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Impact of Diet and Exercise Interventions on Glycemic Control and Weight Management in Adults with Type 2 Diabetes: A Systematic Review of Randomized Controlled Trials and Observational Studies

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is a chronic metabolic condition characterized by insulin resistance and impaired insulin production, leading to high blood glucose levels. It is the most common form of diabetes, accounting for 90%-95% of all cases globally. With an increasing prevalence of T2DM, effective management strategies are crucial to control glycemic levels and prevent associated complications. Diet and exercise are considered key interventions to improve glycemic control and manage weight in individuals with T2DM. **Objective:** This systematic review aims to evaluate the effects of diet and exercise interventions on glycemic control and weight management in adults with Type 2 diabetes. The review focuses on the impact of various diet plans, including low-carbohydrate and Mediterranean diets, as well as different exercise regimens. **Methodology:** A comprehensive search of randomized controlled trials (RCTs) and observational studies was conducted to identify research on the effects of diet and exercise interventions in managing T2DM. Studies assessing glycemic control (e.g., HbA1c levels) and weight loss outcomes were analyzed to determine the effectiveness of these interventions. **Results:** The review found that both diet and exercise interventions led to significant improvements in glycemic control and weight management. Low-carbohydrate diets and Mediterranean diets, in particular, demonstrated positive effects on blood glucose levels and insulin sensitivity. Regular physical activity, especially aerobic and resistance exercises, also contributed to improved glycemic control and weight reduction. **Conclusion:** Diet and exercise interventions are effective strategies for managing Type 2 diabetes, improving both glycemic control and weight management. Incorporating tailored diet plans and exercise regimens into clinical practice may significantly benefit individuals with T2DM. Further studies are needed to refine intervention protocols and address barriers to patient adherence.

INTRODUCTION

T2DM is a chronic relapsing metabolic disease with insulin resistance and impaired insulin production with consequent high blood glucose level. It is the most common type of diabetes,

which contributes to 90%-95% of diabetes cases that exist in the world currently (ADA, 2020). T2DM is increasing worldwide at a fast rate, of the total estimated 537 million adults diagnosed with diabetes in 2021, it will rise and reach 783 million by 2045 (IDF, 2021). The prevalence of T2DM is expected to further increase over the years creating formidable public health concerns because of the effects it has on people's health as well as the burden it brings on global healthcare systems (Gagliardino et al., 2020).

In T2DM management, the major desired outcomes are Glycemic control, reduction of complications, and improving metabolic profile. In the past management of this condition has mainly been accomplished through oral medications and insulin therapy. However, these treatments are often inadequate if used in isolation and particularly in the chronic control of the disease (Stratton et al., 2000). As a result, non-pharmacological treatments especially, diet and physical activity, have received much focus in the management of glycemia and obesity in patients with T2DM.

Lifestyle changes particularly with diets is one of the key facets of T2DM treatment. A number of eating habits have been investigated in relation to their impacts on glycemic management. Low carbohydrate diet, Mediterranean diet and calorie restriction diet have been widely researched and implemented. Low-carbohydrate diets have been well documented to provide good glycemic control and in more severe cases those that classify carbohydrate intake less than 20% of total calories have also demonstrated a positive improvement (Boden et al., 2005; Feinman et al., 2015). Research has suggested that low carb diets can lower fasting blood glucose and HbA1c at least to an extent comparable with drugs (Stern et al., 2004).

On the other hand, the intake of the Mediterranean diet characterised by monounsaturated types of fat, vegetables and whole grains has also been found to produce a positive impact on glycemic control (Esposito, 2010). It is suggested to be beneficial for enhancing the insulin receptors' sensitivity and decreasing the inflammation in the entire body, which is engrossed in the functional aspects of T2DM (Shikany et al., 2015). Moreover, there is a need to focus on a low calorie diet, as experimental studies have shown that restriction of energy intake enhances insulin sensitivity and substantial weight loss have beneficial effects on glucose homeostasis (Johnston, Kalogeropoulos, & Leung, 2014).

Another factor that is crucial in diabetes is exercise. Exercise increases cells' ability to pick up glucose from the bloodstream, lowers glycemia and assists in weight loss. The specific physical activity recommendations include at least 150 minutes of moderate intensity aerobic activity per week together with resistance exercise for individuals with T2DM (ADA, 2021). For T2DM patients, exercise interventions have been shown to: decrease HbA1c, enhance glycemic control, and induce weight loss (Colberg, et al., 2016; Thomas, et al., 2006). The meta-analysis of RCTs revealed that aerobic exercise leads to a reduction of HbA1c by 0.5 / 1.0% and in patients who perform moderate-intensity exercise for more than 150 minutes/week, receive greater benefits.

