

EXERCISE AND TYPE 2 DIABETES: A REVIEW ON EXERCISE RECOMMENDATION, MECHANISM OF ACTION, EXERCISE-RELATED RISK AND INNOVATIVE EXERCISE APPROACH

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Abstract

Diabetes mellitus or high blood glucose level is one of the non-communicable chronic diseases and complex illnesses that require thorough medical care with multidisciplinary approaches beyond blood sugar level control. Diabetes is defined as a disorder of carbohydrate metabolism due to disturbances in production or utilization of insulin (or both), resulting in high blood glucose levels and loss of sugar in the urine. There are two categories of diabetes which are type 1 and type 2, with most cases of diabetes being type 2. In Malaysia, overall diabetes cases among adults aged 18 years old have grown up to 17.5% in 2015 which is about 3.5 million adults living with this condition. There are a variety of measures diabetic patients can take to control the condition. Engaging in exercise is one of the effective non-pharmacological approaches to manage and/or prevent diabetes. The exercise recommendation for type 2 diabetes patients is well explained and discussed in this review. The mechanism of exercise in lowering blood glucose levels is also described thoroughly. Besides, this review also briefly highlights the exercise-related risk and innovative exercise approaches for diabetic populations.

Keyword: Exercise, Exercise-related risk, Innovative exercise approach, Type 2 diabetes mellitus

Introduction

Diabetes Mellitus or also called diabetes, is a chronic and complex illness that requires comprehensive and continuous medical care with multidisciplinary approaches and strategies beyond blood sugar control (American Diabetes Association, 2019). Diabetes is defined as disorder of carbohydrate metabolism due to disturbances in production or utilization of insulin (or both) and results in a high level of glucose in blood and loss of sugar in the urine (Okur et al., 2017). According to World Health Organization (WHO) (2019), diabetes is described as one of the metabolic disorders characterized by a higher level of sugar in blood or hyperglycemia in the absence of treatment. In 2014, more than four hundred million adults worldwide were diagnosed with diabetes, compared to only about one hundred million adults in 1980. From the number, the global incidence of diabetes is tripled since 1980. This is also closely related with the increase of associated risk factors which are overweight and obesity. Diabetes is also one of the causes of global burden because it leads to a higher number of deaths annually. In 2012, diabetes led to 1.5 million deaths worldwide, plus an additional of 2.2 million deaths by increasing the risk of cardiovascular and other diseases (WHO, 2016). This is because diabetes causes many complications throughout the human body and

increases fatality. Several possible complications are stroke, heart attack, kidney failure, neuropathy, vision loss, and paresthesia (Khardori, 2020).

Diabetes can be categorized into two main types, which are type 1 (insulin dependent diabetes mellitus) and type 2 (non-insulin dependent diabetes mellitus, where insulin is not properly used by own body) (Colberg et al., 2016; Okur et al., 2017). Most of the diabetes cases are type 2 diabetes commonly found among adults, with present incidence also found among children (WHO, 2019).

As the prevalence of this disease is on the rise, proactive and comprehensive approaches need to be taken to manage and prevent diabetes from deteriorating and spiking in number. Non-pharmacological approaches in managing and preventing diabetes include eating a low-sugar diet, not smoking, abstaining from alcohol, and most importantly, engaging in physical activity. This article will focus more on exercise recommendations that can help in managing and/or preventing the occurrence of type 2 diabetes mellitus. In addition, the detailed physiology on how exercise helps manage and control the blood glucose level at a cellular level will be further explained. Other than that, exercise-related risk while performing exercise and innovative exercise approaches also will be further reviewed and discussed.

Discussion

Exercise Recommendation for Diabetes

Regular engagement in physical activity or exercise has been generally known to help in improving blood glucose level control by enhancing insulin sensitivity (Kumar et al., 2018). According to Kumar et al. (2018), participation in structured exercise is effective in the management of type 2 diabetes. This is further supported by Mendes et al. (2016) as they summarize that any exercise prescribed to diabetes patients should include detailed and specific information regarding Frequency, Intensity, Time, Type (FITT) and must be tailored individually based on their current limitation and co-morbidities.

