

---

# Exercise and Diabetes Mellitus

---

Asmare Yitayeh Gelaw

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.71392>

---

## Abstract

In the past 20 years, the magnitude of diabetes has increased dramatically in many parts of the world and the disease is now a worldwide community health problem. Diabetes mellitus is associated with numerous systemic complications that affect the retina, heart, brain, kidneys and nerves. Abnormal/reduced sensation, diminished reflexes, decreased proprioception and reduced muscle strength in lower limbs leads to balance and functional problems in patients with diabetic peripheral neuropathy. Evidences strongly support that physiotherapists play a significant role in the prevention, treatment and management of diabetes mellitus and its associated complications. Physiotherapy management techniques and rehabilitation interventions, including exercise prescription and education will help to facilitate patient participation in programs that improve and maintain physical well-being which has a significant impact on their activities of daily living and health-related quality of life (HRQOL).

**Keywords:** physical therapy, diabetes mellitus, physical rehabilitation, physical activity, ADL, QOL

---

## 1. Overall introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by an increase in the blood-glucose level resulting from a relative insulin deficiency or insulin resistance or both. It is a growing public health problem and is considered as one of the main threats to human health in the twenty-first century. It imposes a significant burden on patients and society [1–3]. It is one of the leading causes of complexity of the illness, an increased risk of medical comorbidities like fatigue, recent weight loss, severe restriction in mobility and strength and increased propensity to falls [4, 5].

According to the Centers for Disease Control, about 26 million children and adults are living with diabetes. In addition, almost 79 million people have “pre-diabetes”. The overall magnitude of DM in adults older than 20 years was estimated as 171 million in the year 2000. The

prevalence will likely to be twice as much as the current prevalence by the year 2030. The type 2 diabetes mellitus is the most common type of diabetes and accounts for 90–95% of overall diabetes cases [5, 6]. The number of adults with DM in the world elevated from 108 million to 422 million between 1980 and 2014 [7].

As the diabetes epidemic grows in size and complexity, there is an increasing realization that physicians alone are unable to provide the care required by people with diabetes. To help them live life to the fullest, people with DM need to have an integrated and interdisciplinary rehabilitation team consisting a range of healthcare personnel, including physiotherapists, psychologists and eye specialists. Diet, medication, physical activity and education play a significant role for the prevention, rehabilitation and self-management of diabetes mellitus [5, 8, 9].

Most individuals with diabetes mellitus will visit a physical therapist in the multidisciplinary clinic where they receive care for their DM-related problems. Physical therapists are professionally allowed to exercise in several treatment settings including acute care, nursing home and inpatient and outpatient rehabilitation settings. Physical therapists also work in conjunction with the rehabilitation team to design components of community-based rehabilitation strategy so as to enhance physiological, anatomical and psychosocial outcomes [10] (**Figure 1**).

Physical therapy is a thus corner stone of prevention and treatment of diabetes mellitus. Physical therapy-directed movement and exercise programs are clinically effective in helping diabetic patients to produce the desired health-related quality of life (HRQOL) outcomes [11].



**Figure 1.** The multidisciplinary rehabilitation team approach centres on the patient and caregiver.

Active and passive range of motion exercises, stretching techniques, strengthening and aerobic exercises are some of the physical therapy management techniques for the inpatients, outpatients and prediabetes. These physiotherapy treatments help patients to regain normal range of motion, muscle strength, endurance and physical functioning. It can also maximize the level of independence of DM patients during mobility and activities of daily living. Ultimately, physical therapy aims to improve the health-related quality of life of DM patients [12].

## 2. The diabetic care pathway and general concept of physical therapy

### 2.1. The diabetic care pathway

It is the right of people with diabetes mellitus to expect a timely, accessible and of uniformly high-quality care. However, diabetes care is complex and multidirectional due to their multifaceted needs [13–16]. It should be delivered in a wide range of clinical settings by healthcare professionals from diverse backgrounds and with diverse skills. The diabetic care pathway improves the delivery of effective care, facilitate critical evaluation of that care and strengthen multidisciplinary communication [17]. They promote a uniform standard of care delivery in a wide variety of clinical settings (Figure 2).