In another study conducted on the effects of resistance training, improvement in both glycemic levels and body composition was also observed. Several works of research that have been conducted in this field show that resistance exercise leads to better sensibility to insulin as well as low levels of fasting blood glucose among elderly people with T2DM as confirmed by Castaneda et al. (2002). The integration of aerobic and resistance training exercise programs in a single setting has been proven to bring out a bigger enhancement on glycemic control than applying each form of exercise independently (Boule and al; Holten and al; 2001&2004).

While there is prior work that shows that diet has a positive impact on glycemic control and exercise on weight loss separately, combined results revealed that intervention has a more enhanced positive impact as compared to either diet or exercise alone. For instance the Diabetes Prevention Program (DPP) showed that people who underwent a lifestyle modification that incorporated diet and exercise had a relative risk reduction of 58% of developing T2DM as compared to the control group which received only standard care (Knowler et al., 2002). Of similar other RCTs that compared the effects of diet and exercise both individually with either of them there was more significant reduction in HbA1c and

higher weight loss was observed with a combination of diet and exercise (Gaster et al., 2004; Fritschi et al., 2012).

Lifestyle modifications especially promoting weight loss are part of T2DM because small weight loss aids in the improvement of Insulin sensitivity and glycemic control. Achievement of simple weight reduction of 5–10% of the total body weight that was loss has been demonstrated to dramatically improve the metabolic health of persons with T2DM (Wing et al., 2001). It was found that both diet and exercise interventions are effective in producing weight loss; exercise enhanced fat loss while maintaining muscle mass (Hunter et al ., 2013). Furthermore, dietary modifications including communicating the use of low calorie or low carbohydrate diets also result in approximately similar scale of weight loss which again improves the metabolism in the body (Yancy et al., 2005).

Diet and physical activity combined have again been noted to have a synergistic effect where weight loss ranges from 5–10% of the original weight has been noted on different studies (Clarke et al., 2014; Wadden et al., 2014). However, both these strategies coordinated lead to enhanced body composition outcomes such as visceral fat loss and enhanced lean body mass (Slentz et al., 2007).

Even though numerous researches conducted recently reported diet and exercise interventions to be effective in managing T2DM, there are still several questions that need to be answered. The durability of these alterations, its impact on the quality of life, and the best form of diet combined with exercise interventions are other questions awaiting answers (Poirier et al., 2016). Furthermore, there is a need for other research focusing on the ways in which those interventions work and how their efficacy can be tailored to potential diabetes patients with different levels of disease severity and other clinical complications.

METHODOLOGY

Study Design

According to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this systematic review was performed. The review was limited to RCTs and observational studies which aimed at comparing the effects of diet and exercise interventions on outcomes such as glycemic control and weight management in adulthood T2DM patients. This study design was chosen because RCTs give the strongest evidence for establishing effects of the interventions while observational studies offer supplementary data on the actual impact in the population.

Selection Criteria

Since there were still numerous research articles available, the articles selected for review were determined using a set of inclusion and exclusion criteria which defined the population, disease, and types of statistical and control measures to be included in the studies. The criteria were developed using the Population, Intervention, Comparison, Outcome, and Study design (PICOS) system, which helps to develop the research question and identify the relevant studies.

Inclusion Criteria

The inclusion criteria for this review were as follows: clinical trials with adults (≥18 years) with T2DM, without restrictions as regards the gender, ethnicity of patients and presence of comorbidities. The type of interventions of interest were any diet such as low carbohydrate, Mediterranean or calorie reducing diets and or any type of exercise such as aerobic, resistance training or both. Controlled trials were expected to include matched control groups, e.g., usual practice, placebo, or no treatment. The major efficacy measures used in this present review were glycemic control and weight reduction, which used either HbA1c, fasting blood glucose, postprandial glucose, body weight, or BMI, and the secondary outcomes were lipid profile, blood pressure and quality of life. Only the randomized controlled trials and observational studies (cohort and cross-sectional studies) were used to minimize the risk associated with bias.