According to Chiang et al. (2019), diabetes type 2 patients benefit from prescribed aerobic exercises. In the study, the subjects needed to perform treadmill running 3 times per week and should achieve 150 minutes per week. Intensity for the exercise was set at a moderate intensity which is 70% heart rate reserve. After 12 weeks of exercise, the value of blood glucose was significantly lower than those not involved in the exercise. Besides, they also concluded that 12 weeks of moderate-intensity exercise improves post-exercise blood glucose and induces blood glucose response. Not even that, aerobic exercise is also highly recommended for type 2 diabetes patients because it acts as a powerful stimulant of mitochondrial respiration as well as Adenosine Triphosphate (ATP), which further enhances insulin sensitivity (Rueggsegger et al., 2018)

Another study from Pan et al. (2018) found that a combination of exercises which are aerobic exercise and supervised resistance exercise gives a more remarkable impact in the improvement of haemoglobin A1c (HbA1c) in diabetes patients compared to aerobic exercise or resistance exercise alone. HbA1c is the average level of blood glucose over the past three months. Although there is pronounced improvement in HbA1c by the combination of exercise, the decrement of cardiovascular risk factors is less significant.

Stretching is one of the important components for exercise for diabetes to increase flexibility and range of motion, although evidence shows it has no effect on glycemic control level (Herriot et al., 2004). Optimal flexibility and range of motion exercise help individuals perform aerobic and strengthening exercises without limitation and reduce the risk of exercise-related injuries. Additionally, balance training should be recommended for diabetic patients because it helps reduce the risk of falling by improving the patient's gait and stability or balance, as well as for patients with peripheral neuropathy (Morrison et al., 2010).

Following the American College of Sports Medicine (ACSM) (2018), aerobic exercise, strengthening, and flexibility exercise are recommended for diabetic patients. Physical activity or exercise for diabetes patients without any remarkable limitation and complications is crucial to maintain and enhance cardiorespiratory fitness, normal body composition, and increase muscular strength and endurance. The detail of FITT recommendations for type 2 diabetes patients can be referred in **Table 1**.

Table 1 Exercise components (FITT) recommendations for individuals with diabetes (ACSM, 2018)

	Aerobic	Resistance	Flexibility
Frequency	3 to 7 days per week	A minimum of 2 nonconsecutive days per week, but preferably 3 days per week	2 or more than 2 to 3 days per week
Intensity	Moderate (40%-59% VO ₂ R or RPE of 11 to 12) to vigorous (60%-89% VO ₂ R or RPE of 14 to 17)	Moderate (50%-69% of 1RM) to vigorous (70%-85% of 1RM)	Stretch to the point of tightness or slight discomfort
Time	T1DM: 150 minutes per week at moderate intensity, or 75 minutes per week at vigorous intensity or combination. T2DM: 150 minutes per week at moderate-to-vigorous intensity	At least 8-10 exercises with 1-3 sets of 10-15 repetitions to near fatigue per set. Gradually progress to heavier weights using 1-3 sets of 8-10 repetitions.	Hold static stretch for 10-30 seconds, 2-4 repetitions of each exercise.
Type	Prolonged, rhythmic activities using large muscle groups. For example, walking, cycling, and swimming.	Resistance machines and free weights	Static, dynamic, and/or PNF stretching

RPE=Rating Perceive Exertion; T1DM= Type 1 Diabetes Mellitus; T2DM= Type 2 Diabetes Mellitus; 1RM= 1 Repetition Maximum; PNF= Proprioceptive Neuromuscular Facilitation, VO₂R= Oxygen Consumption.

Moreover, another exercise recommended for diabetes patients is high-intensity interval training (HIIT). HIIT is one of the interval trainings that is characterized by short, intermittent bouts of vigorous intensity and alternated or interspersed by low-intensity exercise. Jelleyman et al. (2015) show that continuous training of HIIT promotes improvement in body metabolism in terms of insulin resistance and maximal oxygen consumption (VO_{2max}) in their study.

