# The Effect of Physical Activity in Preventing Type 2 Diabetes Mellitus in Prediabetes Patients: a systematic review

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## Abstract

**Purpose:** To search, analyze and identify evidence regarding the use of physical activity interventions in preventing type 2 diabetes mellitus (T2DM) in the pre-diabetic population.

**Method of Research and Design:** Studies that focused on physical activities as an intervention and this also included studies that compare physical activity intervention with others. The participants are a high risk group (prediabetes) to develop T2DM. The studies also had to be randomized controlled trials to be included. The databases that were used in searching for the articles include CINAHL, MEDLINE and PubMed database. These studies were analyzed in terms of whether the interventions had a successful or unsuccessful outcome.

**Results:** Screening process led to the selection of 8 studies relevant to the criteria of inclusion. About six studies compared interventions while the other three examined the effectiveness of one intervention. Most of the physical activity interventions were found to be useful in preventing type 2 diabetes in the high risk group, but with differing levels of effectiveness. The high-intensity-interval training (HIIT) programs were found to be more effective in achieving improvement in body metabolism as well as lower resistance to insulin. They also improved adherence to the intervention. The interventions that were associated with greater energy expenditure showed better outcomes.

**Conclusion:** This systematic review shows that most of the physical activity interventions are effective and this leaves the healthcare providers to choose one that will show to be more effective. Because of the reported effectiveness, the HIIT programs can prove to be the better choice.

**Key words:** physical activity, diabetes type 2, prevention

## Introduction

Diabetes mellitus (DM) comprises of a group of conditions that have in common a metabolic dysfunction that leads to elevation in blood glucose. It is classified according to the etiology into three main types; type 1, 2 and gestational diabetes (GD). Type 1 is differentiated from type 2 by having total lack of insulin due to the destruction of the beta cells in the pancreases while in type 2 there is resistance to the actions of insulin in the cells. The commonest type of DM is T2DM accounting for 98% of DM cases. The cases of T2DM have been on a constant increase in the world and it has been associated with an increase in industrialization. It is considered to be a lifestyle disease being associated with poor diet choices and reduced physical activity (PA). There is also a role of genetics in the etiology of T2DM having some people more predisposed to having it than others (Edelman & Polonsky, 2017).

T2DM is a preventable condition since the etiology has been well described and the points of intervention have also been identified hence it is easy to prevent its development. Diet and PA have been at the heart of most of the interventions put in place to prevent T2DM. Prediabetic states are when there is impaired glucose tolerance, impaired fasting glucose, or an A1C of 5.7-6.4 % (Knowler et al., 2002). Most T2DM cases are often preceded by a period of prediabetes (Bansal, 2015). The CDC (2017) reports that in America approximately 84 million adults have prediabetes, accounting for about a third of the population. More than 90% of those with prediabetes are unaware of their state. Studies have shown that when the right interventions are put in place the progression of prediabetes to T2DM can be reduced. The aim of this study is to conduct a systematic review of literature on the effectiveness of physical activity (PA) in preventing the development of T2DM. The question that this study asks is among those who have prediabetes, are PA activity interventions effective in preventing the development of T2DM compared to no PA.

## Methods

For the conducting and reporting of this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were utilized. PRISMA gives the minimum items that can be included in the systematic analyses and meta-analyses and is supported by evidence based studies. It mainly focuses on the reviews that report on randomized trials but the same concepts can be applied in reviewing other studies.

### Eligibility Criteria

The studies that were included in this study are those that are peer-reviewed and are based on the prevention of T2DM among individuals who have prediabetes. The studies that were included were those published in English. In establishing the particular inclusion criteria, the PICOS (Participant, Intervention, Comparators, Outcomes, and Study design) guidelines were used. To be included in this study, the article must have had participants that have been proven to be at high risk for T2DM. The articles should have assessed the use of PA interventions in the prevention of T2DM. In addition, they should be primary experimental studies with a preference for randomized control trials. The studies that were included were also those that provided access to the full details of the study. Articles that contained only the abstracts were excluded. Any study that had a combination of interventions was excluded.

### Search Strategy

The databases that were utilized in searching the relevant studies for this review included; Cumulative Index to Nursing & Allied Health Literature (CINAHL), MEDLINE and PubMed. Keywords that were used in searching for the relevant studies included; prediabetes, prevention of type 2 diabetes, physical activity, and randomized control trials.

