

Community-Based Educational Interventions for Type-II Diabetes Prevention: A Systematic Review and Meta-Analyses

Tayebeh Shirvani

Tabriz University of Medical Sciences

Zeinab Javadivala

Tabriz University of Medical Sciences

Somayeh Azimi

Tabriz University of Medical Sciences

Abdolreza Shaghaghi

Tabriz University of Medical Sciences

Zahra Fathifar

Tabriz University of Medical Sciences

Devender Bhalla

Pole Universitaire

Mohammad Hiva Abdekhoda

Tabriz University of Medical Sciences

Haidar Nadrian (✉ haidarnadrian@gmail.com)

Tabriz University of Medical Sciences <https://orcid.org/0000-0003-3129-2475>

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Abstract

Background We assessed community-based educational interventions towards primary prevention of type-II diabetes (T2D), but with a focus on theoretical framework and community factors.

Methods A comprehensive search for eligible studies was carried out on PubMed, EMBASE, ProQuest, CINAHL nursing & allied health source, Cochrane Library, Google scholar, conference proceedings, and reference lists. Eligibility criteria were 1) quantitative interventional studies with all designs implemented on general populations and/or the participants at-risk for T2DM within communities (community-based interventions), 2) had no pharmacological treatments within the intervention; 3) had any theoretical frameworks based on health education theories/models; 4) published 2000 onwards and in English language. Data was extracted by using JBI standardized data extraction tool. The primary outcome variables were incidence rate of T2DM, fasting blood glucose (FBG), haemoglobin A1c (HbA1c), mean body weight, mean body mass index (BMI), waist circumference (WC), systolic/diastolic blood pressure (s/d BP). Random effects meta-analysis was conducted to pool the results. Sub-group analyses based on age-group, gender, theoretical framework, and duration of follow-up were also performed.

Results Nineteen studies were included in the review and ten studies were pooled in the meta-analysis (n = 16106, mean age = 41.52 years). The incidence rate of T2D was reported in 3 trials, within which the risk of developing T2D was reduced by 54% in favour of the community-based educational interventions, (RR =0.54, 95% CI = 0.38- 0.75; p < 0.001). In eleven (n = 11587) and six (n = 6416) studies the pooled mean difference was -0.33 (95% CI -0.45 to -0.20, p<0.0001) and -0.15 (95% CI -0.28 to -0.03, p<0.0001) for FBG and HbA1c levels, respectively. Positive significant effects were observed on reducing BMI [pooled mean difference = -0.47 (95% CI -0.66 to -0.28, I²= 95.7%, p<0.0001)] and WC [pooled mean difference =-0.66 (95% CI -0.89 to -0.43, I²=97.3%, p<0.0001)]. There was no favourable effect on reducing s/d BP. Also decline in FBG was seen for both genders but particularly men, for both adults and children but particularly children, and irrespective of having or not having a theoretical framework but particularly for those studies with a theoretical framework.

Conclusion In the community-based educational interventions with high quality indices, the risk of developing type 2 diabetes may be reduced by half in favour of all other community-based educational interventions. Given the gross lack of reliable community-based educational interventions, there is no doubt on why we lag behind on T2D prevention; especially in low-middle income populations. Nevertheless, the effected interventions are helpful to bring a favourable change in outcome variables, but, with conditions. Interventions with theoretical framework are likely to be more effective towards diabetes prevention.

Background

Type-II Diabetes Mellitus (thereafter referred as diabetes) is the most prevalent form of diabetes with about 422 million adults worldwide. This prevalent burden is rising [1], particularly in the middle-East and

North African populations [2], such as Iran [3] [2]. So, why does the burden of diabetes not reducing even though the community-based interventional data seem to improve the outcomes [4], and many countries, since long, have national public education and prevention programs on diabetes [5].

The two reasons that we suspect are: first, failure to regard interventions as embodiment of theories[6]; second, the effected interventions focus on single factor or theory alone for an otherwise multi-aspect disease condition the diabetes is[7]. In the development and evaluation of interventions for complex disease conditions, like diabetes, focusing on underlying theoretical framework is essential[8]. Theories help to make sense of complex phenomena by providing tentative explanations on the reasons and circumstances behind particular behaviours. Interventions can then target those factors. Also, adhering to rigid theoretical framework is both recommended[8] and beneficial[9] because theoretically-informed interventions lead to better outcomes. To the best of our knowledge, there has not been any systematic analysis of community-based interventional outcomes related to the prevention of diabetes through the necessary perspective of theoretical framework.

Besides the need for attention on theoretical framework, there is evidence that much attention should be paid to the education part as well; which is often considered as a powerful tool for the primary prevention of diabetes [10]. Therefore, the purpose of this study was to systematically review and meta-analyze the community-based educational interventions aimed to prevent diabetes among general or high risk populations, with a focus on the role of behaviour change theories and community factors. We believe our work would provide a comprehensive and unbiased summary of the available research for better designing of anti-diabetes policies for the community.

