.com/biomedical-libraries/the-cinahl-database) from 1969 to December 2016. The search was conducted in December 2016. Search terms were compiled in three categories: (1) Exposure-based MeSH terms: nutrition/die/dietary intervention/health promotion/primary prevention/health behavior/health education/food/program evaluation; (2) Outcome-based MeSH terms: diabetes/hyperglycemia/glucose/HbA1c/glycated hemoglobin; and (3) Setting-based queries: workplace/worksite/occupational/industry job/employee. The details of the search queries used for each search engine are provided in the Supplemental File 1. Additionally, we manually searched the reference citations included in the articles and in relevant review articles and meta-analysis.

Study Selection

We included all randomized and non-randomized intervention and observational prospective cohort studies that reported the effects on glycemic control of dietary interventions. We excluded all cross-sectional studies and predictive modeling studies. We contacted corresponding authors in cases wherein information on effect size with variance or p-value was not reported and excluded the studies for which the variance or p-value of the effect size was not available. When studies reported outcomes from a larger community in addition to a worksite, we only included the results from the worksite.

Data Extraction

Two reviewers (AS and BMK) independently extracted information using the Data Abstraction Form published by the Guide to Community Preventive Services (the Guide)[41]. The form requires the following information: (a) Intervention under study (what was the intervention, how was it delivered, and who delivered it); (b) Evaluation setting (geographic location, workplace name, and where outcome is measured); (c) Study population (eligibility criteria, sample size, age, sex, race/ethnicity, and socio-economic status); (d) Outcomes (definition and measurement); and (e) Results (effect size, standard error, confidence interval, and p-value). Discrepancies in extraction were resolved by consensus. The results were extracted based on pre- and post-intervention scores. Follow-up/maintenance scores were not included. The results were abstracted or derived from data reported in the manuscripts. When the data were insufficient, we contacted corresponding authors for the required information. Five authors were contacted out of which one responded, allowing us to include his study in the meta-analysis.

Quality Assessment

Two investigators (AS and BMK) independently assessed the quality of studies and disagreements were resolved by reaching a consensus. The quality of studies were scored (Yes=1, No=0) on following criteria based on the Guide[41]: (a) well-described study population and intervention; (b) clearly specified sampling frame; (c) probability sampling; (d) measured exposure to intervention; (e) valid and reliable exposure measurement; (f) valid and reliable outcome measurement; (g) used appropriate statistical test; (h) controlled for design effect; (i) controlled for repeat measurement; (j) controlled for differential exposure; (k) handled multi-level data; (l) completion rate of 80% or more; (m) assessed comparability; and (n) controlled for confounding (Supplemental File-2). A percentage quality score (total quality score/14) was calculated (Supplemental File-3). The interrater reliability was substantial with Kappa equal to 0.71 (95% CI: 0.62-0.79).

Statistical Analysis

The primary outcomes were the mean change in glycated hemoglobin (HbA1c, %) and fasting glucose (mg/d*l*) from baseline to post-intervention or between intervention and control groups. Study-specific effect sizes were pooled using random-effects models[42] (%metaanal macro available at https://www.hsph.harvard.edu/donna-spiegelman/software/). Cochran's Q-statistics, R_B, a variant of I^2 with better statistical properties[43,44], and the coefficient of variation between studies were used to assess the between-study heterogeneity. Meta-regression[45] (%metareg macro available at https://www.hsph.harvard.edu/donna-spiegelman/software/) was used to explore the potential sources of heterogeneity, including the study design (pre-post/randomized controlled trial), location (US/Europe/other), frequency of intervention (per month), duration of intervention (in months), eligibility criteria (mixed/high risk/diabetic), size of worksite (in number of employees), mean age (in years), female participants (%), intervention level (environment/individual), and intervention unit (group/individual). We conducted a step-wise meta-regression with forward selection at cut off p-value of 0.20[46]. Publication bias was assessed by visual inspection of funnel plots, Egger's test and Begg's tests.

Results

Study Selection

Fig. 1 shows the flow diagram of the identified and subsequently included studies. The electronic database search resulted in 1663 studies. After screening the titles and the abstracts, 1641 articles were excluded (1502 did not meet the selection criteria and 139 were duplicates). Following the screening of full texts, another 11 studies were excluded for following reasons: three did not report HbA1c or fasting glucose; one did not have a dietary intervention; one was not conducted at a worksite; one had identical data with another publication; and five did not report the variance of effect size or p-value. We then added six articles identified from review papers and reference lists of included studies. Consequently, 17 articles were included in the meta-analysis. The studies were published between 2001 and 2016.

Characteristic of Studies Included

The characteristics of the studies included in the meta-analysis are summarized in Table 1. Most studies[10] were randomized controlled trials. Seven studies were from the US. Sixty-five percent (n=10) of the studies included only individuals at high risk of CVD, which is defined differently in different studies, mainly considering following characteristics: high body mass index, high lipid profile, high blood glucose, high blood pressure, Framingham, or other risk scores. Four studies targeted individuals with diabetes, and the remaining three studies did not screen individuals for disease risk and included all interested employees.

The median of number of employees in the worksite was 2075. A total of 14,272 participants from the 17 studies were included in the meta-analysis. The mean age of the participants was 49 years, and the median percentage of female participants was 27%. Very few studies reported racial and socio-economic characteristics.