### Method of review

The studies that were considered were those published not later than the year 2013. Duplicates were first removed, followed by articles that contained titles that were irrelevant to this study. A summary of the rest of the studies were reviewed then the eligibility criteria used in the elimination of the irrelevant studies. The final stage was the reviewing of the full texts of the remaining articles.

### Data extraction

After choosing the studies that were to be included in the review, a guide was used to gather relevant information from these studies. The guide included the study objectives, the study design, the intervention setting, the study population, the scales and measures that were used and lastly the findings of the study. Elasy et al. (2001) gave a description of the main components for diabetes interventions and these were utilized in the extraction of data from these studies. These main components include; the target for the intervention, the types of assessments that were conducted, the intervention's components, time and intensity, those providing the intervention and the diabetes-related component.

### Validity Assessment

Jadad et al. (1996), proposed a criteria which was utilized in assessing validity of the studies selected for this study. First, it assesses whether the study was described as being a randomized study. Secondly, it assesses whether the study described the sequence used for randomization and if it was appropriate and if the cases of dropouts and withdrawals were described. Thirdly it assesses for blinding but in the types of studies included in this review, blinding was not necessary. Therefore, assessment for blinding was not done. Lastly, an assessment for a clear description of the intervention used was done.

### Data Analysis

This study used a method described by Kawamoto et al. (2005) that focuses on identifying the associations of success or no success depending on the intervention that was implemented. The analysis was based on the target of the intervention, setting and design, the delivery of the
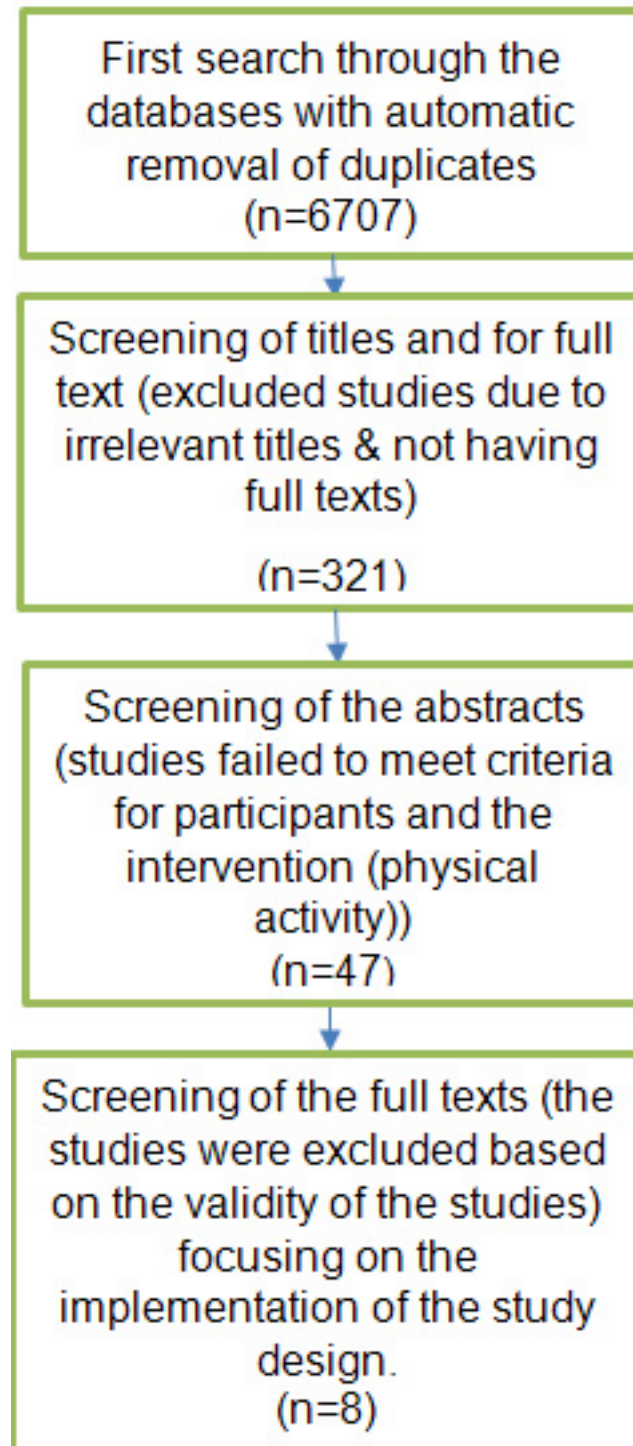
intervention, the duration and intensity of the intervention. These features were used to examine every study. The interventions were reviewed as to whether they led to affirmative results and if it was clinically or statistically significant. Any criteria to describe the clinical importance were absent, but the statistical importance was based on a p-value less than 0.05. Clinical importance was judged based on the findings of each study. The use of this approach made the study more of a descriptive study than a qualitative one. There are two sensitivity analyses that were carried out in this study to assess whether the results were assessed based on the quality of findings. First, only the randomised controlled trials were used in the study.