Methods

Study Selection

Eligibility criteria for our review were those studies that 1) were quantitative interventional studies with all randomised, non-randomised control group designs that implemented on general populations and/or the participants at-risk for T2DM within communities (community-based interventions was defined as those programs that target whole populations living within a specific location, like schools, workplaces, mosques, and churches, and also included populations outside clinical/healthcare settings); 2) investigated the effectiveness of community-based educational strategies (focused on self-care behaviours change, lifestyle change, physical activity, and individual behaviour change); 3) had no pharmacological treatments within the intervention; 4) had any theoretical frameworks based on health education theories/models; 5) investigated the incidence rates of T2DM, glucose outcomes (fasting blood glucose [FBG], hemoglobinA1c [A1C] or 2-h postprandial glucose [PPG], mean body weight changes, mean BMI changes, the incidence of obesity, behavioural outcomes (physical activity, diet control, self-care behaviours, and etc), quality of life, and the educational/ecological factors based on educational models and theories; 5) published 2000 onwards and in English language. Comparison was

defined as no intervention or standard treatment for the control group. The studies that included samples with metabolic syndrome, gestational diabetes mellitus, type 1 diabetes, and T2DM were excluded.

Data Sources and Search

Our aims in the search strategy were to find both published and unpublished studies. In this review, we utilized a three-step search strategy. Initially, we conducted a limited search, of MEDLINE and EMBASE. Then, we undertook an analysis on the text words contained in the title and abstract and on the index terms used to describe the words. As the second step, we searched all identified keywords and index terms across the following databases: PubMed, EMBASE, ProQuest, CINAHL nursing & allied health source, and Cochrane Library. Unpublished studies were searched in Google scholar and conference proceedings. In the third step, we searched the reference list of all articles and identified reports for additional studies. We also contacted the authors of primary studies for missing information or clarifying any unclear data. To search literature, we included Medical Subject Headings (MeSH) terms related to T2DM prevention, and community-based educational and behavioural intervention (Supplementary Data; file 1).

Data extraction and Methodological quality

The initial eligibility was assessed on the basis of title and abstract, and the data were extracted using JBI standardized data extraction tool and a standardized data extraction sheet designed for this study (Supplementary Data file 2). In case the data of interest were not reported, we tried to contact the authors for the information or to compute it instead based on the reported findings. The risk of bias in the inclusion of studies was assessed independently by two authors (TSh and SA), and a third reviewer (HN) resolved any disagreement.

Community-based educational interventions are often conducted under real-world conditions, so they are often with quasi-experimental designs and a high level of heterogeneity within samples[11]. That is why we included the studies with both Randomized Control/ Pseudo-randomized designs. Similar with previous meta-analysis studies[11–13] on community-based interventions, we assessed the quality of included studies applying the following quality indicators: a) outcome used: blood glucose (2-points), or, self-reported risk factors (1-point), or, anthropometric measurement (1-point); b) attrition: 20% (2-points), or, 20–40% (1-point), or, different between study arms (0-points); c) analysis technique: intent-to treat (2-points), or, per protocol (1-point); d) external validity: intervention described sufficiently [in terms of program description(1-point), the qualification of intervention delivery agents(1-point), costs and resources used to deliver the program(1-point), and the acceptability of the program among participants and/or providers(1-point)] to allow for reproducibility. All included studies were scored on a 10-point scale and were categorized as of low (≤ 5), medium (6–7), or high (≥ 8) quality.

We considered T2DM incidence rate (the likelihood and relative risk of developing T2DM) and glucose outcomes (fasting blood glucose [FBG], hemoglobinA1c [A1C] or 2-h postprandial glucose [PPG] as primary outcomes of interest. Therefore, among those included studies that reported the outcomes, we extracted the number of samples who developed T2DM at the end of the intervention, as well as the pre-

test/post-test (pre/post) changes in FBG (mmol/L), A1C (percentage points and mmol/mol) and PPG (mmol/L). We also extracted the pre/post changes in weight (kg), body mass index (BMI), waist circumference, and systolic/diastolic blood pressure.

Descriptive analysis

A narrative description of the findings from included studies was structured according to the following characteristics: (1) the target population characteristics, like gender, age, and baseline BMI; (2) the community-based program characteristics, like community involvement and culture components, theoretical framework, number and intensity of educational sessions participants attended, intervention type (Who, how and where delivered the educational program), and intervention duration; (3) study characteristics (country, design, attrition and response rates, and follow-up length); and (4) the type of outcomes, like incidence rate of T2DM, glucose outcomes, mean body weight changes, mean BMI changes, behavioural outcomes (physical activity, diet control, self-care behaviours, and etc), and quality of life. We extracted these data applying a standardized extraction sheet designed for this study. In the case that the data of interest was not reported in the studies, we tried to contact authors for the information or to compute it based on the pre/post intervention values reported.

