

Prevention of Type 2 Diabetes Mellitus: A Focus on Physical Activity and Lifestyle Changes

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ABSTRACT

Diabetes is a costly disease affecting 387 million individuals globally and 28 million in the United States. Its precursor, prediabetes, affects 316 and 86 million individuals globally and in the United States, respectively. People living with elevated blood glucose levels are at high risk for all-cause mortality and numerous cardiometabolic ailments. Fortunately, diabetes can be prevented or delayed by maintaining a healthy lifestyle and a healthy body weight. In this review, we summarize the literature around lifestyle diabetes prevention programs and provide recommendations for introducing prevention strategies in clinical practice. Overall, evidence supports the efficacy and effectiveness of lifestyle diabetes prevention interventions across clinical and community settings, delivery formats (eg, individual-, group-, or technology-based), and implementers (eg, clinicians, community members). **Evidence-based diabetes prevention strategies** that can be implemented in clinical practice include brief behavior change counseling, group-based education, community referrals, and health information technologies. These strategies represent opportunities where practitioners, communities, and health care systems can work together to provide individuals with education, support and opportunities to maintain healthy, diabetes-free lifestyles.

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The worldwide prevalence of type 2 diabetes mellitus is increasing at a rapid rate, predominantly because of changes in environmental factors interacting with individual genetic susceptibility to the disease. Data from 20 longitudinal cohort studies present a consistent picture indicating that regular physical activity substantially reduces risk of type 2 diabetes. Adjustment for differences in body mass index between active and inactive groups attenuates the magnitude of risk reduction, but even after adjustment, **a high level of physical activity is associated with a 20-30% reduction in diabetes risk.**

It is possible to prevent type 2 diabetes. Whether you have several of the risk factors or you've been told you have prediabetes, you can take action and reduce your risk of developing diabetes. Being overweight (BMI greater than 25 kg/m²) increases your risk of developing type 2 diabetes, so if you're overweight, you should take steps to lose weight. By losing 5% to 10% of your body weight, you can reduce your risk. You can do this by eating smaller portions and being more physically active, which, conveniently

enough, are two other ways to prevent type 2 diabetes. First, build your meals around vegetables rather than meat, and cut back on your starches. **Avoiding added sugar and sugar substitutes**, as well as processed grains. Instead, substitute with heart-healthy fats, high protein-whole grains (eg, pasta made from chickpea flour, quinoa, sprouted wheat bread), fruit to add sweetness even to salads or as a snack, and lean meats and dairy products. Seek out new, appetizing recipes; there are many cookbooks that offer lower-fat and healthier recipes. Aim for some daily physical activity. **Exercise is important to help prevent type 2 diabetes** and has so many other benefits. It can help you keep lost weight off, and improve your heart health, and if you're insulin resistant, it can help increase your body's response to insulin (exercise so you will have better blood glucose control. Drinking water throughout the day is always good to keep your organs and skin healthy. Of course, getting some fluid before, during and after exercise is just as important to avoid becoming dehydrated.

INTRODUCTION

Type 2 diabetes (T2D) incidence is increasing worldwide, driven by a rapidly changing environment and lifestyle and increasing rates of overweight and obesity. Prevention of diabetes is key and is most likely achieved through prevention of weight gain and/or successful long-term weight loss maintenance. Weight loss is readily achievable but there is considerable challenge in maintaining that weight loss over the long term. Lower-fat carbohydrate-based diets are widely used for T2D prevention. This is supported primarily by 3 successful long-term interventions, the US Diabetes Prevention Program, the Finnish Diabetes Prevention Study, and the Chinese Da Qing Study, but evidence is building in support of novel higher-protein (>20% of energy) diets for successful weight loss maintenance and prevention of T2D. **Higher-protein diets have the advantage** of having relatively low energy density, aiding longer-term appetite suppression, and preserving lean body mass, all central to successful weight loss and prevention of weight regain. Here, we review the carbohydrate-based intervention trials and present mechanistic evidence in support of increased dietary protein for weight loss maintenance and a possible novel role in prevention of dysglycemia and T2D.[1]