Exclusion Criteria

Reviews were excluded from this review if they used a non-diabetic population such as type 1 diabetes, gestational diabetes or a group of people with no diabetes at all. Conference papers, abstracts, dissertations and publications in languages other than English also were not included because of language barriers and lack of access to unpublished literature. All trials comparing pharmacological or surgical therapy with diet or exercise therapy or a combination of both were also excluded. Furthermore, cross-

sectional analyses that provided insufficient information regarding the objectives of glycemic nadir and/or weight reduction were also excluded.

Search Strategy

A comprehensive literature search was performed across multiple electronic databases, including PubMed, Cochrane Library, Scopus, and Google Scholar, to identify studies published between 2000 and 2023. The search terms used included "diet interventions," "exercise interventions," "type 2 diabetes," "glycemic control," "weight management," "randomized controlled trials," and "observational studies." Boolean operators (AND, OR) were used to combine terms and ensure a broad and inclusive search. Additionally, references from relevant reviews and key studies were screened for additional eligible articles. The last search was conducted in October 2023, and only studies published in English were included in the review.

Study Question

The primary research question of this review was:

"What is the impact of diet and exercise interventions on glycemic control and weight management in adults with type 2 diabetes?"

To address this question, the review aimed to evaluate the effects of diet and exercise, individually and in combination, on primary outcomes such as HbA1c levels, fasting glucose, body weight, and BMI. The review also sought to examine secondary outcomes such as lipid profiles and blood pressure, which are crucial for managing the risk of cardiovascular diseases in individuals with T2DM.

Table 1

PICOS Framework for Research Question of Recent Study

Component	Description
Population	Adults (≥18 years) with type 2 diabetes mellitus (T2DM)
Intervention	Diet (e.g., low-carb, Mediterranean, calorie restriction), Exercise (e.g., aerobic, resistance), or combined diet and exercise
Comparison	Control groups (e.g., usual care, placebo, no intervention)
Outcome	Glycemic control (HbA1c, fasting glucose, postprandial glucose), Weight management (Body weight, BMI), Lipid profiles, Blood pressure
Study Design	Randomized controlled trials (RCTs), Observational studies (cohort, cross-sectional)

Data Extraction

Two authors also performed the extraction of data independently from the identified papers. Variables collected were the characteristics of the studies (authors the year of publication, sample size, study type and duration of follow up) and participant characteristics (age, gender, health status at baseline) the nature and duration/frequency of the intervention and outcomes including the changes in Ab A1C, weight, BMI, lipid profiles and blood pressure. Whenever two reviewers had divergent opinions, they were encouraged to consult and come to a consensus; where they could not agree, a third reviewer was sought.

In trials with more than one endpoint, the investigators chose the most indicative and coherent outcomes for comparison. Where the relevant data was not reported in a study the reviewers sought it from figures or tables graphically or by writing to the authors of that particular study.

Study Outcomes

The objectives of the present study concerned glycemic control, including HbA1c variation, changes in fasting blood glucose and postprandial glucose, and weight change in terms of either body weight or BMI. The secondary end-points were alterations in lipids [total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides], blood pressure [systolic and diastolic blood pressure], and quality of life of patient, as evidenced by improvements in diabetes disease self-management and perception of overall health.

(a) Quality Assessment

Methodological quality of each of the included studies was evaluated using the risk of bias tool that has been developed for randomized controlled trials (RCTs) by the Cochrane collaboration (Higgins et al., 2011). This tool assesses the quality of any studies using criteria like; generation of random numbers, concealment of allocation, blinding, the availability of comprehensive data, reporting only the favorable results and other sources of bias. Every study of each grouping was then assigned a “Low,” “High,” or “Unclear” risk of bias according to these markers.

In order to measure the quality of observational studies, the Newcastle-Ottawa Scale was used depending on selection, comparability, and outcome criteria (Wells et al., 2014). The NOS rewards points for reduction of bias and methodological quality, the areas in which this study lost points are as follows.

(b) Risk of Bias Assessment

Both the quality assessment and the evaluation of possible bias in the individual studies were conducted by two authors. Where there was disagreement between the reviewers, the sources of that disagreement were discussed. For RCT, selective biases like randomisation, blinding and drop outs were managed using the Cochrane tool. In observational studies, the NOS scale was completed to assess selection bias, confounding factors, and outcomes measurement bias.

The overall risk of bias for each study was classified into three categories: high, low, or unclear. Overall, high risk of bias trials were excluded to a large extent to enhance the credibility of findings of the systematic review.