Heterogeneity assessment, Small study bias assessment and Data synthesis

In order to assess small study bias, we calculated Egger's test score and used funnel plots. In case of positive Egger's test, we conducted a metatrim analysis and calculated an adjusted effect size. We estimated intervention effect in terms of standardized mean difference (sMD). With respect to meta-analysis, we pooled our quantitative data and the results were expressed in terms of weighted mean difference. In case where the statistical pooling was not possible, we presented our findings in narrative form using tables and figures, as appropriate. We used Cochran Q test to examine the between-study heterogeneity using I^2 values and τ^2 of between-study variance. We also performed sub-group analysis based on age-group, gender, theoretical framework, and duration of follow-up.

Ethics approval was obtained from the Committee in the Research Affairs of Tabriz University of Medical Sciences (IR.TBZMED.REC.1397.352).

Results

General characteristics:

A total of 8181 records were searched through various sources, including 56 through hand search; of which, a total of 19 studies were found to match our inclusion criteria (Figure 1) and included in the systematic review. Eventually, 10 studies with randomized controlled filed trial design were included in the meta-analysis. Nine studies were not considered for meta- analysis due to lack of full report on complete data. The characteristics of community-based educational interventions across the 19 studies are provided in Supplementary file 2.

Judgments of review authors about the quality indicators for all included studies are presented in Table 1. Five, eight, and six studies were judged to have low, medium, and high quality indicators, respectively.

As expected, most (n=12) studies were conducted in high-income countries [14-26], and, importantly, in merely three of them including nine studies in USA, two in UK, and one in Canada. Moreover, only seven studies were conducted in upper-and lower-middle income countries [27, 28], including three in India and one each in China, Thailand, Iran, and Malaysia (Supplementary file 2). The studies included in the meta-analysis altogether had a data from 16,106 participants (7391 cases and / 9715 controls). The mean age of these participants was 41.52 years (range 10 to 64). Other details are provided in Supplementary file 2.

Thirteen studies were conducted in urban and sub-urban areas [14, 15, 18-28], four in rural areas [16, 17, 29, 30] and two in both kinds [31]. Ten studies were randomized [15, 16, 18-20, 22, 24, 27, 30, 31], five had pre-post design [14, 17, 24, 25, 29], while two studies were non-randomized [21, 28], Supplementary file 2. Thirteen studies had adults alone [14, 15, 17-20, 22, 25-28, 30, 31], one had both children and adults [29], while two studies had children alone [21, 24].

Of 19 studies, theoretical framework was evident in only eight studies, including social cognitive theory in four studies [15, 16, 21, 24], t5 instructional design in two studies [23, 31], and health belief [28] and social marketing [25] theory in one study each. In terms of educational interventions, 12 were aimed at improving lifestyle and increasing physical activity.

Diabetes Incidence:

The incidence rate of diabetes was reported in 3 trials (19)[27, 32], within which one study was cluster randomized trial [27]. Results on diabetes incidence rate at 36 and 30 months follow-ups for the trials (19) [27, 32] were compared. Pooling the effects, we found that in the intervention groups 70 out of 2096 cases developed T2DM. However, in the comparator groups 150 out of 2864 cases developed to the disease. Calculated absolute effect for the interventions was 29 fewer individuals per 1000 (95% CI: 18-41). The risk of developing diabetes was reduced by 54 % in favour of the community-based educational interventions, RR =0.54, 95% CI = 0.38- 0.75; p < 0.001) (Fig. 2, part A).

Glycaemic control:

A total of 11 (no. of participants=11587) and six (no. of participants=6416) studies assessed the effect of interventions on reducing FBG and A1c levels, respectively, as compared to their control groups (6417, 3055). The pooled mean difference was -0.33 (95% CI -0.45 to -0.20, p<0.0001) and -0.15 (95% CI -0.28 to -0.03, p<0.0001) for FBG (Figure 3) and A1c levels (Figure 2, part B), respectively.

Secondary outcomes:

The effect of interventions on reducing BMI, WC, sBP and dBP levels was assessed in ten, nine, six and five studies with a total of 12555, 12637, 11493 and 11559 participants respectively, as compared to their control groups (6936, 7000, 6374, and 5845). The pooled mean difference was -0.47 (95% CI -0.66 to

-0.28, $I^2=95.7\%$, $p<0.0001$) and -0.66 (95% CI -0.89 to -0.43, $I^2=97.3\%$, $p<0.0001$), indicating a positive effect on reducing BMI and WC alone (Figure 2, parts C, D, E, and F), respectively. There was no favourable effect of effected interventions on reducing sBP and dBP.

Sensitivity analysis:

The sensitivity analysis showed that after excluding studies with large effect size[21, 23], the decrease was not seen in the heterogeneity of results (Figures 2 and 3).