Components of lifestyle include exercise, nutrition, and sleep, the first two of which have gained

significant attention over the past three decades. Sleep research has also gathered recent research interest in T2DM prevention, though is beyond the scope of this review. Although selecting components for a lifestyle intervention varies across different T2DM programmes (single components such as structured or unstructured exercise, nutrition, unstructured or unsupervised education and counselling, or multicomponents), the timing of the intervention determines its component effectiveness. T2DM interventions can be classified into two timings or phases: a late phase (e.g., targeting T2DM risks such as prediabetes and obesity) or an early phase targeting the whole population (e.g., targeting all risk factors). Interventions with the early-phase interventions target all risk factors and engage multilevel stakeholders and policy makers (e.g., health, education, and sport authorities and nutrition providers). Late-phase interventions, which target sedentary, older, and postmenopausal individuals, and those with prediabetes with high cardiovascular disease (CVD) risk (elevated fasting blood glucose [FBG] and postprandial glucose [OGTT]), are likely to induce better effectiveness compared with those who are at reduced risk. Therefore, **personalised preventive measures are most effective** for those at high risk for T2DM in the late phase .[2]



Figure 1: Schematic of personalised Type 2 diabetes mellitus prevention based on the intervention phase.

Increases in type 2 diabetes have been observed in many other populations in the past half-century. For example, among the Pima Indians a 40% increase in the prevalence occurred between 1967 and 1977, primarily due to an increase in the incidence (the rate of development in new cases) of the disease. Incidence studies using standardised glucose tolerance tests have been performed in the Pima Indians of Arizona and among Micronesians in the central Pacific island of Nauru, populations with very high incidence rates. Among Pima Indians, the age-specific incidence and aged-adjusted incidence rates of diabetes have increased over the course of two decades whereas in Nauru, the incidence may now be falling.[3]

Promotion and evaluation of ‘healthy’ lifestyle programmes, which focus on the following aspects:

1. Prevention and early treatment of overweight and obesity, particularly in high risk groups;
2. Consumption of a nutrient-dense diet, which is low in fat, particularly saturated fat, and free sugars and high in NSPs.
3. An active lifestyle, which includes regular physical activity of at least 1 hr/day, and vigorous activity, which is required to reduce the risk of developing type 2 diabetes.
4. Moderate alcohol intake and cessation of cigarette smoking.

5. Demonstration projects in developing and developed countries since it is recognised that there is a paucity of data on the efficacy of community based lifestyle programmes.

DISCUSSION

Type 2 diabetes is not inevitable. Preventing and even reversing the onset of diabetes is entirely possible, but it takes commitment. Taking charge of your health involves a two-pronged approach: diet and exercise. Both are crucial for long-term success and optimal health. A major clinical study called the **Diabetes Prevention Program** studied people at risk for diabetes. It showed that lifestyle changes involving 150 minutes of exercise per week decreased the risk of progressing to type 2 diabetes by 58 percent. Cardiovascular health and diabetes are also intricately linked. Committing to a better diet and daily exercise promotes better blood sugar levels, blood lipid control, and mood. It also leads to higher energy levels, which makes it easier to exercise. Daily exercise helps keep blood vessels healthy, makes you feel better about yourself, and may aide in weight loss.

The aims of dietary treatment of diabetes are:

- To achieve optimal blood glucose concentrations.
- To achieve optimal blood lipid concentrations.
- To provide appropriate energy for reasonable weight, normal growth, and development, including during pregnancy and lactation.
- To prevent, delay, and treat diabetes-related complications.
- To improve health through balanced nutrition.[4]

The beneficial effect of the dietary pattern on diabetes mellitus and glucose metabolism in general and traditional food pattern was associated with a significant reduction in the risk of developing type-2 diabetes. The dietary pattern emphasizes a consumption of fat primarily from foods high in unsaturated fatty acids, and encourages daily consumption of fruits, vegetables, low fat dairy products and whole grains, low consumption of fish, poultry, tree nuts, legumes, very less consumption of red meat. Type-2 diabetics require insulin or oral hypoglycemic agents (medication that helps lower blood sugar), if diet and exercise alone fail to lower blood glucose.