Description of the included 17 studies is presented in Table 2.

Interventions

Interventions varied substantially across the studies. A large variation in frequency, duration, and intensity was observed. The median total number of intervention visits was seven (range=3 to 365); intervention durations ranged from 3 months to 36 months (median 12 months). The most frequently used strategies were group education sessions (a certified health educator teaching about healthy diet and lifestyle to a group of people); individual counseling (face-to-face or telephone calls with a counselor focusing on diet and/or lifestyle); and goal setting (participants set short-term and/or long-term health goals and formulate how to implement their intentions). Most of the educational sessions covered lifestyle modification, focusing on improving diet, increasing physical activity, and smoking cessation. Three studies had environmental level interventions that involved providing a Japanese style healthy lunch[64] in one case and a Mediterranean lunch[54] in another and environmental prompts[48] in the form of brief messages that encourage employees to make healthy choices such as low calorie foods at vending machines and increase physical activity at staircases. Only one study[58] reported using a behavioral change model as a basis for planning the intervention but did not specify the

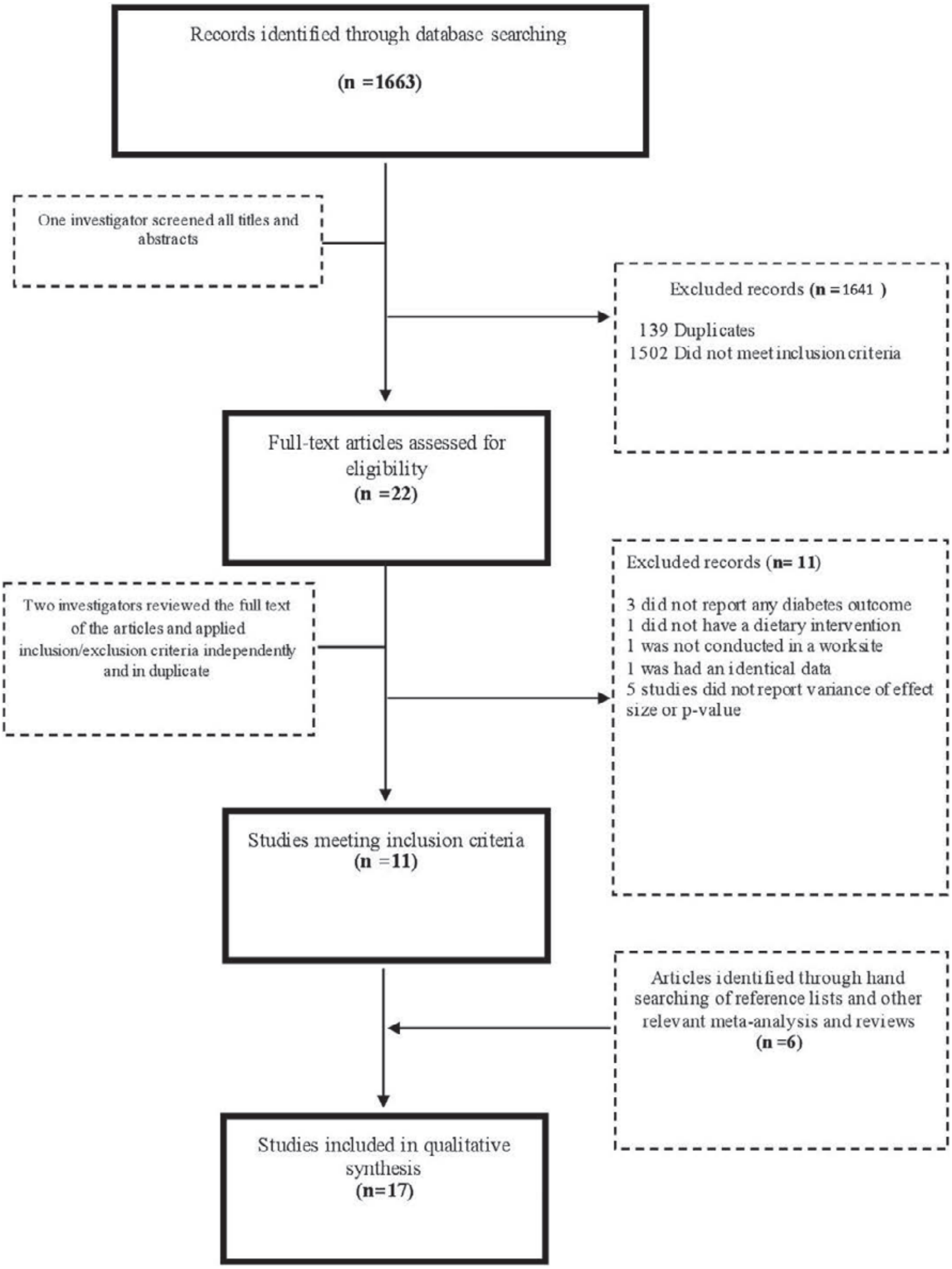

Fig. 1. Screening and selection process of the studies

model.