Sub-group analysis:

A sub-group analysis was performed on the basis of duration of follow-up, gender, age and theoretical framework vis-a-vis change in the FBG levels (Figures 1-4). These results showed that the standardized mean difference in FBG did not seem to depend upon the duration of follow-up since a six month follow-up showed a mean difference of 0.40, while those with 36 months of intervention provided a mean difference of merely 0.07 (Figure 3, part A). Similarly, this decline in fasting glucose was seen for both genders but particularly men (Figure 3, part B), for both adults and children but particularly children (Figure 3, part C), and irrespective of having or not having a theoretical framework but particularly for those studies with a theoretical framework (Figure 3, part D).

Publication bias:

Funnel plot did not show an evidence for publication bias, and the Egger test was not significant ($p>0.05$) (Figure 4).

Discussion

We were correct to address this topic because diabetes has the second highest rate of increase in our region than elsewhere, thereby, requiring strong newer evidence to restrain the ever-growing burden and natural course of diabetes here [2]. Despite the enormity of this problem, we were surprised to find out the scarcity and deficiency in community-based interventional studies effected for diabetes prevention. For instance, out of 8181 records from various sources, only 19 (0.23%) met our inclusion criteria. Moreover, the most ($n=12$, 63.1%) of these studies were conducted in merely three high-income countries, and only one (5.0%) in our region (Supplementary file 2). Thus, we are not surprised that the burden of diabetes is not reducing and that we lag fairly behind in having effective and sustainable interventions for diabetes prevention[33].

Our results bringsforth another important question related to database efficiency because even after using suitable search strings (Supplementary file 1), the databases provided 99.7% misfits, Fig. 1. This may mean that the databases are a cumbersome and imprecise source of literature, leading to unwarranted loss of precious time and labor.

Moving further, only few (n = 8, 40.0%) studies had a pre-defined theoretical framework for their intervention, and all of these had a single-theory module. Using a single-theory rationale is a kind of drawback because health behaviors often cluster together[7]. For instance, diabetes is a multi-factorial disorder and addressing multiple health behaviors at once may support the corollary that intervening on multiple behaviors may greatly increase the impact of intervention[7]. As expected, those studies that used a theoretical framework provided a greater standardized mean change in our outcome variables than those studies that did not have any theoretical framework, Fig. 4. This result validates our premise fairly well that the use of social theories provide better model-fit with diabetes prevention[9].

The most commonly used theory was social cognition (Supplementary file 2); which aligns fairly well with community-based interventions because social cognition means that one learn from others through social interaction and social experience. Such social cognition theories may have a disadvantage as well because apart from following the safe behavior of others, one may also follow the unsafe behavior of others, as we may learn from a simple example of pedestrian road traffic injuries, “Well, someone in the front didn’t respect the traffic lights and passed, So I pass too” (currently submitted, 2019). The possibility of this disadvantage can be learnt from another part of our result wherein it is the health belief theory that provided highest mean change in the outcome variables than all other behavior theories, Fig. 4. Health belief theory targets on why an individual does or does not perform a particular health-related action; thus, health belief theory may align better with disease prevention goals. We could not find a reliable theory-comparison data from elsewhere, but, this is one of the very relevant pending questions on diabetes prevention.

Moving further, the effect of intervention was more profound on FBG than A1c, Figs. 2 and 3. This could possibly be a methodological artefact in our work because the difference in the mean change in FBG and A1c (45.4%, -0.33, vs. -0.15), and the number of studies (54.5% 11 vs. 6) and sample size (55.3%, 11587 vs. 6416) were close enough. Nevertheless, our results match fairly well with others[34] in the sense that educational interventions brings favorable changes in these outcome variables[35].

A1c is a more useful parameter of surveying intervention effect because A1c may indirectly reflect an influence of intervention on glycemic control over an average of 3–4 months. However, there are other factors that may bias the effect of intervention on A1c level. For instance, A1c is genetically-determined [5, 6] while FBG is not likely[36]. A1c thresholds are not uniform worldwide and the sensitivity of these thresholds differ in different racial groups [37, 38]. There are also different laboratory assay methods that may affect the measurement accuracy of A1c [39]. Moreover, A1c levels differ with iron-deficiency anemia[40], a factor whose frequency evidently differs between populations.

Moving further, we performed various sub-group analyses with respect to the effect of interventions. Besides FBG and A1c, the change was particularly seen in WC followed by BMI, Fig. 2, which means that the participants changed in central obesity[41]. This is a good outcome because WC is a better predictor for the development of diabetes than BMI[42]. The maximum change was noted in a study that implemented educational intervention through community health workers, Fig. 2, part D. We expect this

because the success of intervention is based on ensuring social support, feedback and communication, structured program, and monitoring[43]. There was no significant effect on sBP and dBP, probably because the mean age of our participants was not high, and individuals may not have considered them to be hypertensive or at-risk of that. Nevertheless, we have seen that the individual's attitude towards hypertension remains immensely poor in nearly all kinds of populations, which necessitate separate interventional efforts altogether [44] [45].