Animal products contain fat, especially saturated fat, which is linked to heart disease, insulin resistance, and certain forms of cancer. These products also contain cholesterol and, of course, animal protein. It may surprise you to learn that diets high in animal protein can aggravate kidney problems and calcium losses. Animal products never provide fiber or healthful carbohydrates. A **vegan diet** is one that contains no animal products at all. Therefore, you'll have to avoid red meat, poultry, fish, dairy products, and eggs. The health benefits of a low-fat vegetarian diet such as portions of vegetables, grains, fruits, and legumes (excluding animal products) in people with type-2 diabetes. The vegan diet is based on **American Diabetes Association (ADA)** guidelines; the results of this study were astounding: Forty-three percent of the vegan group reduced their diabetes medications.

Limit alcohol to less than 2 drinks per day (1 drink = 12 oz beer = 1.5 oz liquor = 4 oz wine). Drink no more than four (4) cups of coffee or caffeine-containing beverages per day. Avoid adding sugar during cooking. use Splenda (sucralose) instead of sugar if baking or cooking, use low-fat and low sugar sauces and marinades, use reduced-fat cooking methods such as barbecuing, broiling, roasting, and steaming and **avoid frying and deep-fat frying**. Sugar substitutes and artificial sweeteners, low sugar jams/jellies/syrups, sugar-free candies, gelatins, gum, low-sugar and high fiber baked goods, and **low-fat and low-sugar frozen dessert**. **Exercise** decreases total cholesterol, improves the ratio of low-density lipoprotein (LDL) to high-density lipoprotein cholesterol (HDL), and reduces blood triglycerides. It may also decrease blood pressure and lower stress levels. **Walking is one of the easiest and healthiest ways to exercise**. This is one activity that anyone can do for a lifetime without special equipment and with little risk of injury.[5]

RESULTS

Research shows that CDC-recognized lifestyle change program participants who lost 5-7% of their body weight and added 150 minutes of exercise per week **cut their risk of developing type 2 diabetes by up to 58%** (71% for people over 60 years old).

Even a decade later, program participants were **one-third less likely** to develop type 2 diabetes than individuals who did not join a program.

The program can also lower your risk of having a heart attack or stroke, improve your health, help you feel more energetic, and even reverse your prediabetes diagnosis.[6]

It is clear that there is a worldwide epidemic of diabetes that is associated with changes in lifestyle, increased longevity and development of obesity. The metabolic syndrome and IGT (Impaired Glucose Tolerance) are more prevalent than diabetes and are high-risk conditions for the development of both type 2 diabetes and CVD (Cardio Vascular Disease). There are now several randomized controlled trials that have demonstrated that lifestyle modifications focusing on dietary modification, weight loss and increased physical activity are effective in reducing the progression from IGT to type 2 diabetes and in reducing several CVD risk factors. However, the effectiveness of lifestyle modification programs to reduce CVD events has not yet been adequately determined. A major challenge is to successfully implement lifestyle modification programs into clinical practice. Although short-term results are encouraging, long-term outcomes are still uncertain. However, current evidence strongly suggests that increased physical activity and weight control should be the cornerstones of diabetes and CVD prevention strategies.