Next, another form of HIIT, which is REHIT is proven to have positive effects on type 2 diabetes patients. REHIT stands for reduced-exertion high-intensity training. According to Metcalfe et al. (2018) and Francois and Little (2015), REHIT requires minimal time exercise option and significantly promotes better 24-hour glycaemic control in diabetes patients. Not even that, interval walking training also shows good effects on diabetes patients as they show improvement in physical fitness, good blood glucose control, and body composition (Karstoff

et al., 2013).

Mechanism of Exercise in Improving Diabetes

The mechanism involved in diabetes patients is more towards insulin action. Insulin action that works in the liver and muscle can be further altered by engaging in exercise and consistent physical activity (Roberts et al., 2013). For acute aerobic exercise bout, glucose uptake by muscle can be elevated up to 5-fold via an insulin-independent mechanism. It remains high after the exercise session for about 2 hours by insulin-independent and up to 48 hours by insulin-dependent (Bird & Hawley, 2017). According to the same study, the increment of glucose uptake by skeletal muscle is due to the movement action of insulin-responding glucose transporter (GLUT4) from intracellular to sarcolemma and T tubules, thus enhancing the sites for glucose uptake by muscle. As more glucose uptake by muscle, blood glucose levels will slowly reduce.

Besides that, regular exercise training has been proven to increase the level of GLUT4 concentrations among type 2 diabetes and metabolic syndrome patients, which further has a positive impact as it promotes changes in insulin sensitivity (Mann et al., 2014). Moreover, another insulin signaling protein affected by aerobic exercise is insulin receptor substrate 1 (IRS-1). The function of IRS-1 is to enhance phosphorylation or activation of protein kinase B (also known as Akt), and it is activated by insulin receptor tyrosine kinase, thus it will promote uptake of glucose into cells (Guo, 2014). Then, as more IRS-1 gets activated following exercise, insulin sensitivity among type 2 diabetes also improves (de Matos et al., 2014).

In addition, insulin sensitivity improves in type 2 diabetes patients after aerobic training due to an increase in angiogenesis around the skeletal muscle (Walton et al., 2015). Angiogenesis refers to the formation of new blood vessels, which facilitates increased glucose uptake in skeletal muscle. Furthermore, aerobic exercise also improved diabetes by stimulating glycogen synthase activity (Ryan et al., 2014). Glycogen synthase activity is an enzyme that will enhance glycogenesis and reduce glucose levels in the blood, thus resulting in improved insulin sensitivity.

Next, aerobic exercise also improves insulin action by increasing the action of mitochondrial respiration and ATP production. According to Konopka et al. (2015), increased action of mitochondrial respiration and ATP production are due to improvement of cellular redox status. Last but not least, another underlying mechanism that can improve insulin sensitivity among diabetes patients are changes in muscle lipid metabolism and muscle fiber, increase oxidative mitochondria as well as decrement of vascular obesity (Roberts et al., 2013).

Exercise-Related Risk for Diabetes Patients

Hypoglycemia or exercise-induced hypoglycemia is the most common implication and fear in individuals with diabetes who are taking any insulin or insulin secretagogues (Colberg et al., 2016) such as Sulfonylureas and Meglitinides. Hypoglycemia is characterized by reduction of blood glucose concentration that may stimulate the sympathetic nervous system and altered mental status. In order to reduce or prevent exercise-induced hypoglycemia, several strategies can be done. One of the easiest and most effective ways is to have an adequate or extra amount of carbohydrate consumption before, during, and immediately following exercise prescription (Francescato et al., 2015). Besides, for diabetes patients who were taking preprandial bolus insulin, the doses of the insulin need to be reduced if they were involved in exercise programmed (Franc et al., 2015). Preprandial bolus insulin is the insulin taken before lunch or dinner meal and it is characterized by rapid acting or short acting insulin. In addition, another strategy that can be done in managing hypoglycemia is by performing ten seconds briefs, intermittent and vigorous intensity sprinting at the beginning or end of the

moderate-intensity exercise (Guelfi et al., 2007).

The second most implication for diabetes to perform exercise is hyperglycemia. It is characterized by the increased level of blood glucose. Elevated blood glucose among type 2 diabetes should not stop them from exercising if they are physically well. If the recorded blood glucose is more than 16.7 mmol/L, it is important to monitor signs and symptoms for dehydration and make sure adequate amount of water consumption for hydration especially exercising in the heat (for example, hot weather and thick cloth while exercising) (Sigal et al., 2018).