Meta-analysis

For HbA1c, ten studies had sufficient data for inclusion and four of the included studies reported results by subgroup: (1) pre-diabetic and diabetic[47]; (2) <50% compliant and ≥50% compliant[64]; (3) low adherence and high adherence[65]; (4) with diabetes and without diabetes[61]. There was statistically significant heterogeneity in the effect sizes over these ten studies (R_B=0.49, CV_B=0.85, P<

Table 1. Characteristics of studies included

Characteristics	Frequency (%)
Design	
Randomized Trial	10 (59)
Pre-Post Design	7 (41)
Location	
US	7 (41)
Non-US	10 (59)
Eligibility	
At risk of CVD	11 (65)
All employees regardless of risk	6 (35)
Environmental intervention	
Yes	3 (18)
No	14 (82)
Level of intervention	
Group	8 (47)
Individual	9 (53)
Frequency of intervention per month	
Mean (SD)	6.3 (10.5)
Median (IQR)	1.2 (0.5 - 8.2)
Duration of intervention, months	
Mean (SD)	11 (7.8)
Median (IQR)	12 (5-12)
Number of employees	
Mean (SD)	6374 (11176.9)
Median (IQR)	2075 (355-5638)
Age, in years	
Mean (SD)	47.3 (5.6)
Median (IQR)	46.7 (42-53.2)
Percentage of female participants	
Mean (SD)	30.1 (31.9)
Median (IQR)	27 (0-57.5)

0.001). With the random-effects model, the worksite dietary interventions led to a pooled −0.18% (95% CI, −0.29 to −0.06; P<0.001) difference in HbA1c (Fig. 2).

Twelve studies in the review had sufficient data on fasting glucose for inclusion, and two of them reported results by subgroups: (1) <50% compliant and ≥50% compliant; (2) male with <1 kg loss, male with ≥1 kg loss, female with <1 kg loss and female with ≥1 kg loss. There was statistically significant heterogeneity in their effect sizes (R_B=0.78, CV_B=1.80; P<0.001). The interventions resulted in 2.60 mg/d*l* lower fasting glucose with borderline significance (95% CI: −5.27 to 0.08, P=0.06) (Fig. 3).

Evaluation of Heterogeneity

We estimated the common effect size over the studies in meta-analysis. In addition, we tested for heterogeneity of effects and calculated several quantitative measures of heterogeneity. By measuring heterogeneity, we determined whether the observed variation in the studies was likely due to chance alone or to a real difference. We observed moderate to high heterogeneity in the results from unadjusted models for the change in the HbA1c (R_B=0.49) and the change in fasting glucose (R_B=0.78), implying that approximately 49% of the variation in the former analysis and approximately 78% in the latter was due the differences between the studies. After adjusting for the percentage of female participants and the type of intervention (environmental vs no environmental), the heterogeneity was drastically reduced for the change in HbA1c analysis (R_B=0). However, for the change in fasting glucose analysis, we did not observe any material improvement in terms of percent of unexplained variation, R_B. All of the heterogeneity in the estimates of the effects of worksite interventions on lowering HbA1c was explained by the percentage of female participants and the type of intervention. The HbA1c% was 0.25% points lower for each 25% point's higher female participants.

The change in HbA1c% was 0.27% lower for worksite interventions that include individual-level interventions (Table 3). The change in HbA1c was smaller for RCT design in univariate analysis but was not significant in multivariate model. Similarly, the quality score of the studies was not a significant contributor to the heterogeneity in the estimates of the effects of dietary interventions on change in HbA1c (Table 3).

We found significant heterogeneity in fasting glucose by the size of the worksite and the level of the intervention (group vs. individual, P<0.05). However, the two variables did not explain the entire heterogeneity in fasting glucose, although the Q-statistic decreased by 72%. Study design and quality score were not significant contributors to the heterogeneity observed in the estimates of the effects of the dietary interventions on changes in HbA1c or glucose levels (Table 3).

Study Quality and Publication Bias

About half of the studies (n=8) scored 60% or more in the quality assessment. The study population and interventions were well defined in 12 studies. However, 14 studies did not measure the intensity of the exposure to the interventions, such as attendance in the educational classes and food sales in the improved cafeteria. Sixty-nine percent reported the validity of or provided a reference for the procedure for measuring HbA1c and fasting glucose. Only 38% of the studies had a participant completion rate of 80% or more. All the studies were conducted on self-motivated volunteers.

Forest plots did not show any evidence of publication bias for either the evaluation of HbA1c or fasting glucose. The Begg's and Egger's test for publication bias were not statistically significant (Supplemental File 4). However, given the small number of the studies included in each analysis, these tests have limited power.