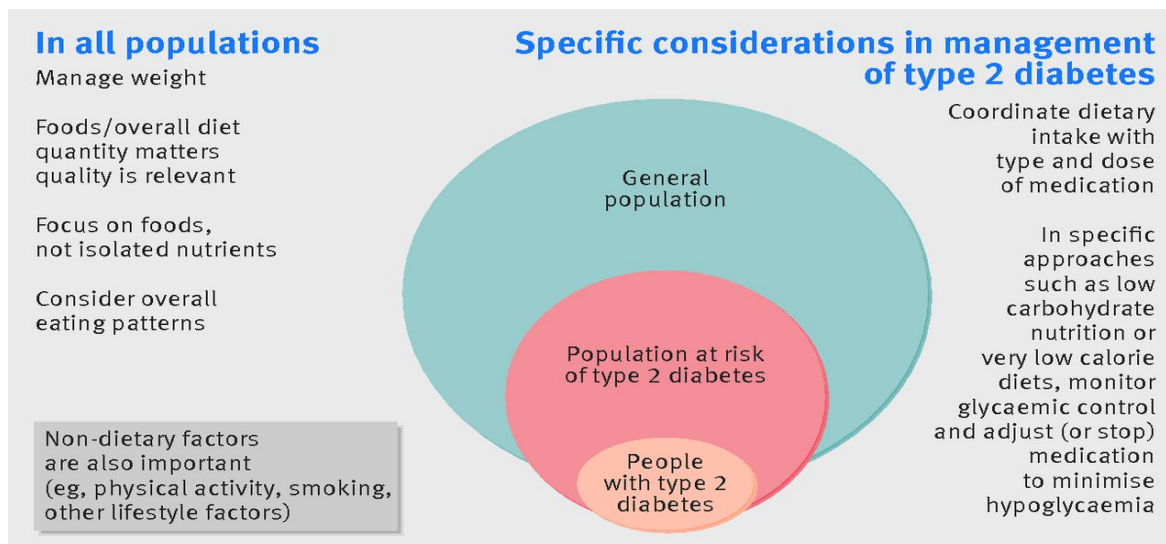


Fig.2: Dietary and nutritional approaches for prevention and management of type 2 diabetes

Preventing T2DM relies primarily on changing lifestyle behavioural components, especially physical activity and nutrition. A personalised behavioural approach can support both early- and late-phase interventions, targeted physical activity, and nutritional guidelines for specific high-risk populations for different settings and risk factors. Quantifying the exercise components within large-scale interventions can inform how much intensity, volume, and mode is required to maximise T2DM risk reduction benefits. The recent high intensity exercise recommendations for T2DM require more personalisation, especially given the concerns about their scalability and long-term adherence. **Mobile technology advances offer objective assessment**, intervention exercise, nutrition, and counselling tools which can target high-risk individuals, especially when integrated with other direct medical approaches and targeted at different settings such as workplaces. **Personalising lifestyle behaviours** offers a holistic understanding which could enhance T2DM prevention guidelines.[7]

Diabetes and CVD share multiple modifiable lifestyle risk factors, such as obesity and physical inactivity, that tend to comingle for many adults, adding to the threat of severe adverse effects already present from a genetic predisposition and other acquired risk factors. In the United States, diabetes affects at least 29.1 million individuals, the equivalent of 9.3% of the entire population and 12.3% of the adult population. Depending on the cohort surveyed and the definition used, another 5.4 million are estimated to have undiagnosed diabetes.

The goals in caring for patients with diabetes mellitus are to eliminate symptoms and to prevent, or at least slow, the development of complications. Microvascular (ie, eye and kidney disease) risk reduction is accomplished through control of glycemia and blood pressure; macrovascular (ie, coronary, cerebrovascular, peripheral vascular) risk reduction, through control of lipids and hypertension, smoking cessation, and aspirin therapy; and metabolic and neurologic risk reduction, through control of glycemia.[8]

Diabetes-related care accounts for more than \$1 of every \$5 spent on healthcare in the United States, equating to \$245 billion in total costs in 2012. Not surprisingly, average medical expenses are more than twice as high for a person with diabetes as they are for a person without diabetes.