Second, the randomised controlled studies were limited to those that described the randomization and also the randomization was appropriate for the study. In addition, the studies described the dropouts and the participants who were unwilling to take part.

## Findings

Study Description
The study description, search results and process are summarized in the following diagram

First search through the
databases with automatic
removal of duplicates
(n=6707)

↓

Screening of titles and for full
text (excluded studies due to
irrelevant titles & not having
full texts)

(n=321)

↓

Screening of the abstracts
(studies failed to meet criteria
for participants and the
intervention (physical
activity))
(n=47)

↓

Screening of the full texts (the
studies were excluded based
on the validity of the studies)
focusing on the
implementation of the study
design.
(n=8)

Following is a summary of the characteristics of the studies that were included in this paper. All the studies were randomized control studies and they all focused on PA strategies for preventing T2DM. Five of the research items were comparative studies having the aim of showing a better mode for intervention while 3 compared a specific PA with the control. In 7 of the studies, the participants were considered to be high risk by having disorders in glucose metabolism while in one of the studies the participants were considered as high risk by being a child of a diabetic parent.

**Study 1:** Jung et al. (2015) assessed if high-intensity-interval training (HIIT) has a role in enhancing short term adherence to exercise compared to Moderate-intensity Continuous Training (MICT) . It was a randomized control study. The participants were randomly selected into a HIIT group and MICT group. 32 participants 30-60 years with confirmed prediabetes were included in the study. 17 were in the MICT group and 15 in the HIIT group. Participation was also based on inactivity over the past 6 months and the results from filling the CSEP PA Readiness Questionnaire-Plus and an Exercise Physiologist's clearance to participate in vigorous activity. The measures in the study included Heart rate, training logbook, the activity, duration, intervals, and hardness of the session, accelerometer, cardiorespiratory fitness and anthropometric and blood pressure. According to the study, those in the HIIT group had better adherence to exercise than the MICT group (p=0.05). The time spent working out was higher in the HIIT group (p=0.049). Systolic blood pressure and cardiorespiratory fitness were observed to improve in both groups (p= < 0.05).

**Study 2:** Philippe et al. (2017) compared the effects of uphill and downhill walking on improving the glucose metabolism and lipids among the prediabetes group in three weeks. Individuals were randomized into a CE group (uphill) and an EE group (downhill). 16 male patients 50-67 years with prediabetes participated in the study. 8 were in the EE group and 8 in CE group. The study measured anthropometric measures, Exercise Capacity, measures of glucose and lipid metabolism and energy expenditure. They found that with uphill walking, there was a significant improvement in glucose tolerance (p=0.05), triglycerides (p=0.036), HDL-C (0.05) and total cholesterol/HDL-C ratio (p=0.012). There were no significant metabolic adaptations with downhill walking.

**Study 3:** McDermott et al. (2014) had the objective of comparing the effectiveness of Yoga with walking, in preventing T2D among the high risk group. The study was a randomized control study and the participants were placed into a yoga group and a control group (walking) randomly. The study had a total of 41 participants and 20 were in the yoga group while the rest were in the control group. High risk for having T2D was based on a family history of T2D in a first degree relative and glucose tolerance that is impaired. The primary measures were blood pressure, waist circumference, and weight. The secondary measures were anxiety, affect, perceived stress and depression. The study reported that the yoga group showed a better reduction in weight (p=0.02), BMI (p=0.05) and waist circumference (p= < 0.01). The groups showed no difference that was significant regarding fasting blood glucose, insulin resistance, and postprandial blood glucose. The study also showed a reduction in both groups regarding blood pressure and cholesterol.