Table 2. Description of the studies and interventions

Author's last name	Study design	Study participants	Intervention
Bevis, 2014 [47]	Before - after study	Employees ≧18 years or more; fasting serum glucose ≧100mg/d*l*; and a score of 10 or greater on an American Diabetes Association Health Risk Assessment questionnaire. Mean age: 53 years; Female: 44% Sub groups: (1) Pre-diabetic(2) Diabetic Location: Florida, USA	Group education session: Participants received a series of required 2-hour educational sessions by a certified diabetes nurse educator, focusing on: Diabetes introduction, Lifestyle changes, Nutrition, Managing cholesterol, glucose, HbA1c and blood pressure; Biometry testing: quarterly measurement of biometry (blood and urine testing); Diabetes screening: For pre diabetic group, diabetes screening at 6 and 12 months
Goetzel, 2009 [48]	Randomized trial	Any non-pregnant employee Mean age: 45 years Female: 27% Location: MI, USA	Individual level: Dissemination of health education materials; Training and education Physical activity and weight management programs - with reimbursement; Preventive screening with reimbursement Environmental level: Environmental prompts and point -of- choice messages in front of stairwells, vending machines, and cafeterias.
Groeneveld, 2010 [49]	Randomized trial	Higher than moderate 10-year risk of coronary heart disease based on the Framingham risk score, and have either: BMI≥30; HbA1c≥6.5%; not meeting the physical activity guidelines; heart complaints; psychological complaints; alcohol intake ≥35 glasses per week. Mean age: 47 years; Female: 0%; Location: Netherlands	Individual counseling: Three 45- to 60-min face to face meetings, and four 15- to 30-min telephone calls with a counselor, focusing on diet, physical activity, smoking cessation; behavior change, and willingness, readiness, and perceived confidence. Goal setting: The participants set long- and short-term goals, and formulate how to implement intentions. Main message
Inoue, 2014 [50]	non randomized trial	Any employee Mean age: 50 years; Female: 0%; Sub groups (1)<50% intake (2)>=50% intake Location: Japan	Japanese lunch: Japanese-style lunch menu offered to provide balanced nutrition and sufficient vegetable consumption over the course of three months with main changes in 600 kcal ≤ Energy <650 kcal, Fat <18 g, Cholesterol ≤ 100 mg, Fiber ≥ 8 g, Total vegetables ≥130 g, Sodium chloride equivalent ≤ 3.8 g.
Johnson, 2014 [51]	retrospective pre post design	Type 1 or type 2 diagnosis from medical claim Mean age: 53.years Female: 55% Location: Kansas, USA	Individual counseling: Counseling with apharmacist averaging six 30-minute visits each year focusing on Pathology, healthy lifestyle habits, medication use and adherence for diabetes Goal setting: Discussed individual goal and self-monitoring
Kamioka, 2009 [52]	Randomized trial	Male employees 30 to 50 years old without any contraindications for exercise or spa bathing Mean age: 44.4 years Female: 0% Sub groups(1) High adherence (2) Low adherence Location: Japan	Group education session: A 2-hour program encompassing comprehensive health education with hot spa bathing was offered once every 2 weeks for 14 weeks, focusing on lifestyle, physical exercise, and diet consisted of lectures (comprehensive health education) and various forms of physical exercise. Goal setting: Set individualized targets and were monitored once a week.
Kraemer, 2012 [53]	Randomized trial	18 years or older employees diagnosed with diabetes mellitus Mean age: 54.1 years; Female: 49% Location: Oregon, USA	Individual counseling: Patients make monthly appointments with pharmacists for the first three months and every 1 to 3 months thereafter. Pharmacists gather patient information, educate and coach patients with diabetes

Table 2. (continued)

Author's last name	Study design	Study participants	Intervention
Leighton, 2009 [54)]	before and after intervention study	Employees who eat lunch 5 days a week at the industry canteen who were not under treatment for diabetes, hypertension and dyslipidemia; or who actively adhered to specific diets or had participated in a weight loss program in the previous 6 months; and persons undergoing pharmacological treatment with drugs that modify lipid profiles, blood pressure, carbohydrate metabolism, plasma antioxidant capacity and inflammation; Mean age: 39 years; Female: 0%; Location: Chile	Mediterranean diet: It was offered as main lunch in the canteen. Daily Mediterranean diet menu, a vegetarian dish was available plus an option of beef with rice for consumers not interested in adhering to a Mediterranean diet. A salad bar with 4 different mixed salad with olive oil, gastronomically attractive, two options for main dishes and fruits for desert Group education session: Workers attended educational talks on the health benefits of the Mediterranean diet.
Makrilakis, 2010 [55)]	before and after intervention study	Finland Diabetic Risk score ≧ 15 (Max 26) Mean age: 56 years Female: 60% Location: Greece	Group education session: The 1-year intervention program consisted of six sessions (1 hour each) held by a registered dietitian at the participants' residence or work. Groups consisted of 6-10 people, focusing on healthy lifestyle with written material (leaflets)
Maruyama, 2010 [56)]	Randomized trial	One or more abnormalities of the following condition: triglyceride (TG) ≧ 150 mg/d*l* and/or HDL-cholesterol (HDL-C) b40 mg/d*l*, systolic blood pressure ≧130 mmHg and/or diastolic blood pressure ≧85 mmHg, fasting glucose ≧110 mg/d*l* and/or HbA1c ≧ 5.5%; with visceral obesity (umbilical circumference: ≧85 cm) and/ or BMI ≧25; Mean age: 39 years; Female: 0% Location: Japan	Individual counseling: Participants had monthly individual contact with a well-trained dietitian and a physical trainer. Goal setting: After baseline assessment, the participants attended an individual goal and action planning session, and at 1 and 2 months, they reviewed their plans with counselors.
Muto, 2001 [57)]	Randomized trial	Employees with abnormal findings in at least one of the following: body mass index, systolic or diastolic blood pressure, total cholesterol, HDL, triglycerides, and fasting blood glucose. Mean age: 42 years Female: 0%; Location: Japan	Group education session: The main program was conducted 4 times at a hot spring resort; Individual counseling: Individual counseling was provided with practical training and self-learning; focusing on nutrition, physical activity, stress and CVD risk factors. The emphasis was on nutrition with decreased consumption of dietary fat and salt and physical activity. Goal setting: A goal was set at the baseline and followed up with self-evaluation of goals at three months interval throughout the year
Nanri, 2012 [58)]	Randomized trial	Waist circumference of ≥85 cm plus two or more of the following factors: 1) fasting blood glucose of ≥110 mg /d*l* and/or medication for diabetes, 2) high density lipoprotein (HDL) cholesterol of <40 mg/d*l* and/or triglyceride of ≥150 mg/d*l* and/or medication Mean age: 53.3 years Female: 0%; Location: Japan	Individual counseling: A trained occupational health nurse and the participants discussed their health-related lifestyles choices that might have caused weight gain. The nurse recommended increased intakes of vegetables, fruit and dairy products, and to consume alcohol in moderation. Goal setting: With advice from the health nurse, the participants set goals for their body weights in six months and three to five goals for health related behaviors including both physical activity and diet.