Although **drug therapy** may be required to control metabolic risk factors, particularly when they arise from genetic aberration and aging, modification of life habits remains at the heart of the public health strategy for prevention of CVD and diabetes. Research has repeatedly demonstrated the benefits of lifestyle

interventions, including **engaging in physical activity, adopting healthier eating practices, managing stress, and using social-environmental support to initiate and sustain health-related behaviors.**[9]

Table: Detailed recommendations for type 2 diabetes cases

Micronutrient	Metabolic function	Supplementation effectiveness	Related recommendation for T2DM prevention
Vitamin B group	Involved in the synthesis of methionine, pyrimidine, and purine bases. Its deficiency due to DNA damage or faulty repair is involved in cancer, vascular diseases, and some birth defects, while a consequent hyperhomocysteinemia is also related to folic acid deficiency. They are also a risk factor for hypertension and atherosclerosis. ¹⁷	Folic acid, pyridoxine, and B12 or placebo produced no difference in T2DM incidence following 7-year supplementation in women with or without cardiovascular disease risk factors. ²⁴	Supplementation is not necessary. Dietary intake from dietary sources (e.g., green leafy vegetables) is recommended.
Vitamin C	Inversely correlated to glycosylated haemoglobin and fasting and postprandial blood glucose and oxidative stress. ¹⁷ Acts as a potent antioxidant, in collagen, neuropeptide, and carnitine synthesis, increasing iron absorption, inhibiting histamine release, and stimulating the immune system. ^{17,21}	Associated with antioxidative enzymes in T2DM patients. ²¹ 3-month supplementation of vitamins C and E decreased hypertension and blood glucose while increasing superoxide dismutase and glutathione levels. ²²	Supplementation when oxidative stress is high is useful, and in the short term in reducing cardiovascular disease risk, particularly hypertension in individuals with T2DM.
Vitamin D	Can improve insulin sensitivity and promote pancreatic β -cell survival by modulating the effects of cytokines and nuclear transcription factors such as NF- κ B. ¹⁷	A 24-month vitamin D supplementation (a dose of 4,000 IU/day) in 2,423 adults with obesity and prediabetes (criteria of: HbA1c 5.7–6.4%; FPG 100–125 mg/dL; 2h-OGTT 140–199 mg/dL) did not reduce T2DM incidence. ¹⁹	Supplementation may be effective in those with prior vitamin D deficiency.
Mg ²⁺	Regulates electrical activity and insulin secretion in pancreatic β cells. Intracellular Mg ²⁺ helps the phosphorylation of the insulin receptor and other downstream signal kinases of the target cells. Low Mg ²⁺ levels result in defective tyrosine kinase activity, postreceptor impairment in insulin action, and altered cellular glucose transport and utilisation, which promotes peripheral insulin resistance in T2DM. ²²	Cross-sectional associations showed Mg ²⁺ levels correlated negatively with fasting insulin levels, and positively with the lipid profile. There is a 20% T2DM risk reduction for each 1 mg/dL increase of circulating Mg ²⁺ in those with hypomagnesaemia <0.5 mM (healthy circulatory threshold is 1 mM). ²⁴	Mg ²⁺ supplementation could ameliorate insulin sensitivity, reducing the risk of developing T2DM in those with hypomagnesaemia.
Multivitamins and minerals	Can enhance antioxidative capacity in T2DM patients. ^{17,23}	Has been shown to reduce the incidence of infections in T2DM patients with subclinical micronutrient deficiency in older adults. ²³	Supplementation may be effective in advanced states and in older T2DM adults.