Moving further, there was no publication bias or that from studies with large effect size. All studies were trying to essentially measure the same thing at the end. We detected heterogeneity, but that becomes evident only after data collection and analysis, and for that reason, we used random-effect analysis which may in-part account for heterogeneity. Nevertheless, some sources of heterogeneity may have remained, for instance, in terms of theoretical framework, content of interventions used, etc. Elsewhere, it is seen that there is a lack of framework for the design of interventions and each team use their own ways to develop and report interventions[46]. As a result, many of such interventions become short of comparability.

Our work has some limitations. Ours is a post-hoc work, thus, we had to depend on the available information alone. Because of the limited number of eligible studies, we could not do many sub-group analyses that we wanted to perform, for instance, the comparison of effect between individual theories, or gender-based differences such as in waist circumference, etc. We restricted ourselves to English language alone because of enormity of records to search-for, although the authors understand Persian, Spanish and French fairly well. The future work may focus on data in these languages. Our education interventions were fairly assorted and future work may compare each intervention with other modes of intervention. We did not look at the aspects of compliance and incentives. The presence of heterogeneity is fairly seen in most published works, and in our case, it simply means that there is a need of testing framework-based interventions that may in turn enhance communality and gold-standard between different interventions. Our work also does not take into account the aspects of feasibility, efficaciousness, or sustainability outside a study setting.

Conclusion

Based on a comprehensive data collection and reasonable analyses, we conclude that there is a dearth of reliable community-based educational interventions towards prevention of diabetes; especially from low-middle income populations. The effected interventions are helpful for fasting blood glucose more than A1c, for children more than adults, for women more than men. Interventions with theoretical framework are likely to be 57.1% more effective towards favourable changes in fasting glucose. Of all effected theories, health belief model seemed to provide the greatest possibility for having a desirable change in outcome variables. Unfortunately, there is a lot left to discover and identify before we may eventually reach towards having efficacious and effective strategies for the prevention of diabetes.

Declarations

Ethics Approval and consent to participate

Ethics approval was obtained from the Committee in the Research Affairs of Tabriz University of Medical Sciences (IR.TBZMED.REC.1397.352).

Consent for publication

Not applicable.

Availability of data and materials

All data has been summarized and provided in the supplementary files.

Competing Interest

The authors declare that they have no competing interests.

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Authors' contributions

HN has been the lead author on this study and has participated in all steps and the writing process. TS, MHA, AS, DBH, ZJV, ZF together with SA and HN have designed the search strategy and have participated in all steps of the writing process. All authors read and approved the final manuscript.

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Abbreviations

T2DM: Type 2 Diabetes Mellitus;

HbA1C: Haemoglobin A1c;

JBI: Joanna Briggs Institute

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Table

Table 1: Quality indicators for the studies included in this systematic review and meta-analysis: L, low quality; M, Medium quality; H, High quality; U, Unclear. ×

| Reference | Outcome | Attrition | Analysis technique | External validity | | | | Quality in total |
|--------------------------------|---------|-----------|--------------------|---------------------|---|---------------------|------------------------------|------------------|
| | | | | Program description | Qualification of intervention delivery agents | Costs and resources | Acceptability of the program | |
| Balagopal et al. (2008) | √ | √ | U | √ | × | × | √ | M |
| Norliza et al. (2016) | √ | √ | U | √ | √ | U | U | M |
| Rowan et al. (2016) | √ | × | U | √ | √ | × | × | L |
| Penn et al. (2013) | × | √ | × | √ | √ | × | √ | M |
| Katula et al. (2011) | √ | √ | U | √ | × | × | √ | M |
| Ackermann et al. (2011) | × | × | U | √ | × | U | × | L |
| Ockene, et al. (2012) | √ | √ | U | √ | √ | U | √ | H |
| Daniel et al. (1999) | √ | × | × | √ | × | × | U | L |
| Raman et al. (2010) | √ | × | U | √ | √ | U | × | L |
| Balagopal et al. (2012) | √ | U | √ | √ | × | U | √ | M |
| Ramachanran et al. (2006) | √ | U | √ | √ | √ | √ | √ | H |
| Harati et al. (2010) | √ | × | √ | √ | √ | √ | √ | H |
| DPPC Centre* (2009) | √ | √ | √ | × | U | √ | √ | H |
| Davies et al. (2016) | √ | × | √ | √ | √ | √ | √ | H |
| Yin et al. (2018) | √ | √ | √ | √ | × | U | √ | H |
| Pedley et al. (2017) | √ | √ | U | × | × | U | √ | M |
| Sranacharoenpong et al. (2018) | √ | × | U | √ | × | × | √ | M |
| Soltero et al. (2019) | √ | U | U | √ | × | √ | √ | M |
| Soltero et al. (2018) | × | U | U | √ | √ | U | √ | L |