Table 2. (continued)

Author's last name	Study design	Study participants	Intervention
Nilsson, 2001[59]	Randomized trial	The persons (N=128) with a cardiovascular disease risk score sum of ≥9 were recruited. Risk score was calculated from 54 questions based on known association with CVD, risk score ranged from 1-20. Mean age: 49.7 years; Female: 61% Location: Sweden	Group education session: The subjects received 16 group sessions a year with educational and practical content. Outside the workplace but within work hours; Individual counseling: Individual counseling from a nurse; focusing on improved diet and physical activity, stress management, and smoking cessation. Health check-up: The program continued for 18 months with health check-ins at 12 and 18 months.
Racette, 2009[60]	Randomized trial	Employees of 18 years or older Mean age: 45.0 years Female: 88% Location: Missouri, USA	Specific interventions: Pedometers, weekly healthy snack cart, on-site Weight Watchers group meetings, on-site group exercise program, team competitions, participation cards, and participation rewards; Group education session: monthly lunchtime seminars; Health education materials: Monthly newsletters, walking maps. Each week a registered dietitian/exercise specialist was available at the worksite to hand out new material, punch participation cards, give rewards, measure blood pressure, and discuss individual health questions.
Rouseff, 2016[61]	Before - after study	Employees with two or more of the following: total cholesterol ≥200 mg/d*l*, systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg, hemoglobin A1C (HbA1c) ≥6.5%, or BMI ≥ 30 kg/m2. Mean age: 48.4 years; Female: 50% Sub group analysis 1) Non Diabetic (2) Diabetic; Location: Florida, USA	Goal setting: Participants set short and long term diet goals with a dietitian and created individualized nutrition plans. The participants attended one individual 30 minute nutrition session. Individual re-assessments were completed monthly for 6 months and at 12 months. Reassessments included recording food and vegetable intake, and addressing nutritional concerns; Nutrition prescription, review of food log results and provision of fresh produce.
Salinardi, 2013[62]	Randomized trial	non pregnant, 21 years old or older, BMI (in kg/m2) ≥25.0, and a letter from the primary care physician with approval for weight loss. Mean age: 42 years; Female: 78% Location: Boston, USA	Goal setting: Participants set goals of reducing energy intakes to achieve a weight loss of 0.5-1.0 kg/wk through a lifestyle-modification program. Portion-controlled menus that contained $40 g dietary fiber/d and had a low glycemic load. Macronutrient targets were 25% protein, 27% fat, and 48% low-glycemic index carbs.
Zyriax, 2014[63]	Before - after study	Employees with elevated waist circumference (≥80 cm for women and ≥ 94 cm for men) and fasting plasma glucose of >=100 mg/d*l* and/or plasma glucose of >=140 mg/d*l* 2 hrs after an oral challenge with 75 g glucose (OGGT) Mean age: 41.2 years Female: 0% Subgroup analysis (1) Men with <1 kg wt loss (2) Men with >=1 kg wt loss (1) Women with <1 kg wt loss (2) Women with >=1 kg wt loss Location: Germany	Individual counseling: The intervention program consisted of 1.5-h sessions on nutrition or physical activity supervised by a certified dietician or a trainer. Initially, 6 sessions of dietary advice, changed every other week with 6 sessions on advice and motivation for physical activity, including a walking program. During the following 6 months, 6 sessions of advice were held jointly by the dietician and the trainer, followed by 6 biweekly sessions, each integrating a repetition of the elements of the dietary and training program During the two following years, combined sessions of 1.5 h by a dietician and a trainer were offered every 3 months. Every session provided the opportunity to measure the weight and discuss the behavioral consequences.