Several advances in diabetes management over the past few decades have improved the health of many patients and should not be understated. However, these advances are beneficial only to the extent that patients use them appropriately. To do so requires knowledge, problem-solving skills, motivation, environmental support and effective coping skills for life's many stressors. Additionally, due to these behavioral challenges of daily diabetes self-management and despite the technological advances in diabetes care, patients have limited resources, perhaps even limited free will, in their management decisions. Despite this, research still shows that **individual behavior can be shaped and behavioral interventions can help** patients make better choices

for their own diabetes self-management, even in the context of difficult circumstances.[10]

Diabetes self-management is central to diabetes care overall, and much of this entails individual behavior change, particularly around dietary patterns and physical activity. Published recommendations for the treatment of people with diabetes assert the importance of diet, exercise, and education to diabetes treatment. Nutrition is key in the management of diabetes and CVD risk prevention. Current recommendations for patients with diabetes center around a dietary pattern that emphasizes fruits, vegetables, reduced saturated fat, and low-fat dairy products, as well as modification of macronutrient

intake to accommodate individual needs for the distribution of calories and carbohydrates throughout the day. The Dietary Approaches to Stop Hypertension, Mediterranean, low-fat, and monitored carbohydrate diets are effective for controlling hyperglycemia and lowering CVD risk factors. **The Prevención con Dieta Mediterránea (PREDIMED) trial** was a randomized trial that found a 30% reduced risk of CVD events in diabetic patients randomized to the Mediterranean diet, suggesting that this diet may promote CVD risk reduction in this population.[11]

Dietary content heavily impacts the development of diabetes. In the Adventist Health Studies, the prevalence of diabetes was lower in vegetarians than in nonvegetarians, an effect likely mediated by the lower body weights of the vegetarians. And when compared with a standard American diet, the prevalence of diabetes was reduced by **23% with a semi-vegetarian diet, 38% by consuming a pescovegetarian diet, 55% with a lacto-ovo-vegetarian diet, and 75% with a vegan diet.** Dietary interventions with a whole foods plant-based nutrition (vegan diet) have even been shown, through a small randomized trial, to reduce the pain levels in diabetic neuropathy. Similarly, foods with a lower glycemic index have been associated with a lower risk of diabetes development in the Nurses Health Studies. In contrast, the Health Professionals Follow-up Study indicated that eating processed meats increases the risk of developing diabetes.[12]

More recently, several trials have shown surprising outcomes for a commonly consumed food: eggs. One of the larger of these analyses of 14 studies found that for those who consumed the most eggs, there were 19% and 68% increased risks for developing CVD and diabetes, respectively, compared with those who ate the fewest eggs. Further, for those who already had diabetes, the risk for developing heart disease from eating the most eggs jumped to 83%. The authors concluded, **“There is a dose-response positive association between egg consumption and the risk of CVD and diabetes.”**[13]

Research has also demonstrated the benefits of meditation, both mindfulness and transcendental, for diabetes management. A randomized trial published in JAMA found that meditation reduced blood pressure, increased insulin resistance, and significantly reduced the rates of CVD events.

Multiple epidemiological studies suggest that both **obesity and physical inactivity are independent risk factors for diabetes**, and the reduction or elimination of such factors appears to be related to prevention and management of this disease. Further, physical activity and weight loss improve blood

pressure and lipid levels, thereby positively affecting other CVD risk factors. This robust and consistent observational evidence has given rise to large-scale randomized controlled trials that have used lifestyle intervention (including behavioral strategies for reinforcement of prescribed changes in nutritional intake, physical activity, or both) in populations at high risk of developing diabetes. The aim of these trials was to reduce the rate of incident diabetes and ameliorate risk factor profiles associated with both diabetes and cardiovascular morbidity and mortality. For instance, the Diabetes Prevention Study and the Diabetes Prevention Program demonstrated that dietary improvement and increased physical activity reduced the incidence of diabetes by nearly 60% in 4 years. **The Da Qing study later compared diet, exercise, and diet plus exercise with a no-treatment control group** and found that all 3 lifestyle approaches reduced the risk of developing diabetes by 31% to 46%. Later, the Finnish Diabetes Prevention Study demonstrated similar results in over 500 overweight subjects with impaired glucose tolerance—lifestyle intervention designed to produce weight loss improved dietary intake and physical activity and reduced the risk of diabetes by 58%.