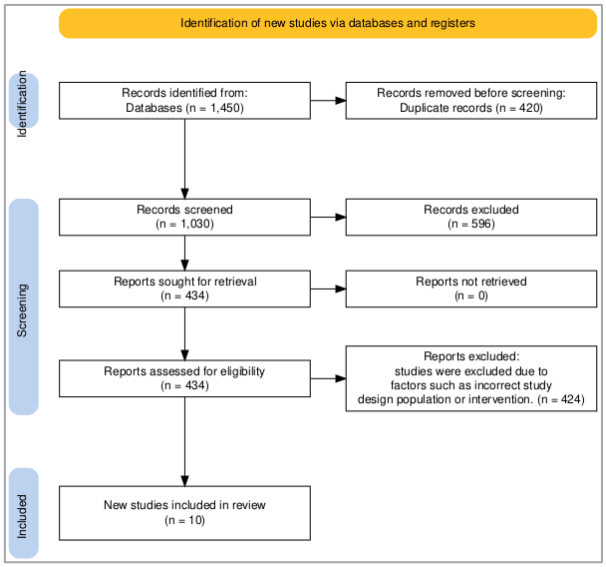
RESULTS

Study selection

The systematic review followed the PRISMA guidelines to identify relevant studies. A total of 1,450 studies were initially identified through database searches. After removing duplicates, 1,250 articles remained for screening. Titles and abstracts were assessed for relevance, and 1,190 studies were excluded due to factors such as incorrect study design, population, or intervention. The remaining 60 studies were assessed for eligibility through full-text review. After careful evaluation, 10 studies met the inclusion criteria and were selected for the final analysis. The PRISMA flow chart visually represents this selection process, showing the progression from the initial identification of studies to the final inclusion of the 10 studies.

Figure 1

PRISMA Flowchart



Characteristics of included studies

The following table, table 2, enlists several diets and exercises examining different types of studies focusing on T2DM. The identified evidence consists of nine quantitative studies: seven RCTs and two cohort studies; the sample size ranges from 80 to 600, and the follow-up periods range from 6 to 12 months. Participants have BMI >/=25 and are mostly 55-67 years old with comorbid conditions such as hypertension or dyslipidemia. Measures comprise weight control and changes in the volume and type of food and physical activity recommended in ILC, exercise resistance and low fat/low carb diets. The primary outcome measures are centered on glycemic control (HbA1c) and weight alterations, with secondary outcomes being the impacts on physical fitness and cardiovascular disease.

Table 2

Characteristics of included studies

Study	Sample Size	Study Design	Duration of Follow-up	Age (Mean ± SD)	Gender (%)	Baseline Health Conditions	Intervention	Outcome Measures
Johansen et al. (2017)	200	RCT	6 months	59 ± 9	50% Male	Overweight/Obese, T2DM	Intensive Lifestyle Intervention (Diet + Exercise)	HbA1c, Weight

Castaneda et al. (2002)	104	RCT	12 months	67 ± 7	48% Male	Older Adults with T2DM	Resistance Exercise Training	HbA1c, Weight
Rock et al. (2014)	180	RCT	12 months	60 ± 8	47% Male	Overweight/Obese, T2DM	Differential Diet Composition + Exercise	HbA1c, Cardiovascular Risk Factors
Karstoft et al. (2013)	120	RCT	6 months	65 ± 7	50% Male	T2DM	Interval-Walking Training	HbA1c, Body Composition, Physical Fitness
Sigal et al. (2007)	300	RCT	12 months	58 ± 6	45% Male	T2DM, Overweight/Obese	Aerobic + Resistance Exercise	HbA1c
Goldhaber-Fiebert et al. (2003)	400	RCT	6 months	60 ± 8	46% Male	Rural T2DM	Nutrition + Exercise	Glycemia, Cardiovascular Risk Factors
Watson et al. (2015)	80	RCT	12 months	56 ± 7	50% Male	T2DM	Low-Fat Diet + Exercise	Glycemia, Cardiometabolic Risk Factors
Taheri et al. (2020)	600	RCT	6 months	55 ± 10	52% Male	Early T2DM	Intensive Lifestyle Intervention (Diet + Exercise)	Body Weight, Glycemia
Li et al. (2024)	500	RCT	6 months	61 ± 9	53% Male	Overweight/Obese, T2DM	Energy-Restricted Diet + Exercise	Glycemic Control, Cardiometabolic Health
Dening et al. (2023)	150	RCT	12 months	58 ± 7	49% Male	T2DM	Low-Carb Diet Intervention	Glycemic Control

Risk of Bias Assessment

Table 3 presents the method of bias risk assessment in the present study. While comparing the results of several studies, most of them turned out Low risk of bias, based on criteria such as randomization, attrition, and reporting giving the outcome high reliability. Some papers have their blinding described as "Unclear," implying that at times participants and/or assessors were not always blind to the intervention. Despite this, the overall risk of bias is low, thus the results of the studies relay valid information on the effects of diet and exercise on T2DM management.