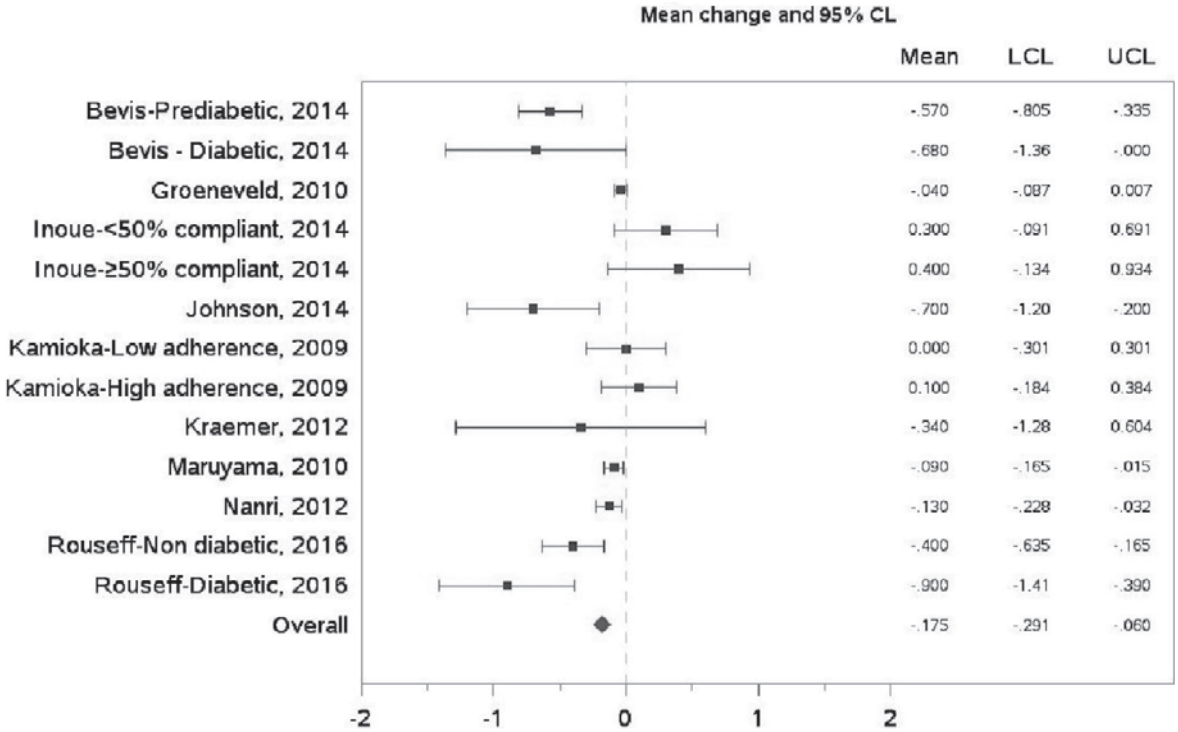

Fig. 2. Meta-analysis of effect of worksite dietary intervention on HbA1c

Discussion

The results from this meta-analysis suggest that worksite dietary interventions produced a 0.20% decline in glycated hemoglobin. Large declines were observed in studies that had more female participants or used individual-level interventions. Although the interventions also resulted in low fasting glucose, the change was not statistically significant.

Glycemic control is an important predictor of chronic complications associated with diabetes[66,67]. The UK prospective diabetes study predicts that a 1% reduction in HbA1c over 10 years can reduce 21% of the diabetes-related deaths, 14% of the myocardial infarctions, and 37% of the microvascular complications[67]. The incidence rates for these diabetes-related endpoints linearly increase with increasing HbA1c levels with no evidence for a threshold[64]. Thus, an improvement in HbA1c of 0.20% over a median of 1 year may well be clinically significant among participants with diabetes. The analysis did not show a significant decrease in fasting blood glucose. This may be due to the fact that fasting blood glucose is associated with relatively high within-person variability, reducing statistical power to detect differences[68,69].

The interventions had a large effect in studies with more female participants. Female participants have been reported to be more compliant and to be a better health care seekers[70]. The effect size was also large for individual-level interventions (delivered the intervention directly to individuals, rather than making overall changes to the environment) for both outcomes considered. Only three studies in our meta-analysis had environmental level interventions that offered healthier diet options at the workplace cafeteria. Individual-level interventions reported in the studies had multiple components, including lectures, goal setting, and personal counseling, which might have resulted in synergistic effect to contributed to large effect size.

Groeneveld, et al reported that lifestyle interventions for reducing CVD risk were most effective for workers with elevated risk of CVD[71]. In our meta-analysis, the studies that screened the employees and included only those at high risk for CVD or diabetes had larger effect sizes in univariate meta-regression; however, the relation was not independently significant in multivariate analysis after controlling for other factors that explained between-studies heterogeneity.

This is the first meta-analysis to look at the effects of dietary interventions on diabetes risk in worksite settings. However, other meta-analyses have reported an impact of behavioral interventions on diabetes reduction in clinical trials. Norris, et al (2002) reported a decreased pooled effect size of 0.26% (95% CI: 0.05 to 0.48) after more than 4 months of follow up among patients with type-2 diabetes[72]. The meta-analysis by Brown, et al (1992) found a decreased effect size of 0.41% for HbA1c (95% CI: 0.31 to 0.52) for self-management of diabetes and reported that