More recently, the **Look AHEAD (Action for Health in Diabetes) study**, conducted from 2001 to 2012, provided extensive longitudinal data on the effect of an intensive lifestyle intervention—targeting weight reduction through caloric restriction and increased physical activity—on CVD rates and risk factors among adults with diabetes.²⁶ Published in 2013, the primary results of Look AHEAD showed that greater weight loss was observed in the intervention arm (8.6%) compared with the usual care arm (0.7%). Additionally, patients in the intervention group had improved physical fitness and high-density lipoprotein (HDL) cholesterol levels, greater reductions in glycated hemoglobin (A1C) and waist circumference, and required less pharmacotherapy for glucose, blood pressure, and lipid control. Although the trial was stopped early due to futility (possibly from discontinuation of cardioprotective drugs, such as statins), the results inform clinicians that increased physical activity and improvements in diet can safely lead to weight loss and a reduced requirement for medications to control CVD risk factors without a concomitant increase in the risk of cardiovascular events.

The **Italian Diabetes and Exercise Study (IDES)** was another randomized trial designed to examine the effects of an intensive exercise intervention strategy on modifiable CVD risk factors in diabetics. The subjects were randomized to an exercise group or

control group (structured individualized counseling alone) for 12 months. Compared with the control group, supervised exercise produced significant improvements in physical fitness, A1C, systolic and diastolic blood pressures, HDL- and low-density lipoprotein cholesterol levels, waist circumference, body mass index, insulin resistance, inflammation, and coronary heart disease (CHD) risk scores.

The multicomponent interventions targeting emotional, social, or family processes that facilitate diabetes management are more potent than interventions that target a single direct behavioral process. Identifying active ingredients and determining the necessary doses of those ingredients would allow both clinicians and patients to focus resources on the most important areas of an intervention. How can we maintain lasting behavioral changes once they have been initiated. Results from many weight loss interventions highlight the need for more consideration of behavior maintenance strategies. Lastly, how can we effectively disseminate interventions to the larger diabetic population. Even the most effective interventions are useful only to the point that patients have access to them. **The internet, telemedicine, peers and community health workers, and mobile electronic devices all hold promise in this regard.**

The magnitude of the behavioral diabetes research agenda is impressive, although much work is still needed to determine the optimal approach to diabetes management. Until then, the lifestyle interventions discussed give patients the behavioral technology they need to more effectively navigate their world with diabetes. They also give healthcare providers greater ability to inform and support their patients with diabetes. **Encouraging patients to self-manage their disease**, as well as engaging all stakeholders in the necessary behavioral changes, can positively influence the long-term treatment outcomes of patients with diabetes.[14]

Finally, educating physicians and allied health professionals on the power of lifestyle changes through diet, exercise and physical activity, and mindfulness is a critically underestimated and underfunded approach. Because of minimal nutrition training in medical school and the lack of exposure to lifestyle medicine, many healthcare providers do not counsel, implement, or coach patients to make these changes. Recently, the **American College of Cardiology** hosted a half-day intensive within its 2016 Annual Scientific Sessions that solely focused on lifestyle modification. Education from leading experts in the realm of lifestyle and nutrition was delivered with an incredibly positive response to a

standing room-only audience. The intensive session started with a debate about commonly held nutrition misconceptions and was followed by sessions on the latest in **behavioral modification and motivational interviewing, smoking cessation, and scientific evidence around the topics of mindfulness, stress reduction, love, and connection.** Overall comments from the audience showed a true desire to learn more about these topics and ways to implement them in common practice.[15]

In summary, treatment for diabetes and the associated CVD has come a very long way. **Behavioral intervention, in the form of lifestyle medicine**, is an approach that both minimizes cost and maximizes yield in dealing with both. Now is the time for the medical community, as a whole, to become aware of this approach and review the research that has often been ignored despite excellent results. While implementation is the major barrier, along with patient compliance and uptake, the time and effort required leads to lasting results that are well worth the initial investment.

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