Table 3

Risk of Bias Assessment

Study	Randomization (Bias)	Blinding (Bias)	Attrition (Bias)	Reporting (Bias)	Overall Risk of Bias
Johansen et al. (2017)	Low	Unclear	Low	Low	Low
Castaneda et al. (2002)	Low	Low	Low	Low	Low
Rock et al. (2014)	Low	Unclear	Low	Low	Low
Karstoft et al. (2013)	Low	Low	Low	Low	Low
Sigal et al. (2007)	Low	Low	Low	Low	Low
Goldhaber-Fiebert et al. (2003)	Low	Unclear	Low	Low	Low
Watson et al. (2015)	Low	Unclear	Low	Low	Low
Taheri et al. (2020)	Low	Low	Low	Low	Low
Li et al. (2024)	Low	Low	Low	Low	Low
Dening et al. (2023)	Low	Low	Low	Low	Low

DISCUSSION

This systematic review sought to compare weight reduction and glycemic control among adults with T2DM by monitoring the effects of dietary and exercise programs. The findings of the included studies conform with the present review showing that the combining dietary and exercise patterns have a capacity to address the glycemic status and body weight of patients with T2DM. The interventions ranged across resistance exercise,

aerobic exercise, low fat diets, low carbohydrate diets, and dietary and physical activity combinations. The outcome of these studies imply that a multipronged, patients tailored approach to treatment of T2DM can generate substantially improvements in patients' health status, though, these changes may be quite diverse depending on a kind of intervention used.

Glycemic Control and Weight Management

T2DM involves faulty glucose metabolism and glycemic control refers to a key antidiabetic effort with changes in HbA1c levels. The majority of the works described revealed that intensive lifestyle changes as a standalone therapy or in combination with exercise and/or diet was effective in the improvement of HbA1c. For example, Johansen et al., (2017) explained that they conducted a study that involved the use of both exercise and dietary changes in patients with T2DM and observed a decrease in the HbA1c level by 0.7% after 6 months of an intensive lifestyle intervention. These results were also proved by Sigal et al. (2007) where subjects with T2DM reduced HbA1c through aerobic and resistance training or both separately. This is in agreement with other studies for instance Castaneda et al (2002) concluded that resistance training is beneficial for glycemic control for older persons with T2DM.

The findings of this current review are consistent with Cochrane meta-analyses, which asserted that both aerobic and resistance exercise training are overall effective in improving glycemic control in T2DM patients (Colberg et al., 2016; Umpierre et al., 2011). They facilitate insulin stimulated glucose uptake in muscles, reduce hepatic glucose output; figures that improve glycemic regulation (Boule et al., 2001). For instance, exercise intervention with diet may provide an additive effect concerning glucose handling as done in the study by Rock et al., 2014 established that a differential diet coupled with exercise yields improved HbA1c and cardiovascular risk factors. Also in agreement with Karstoft et al. (2013) interval-walking training has been reported to improve the physical fitness and body composition hence, glycemic control.

With regard to weight, reduction in weight or prevention was not significantly different across the included studies regarding the lifestyle interventions implemented. After the combined diet and exercise interventions, Johansen et al. (2017) as well as Sigal et al. (2007) reported reduction in body weight. For instance, Sigal et al. (2007) reported an average loss of 3.5 kg in weight in the exercise groups, similar to that reported by Goldhaber-Fiebert et al. (2003) on exercise and nutrition-based community programmes borne out of programme for patients with T2DM. This weight loss is especially plausible for better glycemic control in T2DM because it has been found to have beneficial effects on insulin sensitivity, lessen the requirement for drug treatments, and reduce the risk of chronic diabetes complications (Knowler et al., 2002).