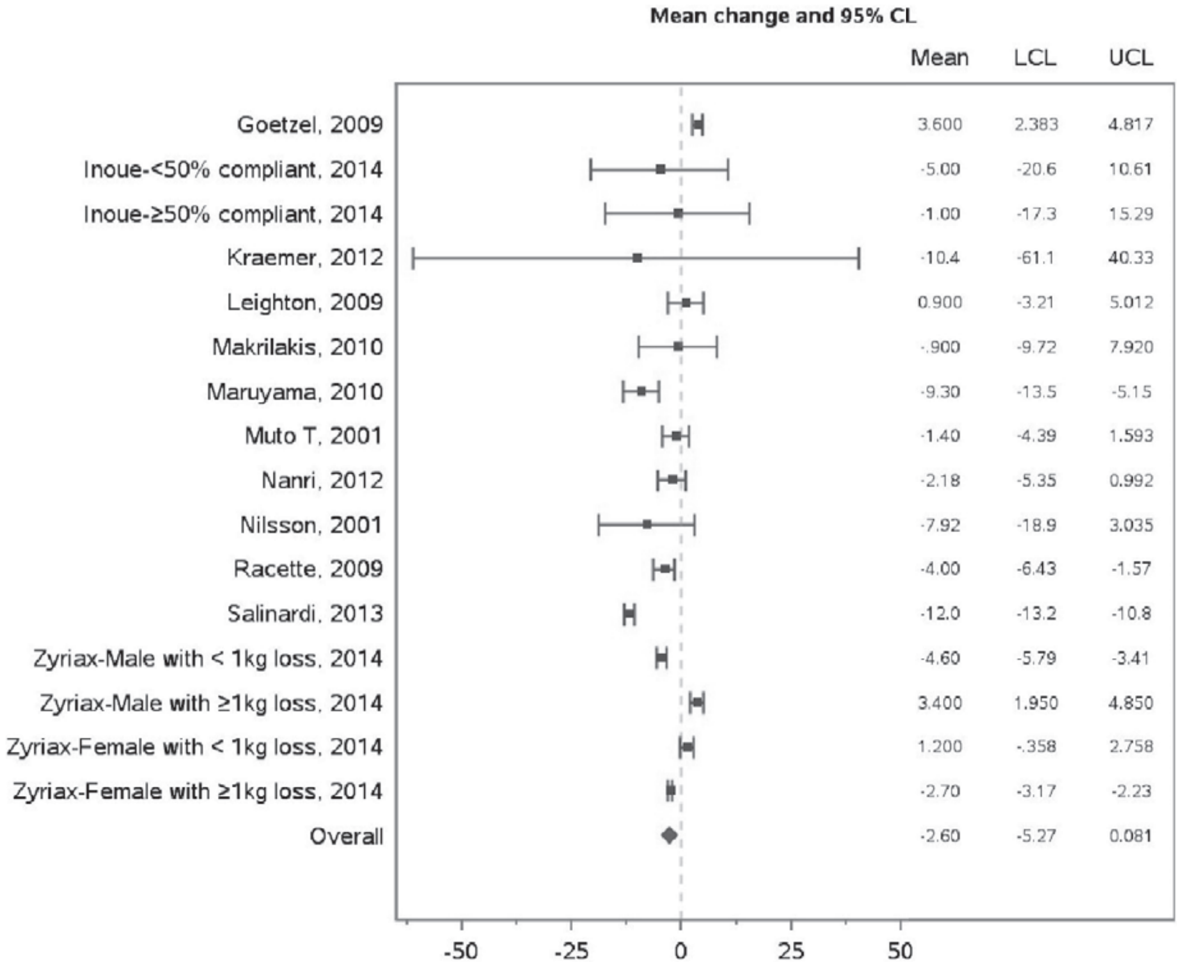

Fig. 3. Meta-analysis of effect of worksite dietary intervention on fasting glucose

dietary adherence was the best predictor of lower HbA1c among adults with diabetes[73]. Although the effect size in the Brown, et al meta-analysis was larger than that observed in our meta-analysis of worksite interventions, Brown's analysis included only the results from individually randomized control trials among patients with diabetes.

This meta-analysis has several important strengths. Each study was double-reviewed and evaluated for accuracy and completeness. The review involved a thorough quantitative synthesis of the literature on the prevention of diabetes in worksite settings, which has not been done previously. Although there are evidences that diet and with physical activity are effective in preventing diabetes[74,75], translating this information into real-life settings has been challenging. The findings from this study should be useful in aiding the design of future evidence-based interventions for diabetes prevention at worksite settings.

The analysis was confined to only published literature that reported an effect size with its variance or p-value. However, we attempted to contact investigators who did not report the variance or p-value corresponding to the effect size, and only one out of the six authors responded. Publication bias is always a concern in meta-analysis; however, evidence for publication bias was not found in this meta-analysis. Moreover, the power to detect this bias is limited, considering the small number of studies included. Threats to internal validity cannot be completely ignored because 80% or more participants completed the intervention in only 38% of the studies, leading to a potential for biased results due to differential follow up. It will be helpful if future studies report both the intent to treat results as well as results adjusted for loss to follow up. Because the ten studies not conducted in the US came from six countries and three continents, we were not able to examine heterogeneity by country or continent and could only assess heterogeneity by the broad category of US versus non-US countries. There was substantial variation in delivery methods, duration, and intensity of the interventions included in this report. However, our multivariate meta-regression showed that the observed heterogeneity in the effect sizes for both HbA1c and fasting glucose was not explained by this variation. Although modes of delivery differed, all but one study delivered a message

Table 3. Heterogeneity of effects in worksite interventions to lower HbA1c and Fasting Glucose