In relation to heat, another limitation of exercise among diabetes patients is heat-related illness. According to Carter et al. (2014), individuals who suffer from diabetes have an impaired capacity to lose heat and further spike up their core body temperature while exercising, especially during the hot day. This happens due to poor sweating mechanism and skin blood flow. It is possible to perform the indoor exercise with a cool and well-ventilated space to minimize or prevent heat stress while exercising in individuals with diabetes. Patients must make sure they are well hydrated so the body can naturally cool down through sweating and restrain the blood glucose level from fluctuating (Kenny et al., 2016).

As stated earlier, diabetes is one of the strong predictors for cardiovascular, metabolic, and renal risk and other complications such as neuropathy. If someone with diabetes performs the exercise, they may develop cardiovascular events like heart attack, which is another limitation to exercise among diabetes patients. Hence, before engaging in exercising vigorously, medical clearance is required, especially for those with a sedentary (inactive) lifestyle before (Sigal et al., 2018). Diabetic individuals with severe neuropathy can also experience a limitation in exercise as it can further worsen the condition. Despite that, moderate weight bearing exercise can be safely performed in individuals with peripheral neuropathy, but without foot ulcer condition (Streckmann et al., 2014).

Innovative Exercise Approaches for Diabetes Populations

Encouragement for diabetes populations to engage in exercise is important. Some innovations need to be taken to make sure exercise performed by them work effectively and safely. According to Li et al. (2018), not only the FITT of exercise is important, timing of exercise also matters as they conclude that post-dinner exercise helps type 2 diabetes patients in improving postprandial high blood glucose and glycemic fluctuations. Twenty-minutes-moderate intensity treadmill walking post-dinner improves the diabetes condition without any consequences or risk of hypoglycemia.

Moreover, Savikj et al. (2018) also reveal that the timing of exercise is important as afternoon HIIT is more effective in improving blood glucose levels among type 2 diabetes compared to morning HIIT. This is due to the circadian clock or rhythm of the human body. The circadian clock acts as a homeostatic regulator that controls cell genomics and their physiological responses (Gabriel & Zierath, 2017).

Besides that, a supervised exercise program prescribed to patients is one of the innovative exercise approaches. A systematic review by Umpierre et al. (2011) found that supervised programs of aerobic and resistance exercise among type 2 diabetes adults show improvement in glycemic control with or without diet intervention. Another report from Balducci et al. (2010) also emphasizes that supervised exercise training definitely leads to better results such as substantial reduction in A1c, blood pressure, waist circumference, improved aerobic fitness, and increased high-density lipoprotein (HDL) cholesterol level.

Other than that, in order to promote the engagement of patients in exercise, some motivational and behavioral change interventions or strategies can be highlighted (Sigal et al., 2018). In managing type 2 diabetes patients, few pieces of evidence propose that goal setting, detailed information about exercise, and self-monitoring by using pedometer, for example,

manifest some success in increasing engagement in exercise and improving blood glucose level (Brown et al., 2016).

Last but not least, another adjunct strategy that promotes exercise engagement is using technology. Although it is not an exercise approach, technology-based such as gadgets may help adults with diabetes. For example, the promotion of internet-delivered exercise can be more successful than usual care (Colberg et al., 2016).

Conclusion

Diabetes management is sophisticated, and one option that helps manage blood glucose levels among diabetes patients is being active and doing exercise. Physical activity and exercise should be commended and prescribed to all diabetes patients as an important management for glycemic control and to improve their overall health. In order to encourage diabetes patients' engagement in certain exercises, some recommendations, and extra precautions need to be taken. Recommendations that need to be taken will vary according to the type of diabetes, age-specific, details of the exercise, and other complications of diabetes. Exercise should be tailored to meet the need of individuals. In a nutshell, it is always important to have regular physical activity and exercise for good maintenance of diabetes condition along a lifetime.

Conflict of interests

The author declares no conflict of interest.

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