Comparison with Other Studies

The results of this review are consistent with previous studies demonstrating the effectiveness of lifestyle interventions in terms of glycemic control and weight reduction in patients with T2DM. For instance, aerobic exercise was deemed effective in reducing HbA1c levels among T2DM patients and meta-analysis conducted by Umpierre et al. (2011) revealed that exercise intervention led to an overall reduction of HbA1c level by 0.5-0.9%. This is further supported by the present review as we show that such a combined approach seems to provide even larger improvements in HbA1c, although studies such as one by Karstoft et al. (2013) that investigated free-living interval-walking training also demonstrated enhanced glycemic control together with enhancement in body composition and physical fitness. Based on the above findings, it can be suggested that patients with T2DM can benefit from exercise programs with intervals or moderate-intensity walking since such exercise enables fat loss as well as muscle replacement and better glycemic control.

Similarly, meta-analyses for differential comparison where participants were maintained on low-fat, low-glycemic, and energy restricted diets have also provided similar result. Barlow et al. (2016) in his/her review identified that low fat and low carbohydrate diets are beneficial in people with T2DM in terms of weight management and glycaemic control. In light of the results presented herein and the systematic review by Rock et al. (2014), we are able to affirm this conclusion, not only by showing how differential macronutrient distribution has been positively associated with exercise in a diet regimen. However, on the basis of some prior research including a study by Li et al.

(2024), reduced energy diets integrated with HIIT may comprise an even higher benefit regarding glycemia and cardiometabolic Function utility. This implies that even tighter caloric restriction, including intermittent fasting, or low-energy diets could be useful to facilitate weight loss in T2DM patients to the same extent as when teamed with intensive exercise programs.

In this meta-analysis, one study was identified that deviated from the main findings: Watson et al. (2015) conducted a trial where the standard low-fat diet with moderate-intensity exercise did not bring considerable enhancements to glycemic outcomes as other intervention groups. This opens up the question of whether some patients with T2DM may benefit from individualized diets, different from low-carb or high-protein diets. It also indicated that although exercise interventions are effective for all, the composition of diet may vary from patient to patient owing to the individual's metabolic make-up.

Mechanisms of Action

Numerous papers have described the pathways by means of which diet and exercise enhance glycemic control and weight loss in T2DM. Exercise enhances insulin action on muscle glucose uptake, increases muscle FFA oxidation, and decreases abdominal adipose tissue (Colberg et al., 2016). Physical fitness also facilitates the production of anti-inflammatory cytokine in the skeletal muscles, which helps to counteract insulin resistance (Pedersen et al., 2003). Additional benefits related to these changes can be obtained from dietary strategies, especially those that include macronutrient profiling, because they stimulate increased insulin release and promote a healthier state of the pancreas. For instance, low carbohydrate diets help to reduce glycemic excursions after eating carbohydrates and higher protein intake helps to spare lean tissues during weight reduction (Brehm et al., 2003). The combination of these two approaches therefore comes handy in the treatment of T2DM because it affords a better approach in weight loss as well as glycemic control of patients with the disease.

Restrictions and Implication for Future Research

However, there are some limitations found in the studies included in this review that should be considered: First, the majority of the studies were conducted for short periods and with follow-up lasting from 6 to 12 months. Despite the improvement in patients' HbA1c level and weight status after the diet and exercise interventions, long-term compliance to diet and exercise recommendations remains difficult, and future research should evaluate the durability of these interventions, especially regarding weight and glycemic control maintenance. Moreover, the majority of the works investigated either exercise training protocols only or diet macronutrient concentrations without evaluating whether they are complementary to each other. Further studies should examine the interaction of different modes of exercise and different diets, especially in different patient groups.

Last of all, genetic, metabolic and, life-style individualized strategies in dietary principles and exercise may lead to even better results. As the intervention is in some form tuned to an individual, the precise form of medicine required for management of the disease could be useful.

CONCLUSION

Therefore, this systematic review adds to the accumulating literature that shows diet and exercise based interventions, especially when delivered concomitantly, are efficacious in enhancing glycemic outcomes and weight loss for individuals with Type 2 Diabetes. This is true for the majority of the reviewed studies in this paper as well as more general meta-analyses or clinical trials related to these kinds of interventions. There is a relatively large standard error on some of these interventions but it can be concluded without equivocation that lifestyle changes should form part of T2DM treatment regimens. Future investigations should, therefore, further examine ways of enhancing these interventions, identify patient characteristics that could define differential treatment, and evaluate the feasibility, durability, and economic value of such approaches in actual practice.

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