Variables	Univariate model		Heterogeneity Test (Univariate)			Multivariate model		Heterogeneity Test (Multivariate)		
	Change/ Difference(SE)	p-value	p-value	R_B	CV_B	Change/ Difference (SE)	p-value	p-value	R_B	CV_B
HbA1c										
None	− 0.18 (0.06)	0.003	<0.001	0.49	0.85					
Percent female (unit=25%)	− 0.25 (0.04)	0.000	1.000	0.00	0.00	− 0.25 (0.04)	<0.001	1	0	0
Intervention type			<0.001	0.12	0.05		0.03			
No environmental	− 0.09 (0.02)	<0.001				− 0.27 (0.03)	0.007			
Environmental	0.34 (0.16)	0.06				0.12 (0.16)	0.064			
Year of publication	− 0.07 (0.01)	0.000	1.000	0.00	0.00					
Design										
RCT	− 0.06 (0.02)	0.009								
Pre-post	− 0.39 (0.07)	<0.001	0.463	0.00	0.00					
Frequency per 10 months	− 0.01 (0.06)	0.90	<0.001	0.19	0.07					
Duration (in years)	− 0.23 (0.13)	0.08	<0.001	0.13	0.05					
Size (number of employees) (unit=5,000)	0.02 (0.01)	0.09	<0.001	0.19	0.07					
Mean age (unit=5 years)	− 0.12 (0.09)	0.11	<0.001	0.17	0.07					
Location			1.000	0.00	0.00					
US	− 0.54 (0.07)	<0.001								
Other	− 0.06 (0.02)	0.011								
Eligibility			<0.001	0.01	0.03					
Mixed	− 0.03 (0.02)	0.26								
High risk	− 0.17 (0.03)	<0.001								
Level			<0.001	0.04	0.07					
Group	− 0.13 (0.07)	0.08								
Individual	− 0.08 (0.02)	0.001								
Quality score (unit=1%)	0.003 (0.001)	0.045	<0.001	0.18	0.07					
Fasting glucose										
None	− 2.62 (0.18)	<0.001	<0.001	0.78	1.80			<0.001	0.78	0.58
Size (number of employees) (unit=5,000)	0.84 (0.07)	<0.001	<0.001	0.79	0.61	0.86(0.22)	0.002			
Intervention			<0.001	0.79	0.62		0.01			
No environmental	− 3.23 (0.19)	<0.001				− 2.88 (0.21)	<0.001			
Environmental	3.31 (0.59)	<0.001				− 3.02 (1.73)	0.08			
Year of publication	− 0.37 (0.08)	<0.001	<0.001	0.83	0.76					
Design			<0.001	0.80	0.65					
RCT	− 4.20 (0.38)	<0.001								
Pre-post	− 2.14 (0.21)	<0.001								
Frequency per 10 months	2.15 (0.21)	<0.001	<0.001	0.79	0.63					
Duration (in years)	0.89 (0.20)	<0.001	<0.001	0.81	0.69					
Mean age (unit=5 years)	2.14 (0.43)	<0.001	<0.001	0.82	0.76					
Percent female (unit=25%)	− 0.58 (0.11)	<0.001	<0.001	0.82	0.74					
Location			<0.001	0.71	0.42					
US	− 4.32 (0.41)	<0.001								
Others	− 2.20 (0.20)	<0.001								
Eligibility			<0.001	0.88	0.73					
Mixed	1.95 (0.53)	0.003								
High risk	− 3.21 (0.19)	<0.001								

Table 3. (continued)

Variables	Univariate model		Heterogeneity Test (Univariate)			Multivariate model		Heterogeneity Test (Multivariate)		
	Change/ Difference(SE)	p-value	p-value	R_B	CV_B	Change/ Difference (SE)	p-value	p-value	R_B	CV_B
Level			<0.001	0.82	0.76					
Group	−2.39 (0.84)	0.013								
Individual	−2.63 (0.19)	<0.001								
Quality score (unit=1%)	−0.40 (0.03)	<0.001	<0.001	0.82	0.75					

on lifestyle modifications that focused on healthy diets. Most studies had common intervention themes such as increased intake of fruits and vegetables, fibers and low fats, and increased physical activity.

The results of this meta-analysis are likely to be generalizable to adults in worksite settings of high-income countries. A broad range of age and intervention characteristics were evaluated without any evidence that any of these characteristics other than gender modified the outcome. All the participants in the study were volunteers; thus, participants may have been healthier and more motivated compared to non-participants, limiting external generalizability. All interventions in these studies had diet-related messages. However, the studies also included other messages aimed at increasing physical activity, smoking cessation, and maintaining healthy lifestyle in general.

Further research is needed to better quantify the effectiveness of interventions for reducing fasting glucose. In addition, studies from low- and middle-income countries representing different socio-economic strata are needed to better understand the effectiveness of these interventions in low-resource settings. Men may need additional support or different intervention strategies compared to women to achieve the same reduction in HbA1c%. When reporting studies, researchers should continue to provide adequate background information, including demographic data and the detailed descriptions of the interventions (messages, contact frequency, duration, and year) to facilitate the interpretation of the results. These variables are essential for robust meta-regression for understanding the sources of heterogeneity and for systematic reviews of intervention implementations.

Conclusion

This meta-analysis fills the gap in knowledge about the effectiveness of population-based interventions for preventing diabetes at worksites. Dietary interventions combined with other messages such as increasing physical activity, smoking cessation, and stress management at worksites lowered employees' HbA1c, which if sustained, might result in the prevention or delay of developing diabetes and associated morbidity and mortality. The effect sizes are large for female participants and for individual-level worksite interventions. For intervention planners and policy makers, it is worth noting that men might need additional support to attain the same effect as observed in women.

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