**Study 4:** Patil et al. (2019) had the aim of determining the effects of yoga on insulin resistance and cardiac dysfunction among the offspring of diabetic parents, who are non-diabetic, in 8 weeks. It was a randomized controlled study. A total of 57 participants between 18 and 40 years old, were included with 28 in the yoga group and 29 in the control group. One was considered high risk by being offspring to a diabetic parent. The study measured serum insulin, heart rate variability-low frequency (LF), high frequency (HF) and LF/HF ratio, tolerance to glucose and resistance to insulin. According to the study the yoga group showed a reduction in LF (p=0.005), LF/HF ratio (0.004), insulin resistance (p= < 0.001) and OGTT (p=0.003). There was an increase in HF (p=0.022) in the Yoga group. There was no significant change among the control group.

**Study 5:** Martins et al. (2018) compared the effects of High-intensity-bodyweight training with combined training on insulin resistance, inflammatory markers, and composition of the body and walking test in postmenopausal women with a high risk for T2DM. The study was a randomized controlled study. There were 16 post-menopausal participants, 8 in the combined training and 8 in the high-intensity-interval-bodyweight training group. They were considered high risk using the levels of HbA1c. The measures in the study included, inflammatory markers, body composition, muscle function, and insulin resistance. The study results were both the groups showed an increase in 6-minute walk test, muscle mass index and Il-1 receptor antagonist (P < 0.05). There was a decrease in fasting blood sugar, HbA1c, insulin, and monocyte chemo-attractant protein (p=0056).

**Study 6:** Herzig et al. (2014) aimed to determine the threshold of PA that affects glucose, lipid, insulin concentration and body fat composition in prediabetes patients. It was a randomized control study. The study had 68 participants; the intervention group having 33 and the control group having 35. The study measured fasting and 2-hour glucose, insulin, maximal oxygen uptake, daily steps, lipids, fat distribution and body weight. The researchers found that a collected daily steps at an acceleration level of 0.3–0.7 g were 4,434 in control and 5,870 in the intervention group. In the first 3 months, there was no significant change in fasting and 2-hour glucose, body weight and maximal oxygen uptake. The intervention group showed significantly greater changes in fasting and 2-hour insulin (p=0.035 and p=0.003 respectively), insulin resistance (p=0.36), total cholesterol (p=0.041), LDL (p=0.008) and visceral fat (p=0.03).

**Study 7:** Slentz et al. (2016) had an aim of determining the relative contribution of exercise alone in preventing the progress to diabetes and to determine its effects on the measures of glucose metabolism. It was a randomized control trial. They had 4 intervention groups in which the participants were placed randomly. There were 237 participants 45-75 years who had elevated fasting glucose and they were sedentary non-smokers. The high amount MICT group, high amount vigorous-intensity group and low amount moderate-intensity group had 61 members each and the low amount moderate-intensity training group had 54. The measures were fasting glucose, fasting insulin and Insulin AUCs, cardiometabolic health and glucose tolerance. They reported that the exercise plus diet group was the only one that showed a decrease in fasting glucose (p= <0.001). Fasting glucose showed the following changes: high-amount and moderate-intensity −0.07 (p=0.06); high-amount and vigorous 0.06 (p=0.19); low-amount and moderate 0.05 (p=0.15); and diet and exercise −0.32 (p=−0.18).

**Study 8:** Lee et al. (2013) had an objective of comparing resistance exercise (RE) against aerobic exercises (AE) regarding their effects on insulin sensitivity and secretion, and abdominal fat adiposity. The randomized control trial had three groups; AE, RE, and control group. The participants were 45 adolescent obese boys; the control group had 13, the exercise group 16 and resistance group 16. The measures were intrahepatic lipid, abdominal fat and intramyocellular lipids and sensitivity to insulin and insulin secretion. They found that both groups showed low weight gain that was significant when compared to the controls. Both the groups also showed a reduction in total and visceral fat and intrahepatic lipids that was significant. The RE group was the only group that showed an improvement in the insulin sensitivity, which was significant.

## Methodological quality

All the included studies were randomized control trials. All the studies had a clear description of the randomization process and it was appropriate in all the cases. All the studies also had an account of all the participants and they described the dropouts and the withdrawals.

## Interventions

All the studies targeted physical activity-based interventions. The comparative studies compared; interval training of high intensity accompanied by less intense training that is progressive, Yoga and walking, intense interval bodyweight exercise with combined training, PA alone and with combination with diet, resistance exercises with aerobic exercises and uphill walking with downhill walking. The PA interventions that were studied include; yoga, resistance exercises, walking, MICT, HIIT, combined training, and open-air exercise. The main focus of the studies was to show the efficacy of these strategies in preventing progression to T2DM among those who are highly predisposed to developing the condition.