*DPPC: Diabetes Prevention Program Coordinating Centre

Figures

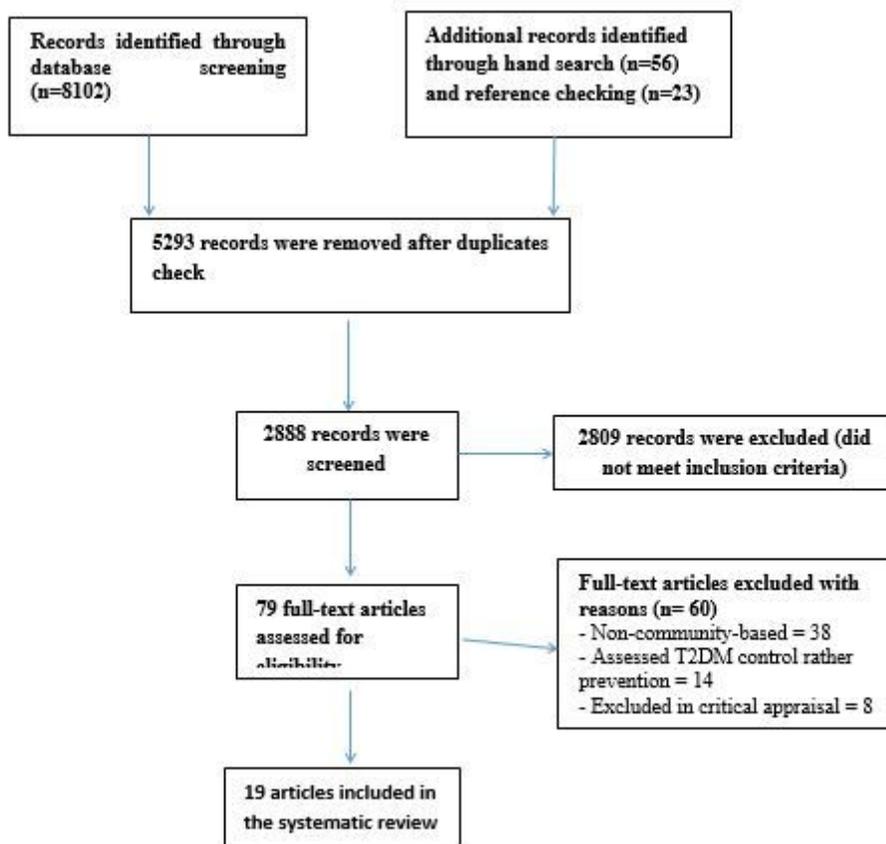


Figure 1

Flow diagram of the study

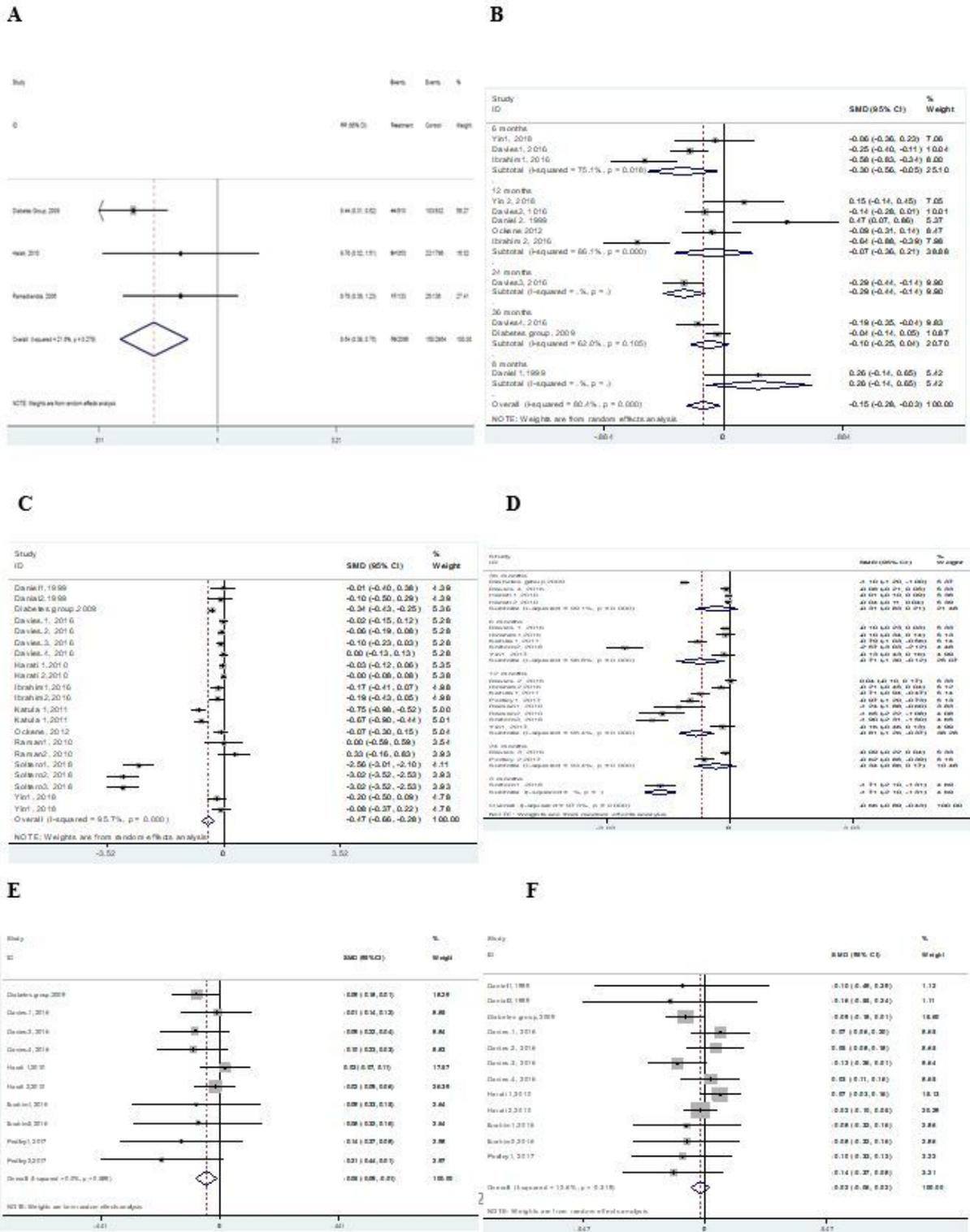


Figure 2

Meta-analysis of the interventions on Type 2 Diabetes incidence (A), HbA1c level (B), body mass index (C), waist circumference (D), and diastolic (E)/ systolic (F) blood pressure levels

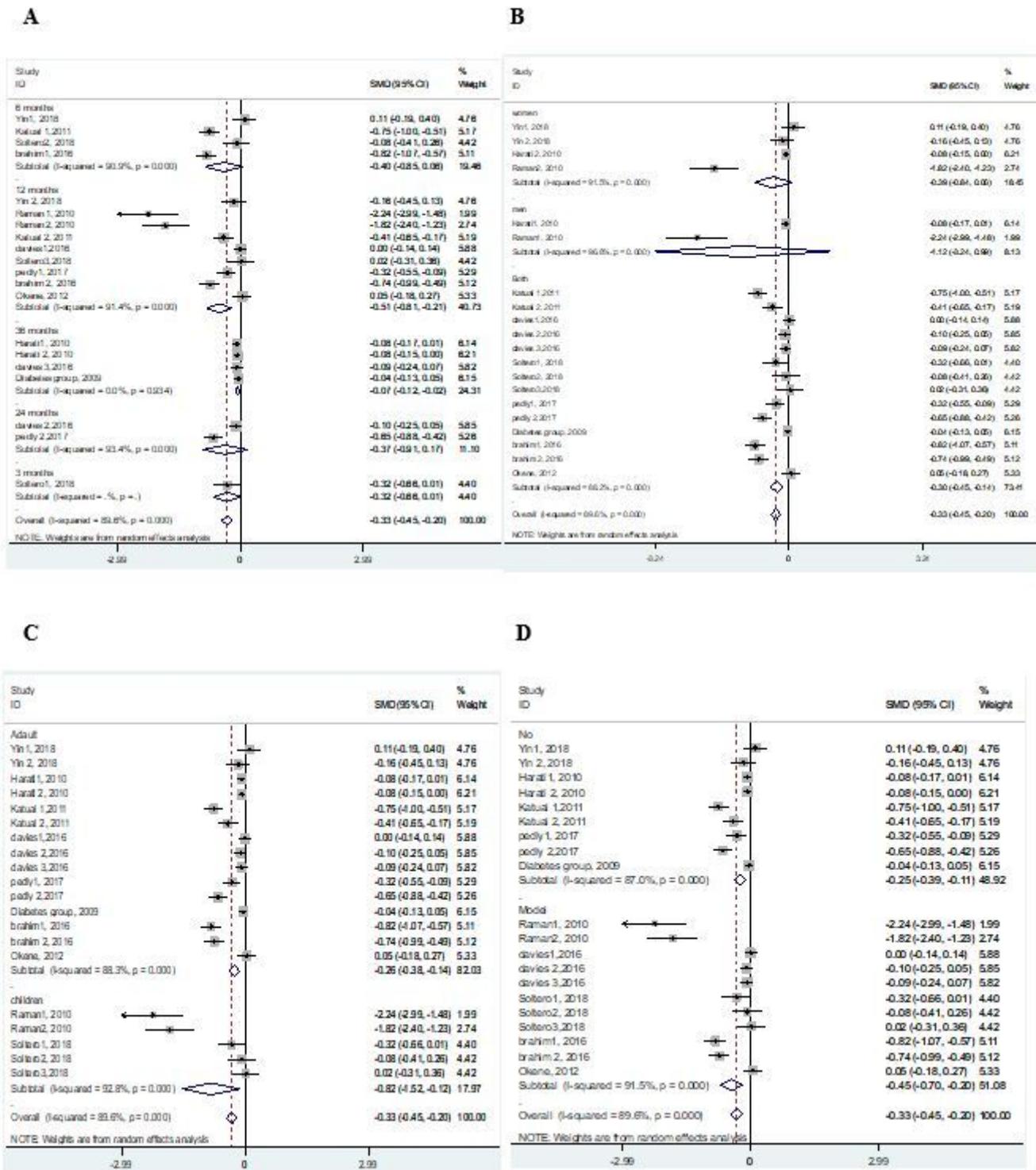


Figure 3

Sub group analysis on effect of interventions on FBG based on duration of follow-up (A), gender (B), age (C), and using theory /model (D)

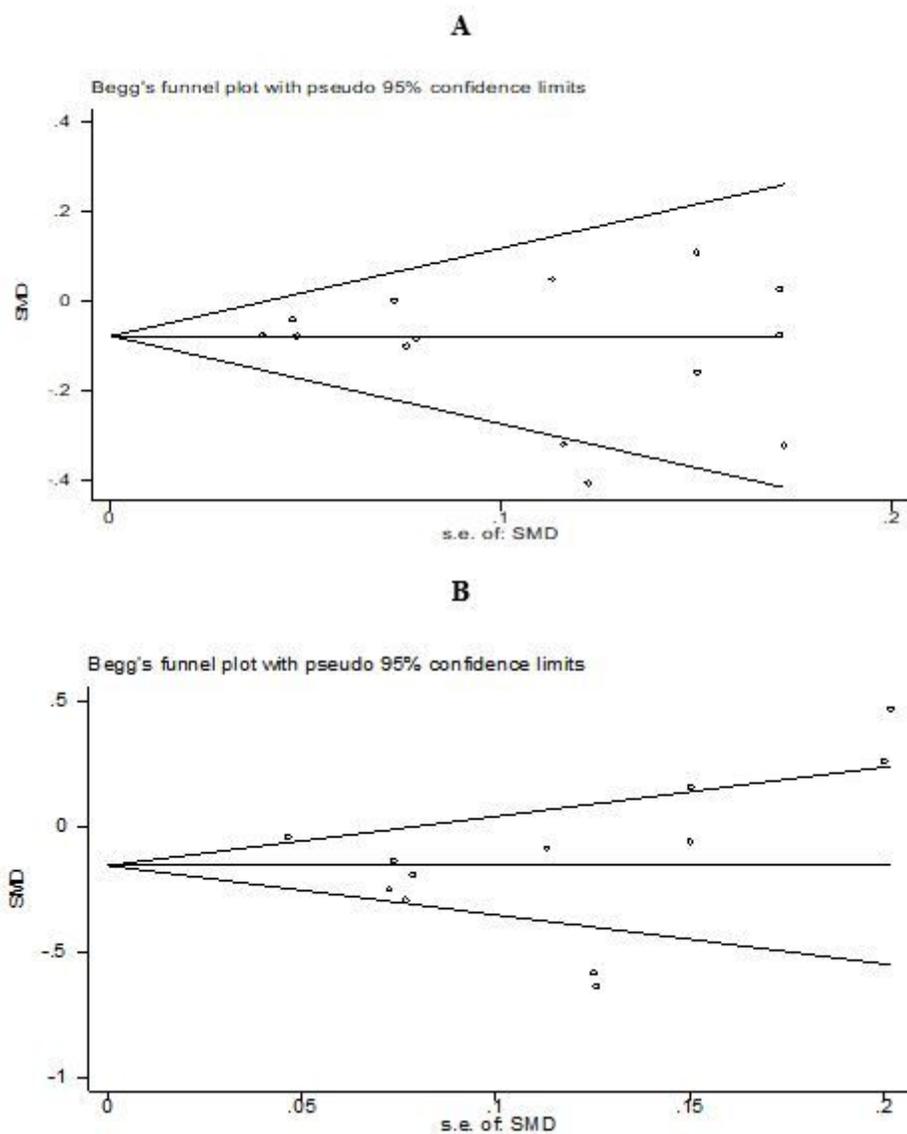


Figure 4

Funnel plots of interventions on fasting blood glucose (A) and haemoglobin A1c (B) levels

Supplementary Files

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- [PRISMA2009checklist.doc](#)
- [SupplementaryDatafile1.docx](#)
- [SupplementaryDatafile2DataExtractionSheet.docx](#)