## Analysis of features

This study was aimed at determining the effectiveness of PA interventions in preventing T2DM among those who are at high risk. Out of the eight articles, 7 studies had prediabetes participants while one study had individuals that were at high risk due to family history (parents). When each intervention modality is viewed in isolation, it can be inferred that the usefulness of exercise in preventing T2DM is dependent on the type of PA. Although they have different levels of effectiveness, MICT, HIIT, yoga, uphill walking, combined training, resistance exercise, open air activity are effective for preventing T2DM by improving both glucose and lipid metabolism and improving the state of insulin resistance. Downhill walking and no PA were found to be ineffective in T2DM among the high-risk group (McDermott et al., 2014).

Most of the comparative studies were aimed at coming up with an effective mode of PA that also encouraged adherence to the routine. According to Jung et al. (2015), HIIT was found to be more effective compared to the conventional MICT in preventing T2DM among predisposed individuals. In addition, it was observed that the HIIT is useful because apart from improving the metabolic indices, it also encouraged adherence. Philippe et al. (2017) reported that walking uphill is effective in improving the metabolic state in the prediabetic patients while walking downhill is ineffective. McDermott et al. (2014) say that yoga is effective while walking is ineffective in preventing T2DM among the high-risk participants. Lastly, both aerobic and resistance exercises are effective in improving metabolic metabolism in prediabetes. However, it can be noted that resistance exercises would significantly improve insulin sensitivity while the aerobic exercises do not.

## Discussion

### Adherence
In the current healthcare field, there are many effective interventions that have been developed and most of them are considered to be effective. One of the advantages that some of these interventions bring and makes them a better choice is encouraging adherence. In PA interventions for preventing type 2 diabetes among high-risk groups, there some interventions that have shown to be superior and also encourage adherence. The modalities that were found to be effective in this way are the HIIT and high-intensity-interval bodyweight training. Roy et al. (2018) also conducted a study to demonstrate the usefulness of HIIT compared to the MICT group. They identified that there is higher adherence and better outcomes in the group that did supervise HIIT. HIIT shows better outcomes in a short period of time encouraging participation and the sessions are nicely spaced and that encourages adherence to the intervention (Aamot et al, 2016).

### Intensity and Energy Expenditure
One of the ways in which the PA interventions are classified is according to intensity. For the same duration

of time, the high-intensity interventions have been shown to improve the metabolism in the prediabetes group. With increased intensity, there has been shown to be better glucose tolerance, improved fasting blood glucose levels, improved insulin resistance, and improved lipid metabolism as well as weight loss. Cassidy et al. (2017) conducted a study that supported the effectiveness of high-intensity interventions. These interventions are often personalized to fit the individual's physical health status. They have the advantage of requiring less time commitment while having superior effects compared to the traditional methods. There is increased effectiveness in improving cardiorespiratory fitness which is an advantage. Francois & Little (2015) conducted a study that agrees with this study on the effects of HIT on insulin resistance. While some MICT exercises may improve glucose metabolism, most of the time they either fail or take longer to improve insulin resistance. However, the HIIT exercise programs have been associated with improved insulin resistance in a shorter period of time.

One of the factors that have been found to be a common factor in the interventions that are effective, is adequate energy expenditure during the exercise period. While concluding, Philippe et al. (2017) report that downhill climbing could have had the same effectiveness as uphill climbing if the energy expenditure was adjusted. Uphill climbing is part of some HIIT programs and this can show that one of the factors that make the PA interventions effective, is the energy expenditure. Also, while comparing aerobic exercises and resistance exercises, Lee et al. (2013) report that resistance exercises showed higher energy expenditure which was tied to their success.

In summary, this study found that usefulness of physical exercise interventions in preventing T2DM is dependent on individual intervention. While most of them were found to be effective, the comparative studies showed that some of them were more effective than others and some offered the advantage of improving the level of adherence to the intervention.

## Conclusion

In conclusion, PA interventions are useful in the prevention of T2DM among a high risk group. The level of effectiveness differs across the interventions and it is important to carry out more studies that will lead to the development of effective models. The current study has shown that interventions that are based on HIIT exercise programs are more effective and have the advantage of enhancing adherence and this makes them good for practice. Energy use forms one of the most important factors in determining the effectiveness of an intervention.

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