### 2.2. General concept of physical therapy

Physical therapists must undergo assessment based on the International Classification of Functioning, Disability and Health (ICF) model before, during and after physical therapy for each diabetic patient (Figure 3). ICF enables physical therapists to identify and analyze problems to provide diabetic patients with therapy. Diabetic patients have many problems caused by diabetes itself and its associated complications. Physical therapy assessment should include

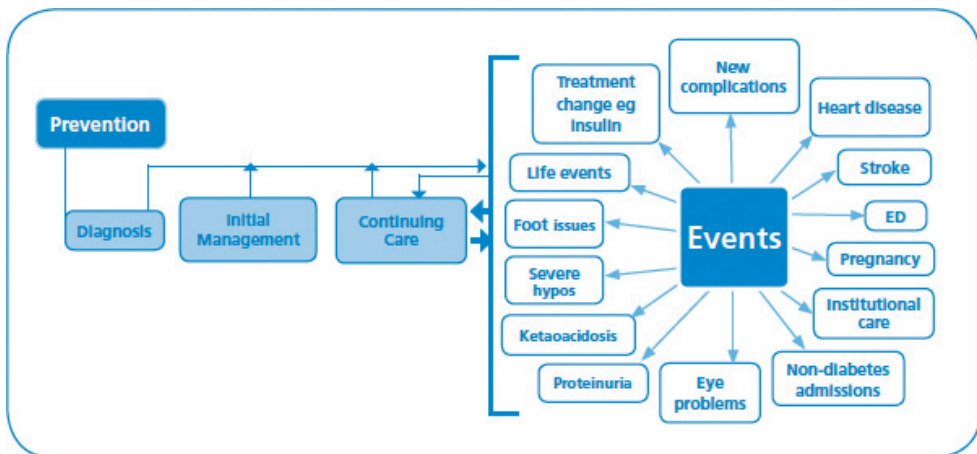
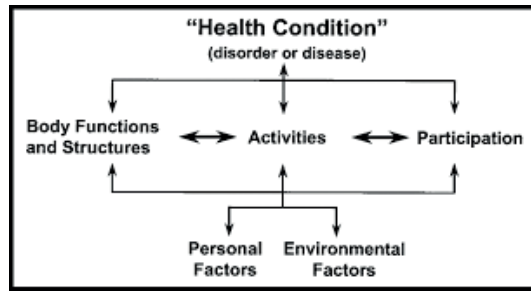


Figure 2. The integrated diabetes care pathway.



**Figure 3.** International Classification of Functioning, Disability, and Health.

sensory integration, motor control and manual muscle testing (MMT), range of motion (ROM), balance test, endurance test, ADL test and participation in social affairs.

Physical therapists should be aware that diabetic patients are exposed to various risks such as infections and bedsores.

The importance of different modes of exercises in patients with type 2 diabetes is emphasized by increasing uptake of glucose by muscles, improving utilization, altering lipid levels, increasing high density lipoprotein and decreasing triglyceride and total cholesterol. Thus exercise helps people to overcome disability by preventing, treating and rehabilitating neuromuscular complications like neuropathies, skin break down, foot ulcers, arthritis, other joint pains, frozen shoulder, back pain and osteoarthritis associated with DM [17–20]. Moderate to high levels of different modes of exercises like cardio respiratory fitness exercises, aerobic exercise and progressive resistance exercises are also associated with substantially lower morbidity and mortality in men and women with diabetes. [11, 12, 15].

### 2.2.1. Subjective assessment

An effective problem-solving approach exploits historical data and information gathered from a basic screening physical examination in a problem-oriented method to guide further investigation. Subjective assessment is an explanation which describes the patients self-report of their current status in terms of their function, disability, symptoms and history. Problem-oriented assessment forms should be used to record the relevant patient reported data, clinical investigation and physical examination results. Record-keeping is an essential component of patient management. It is used for follow-up and evaluation. Taking a full history of the present condition and its possible risk factors, such as smoking, hypertension, obesity, hyperlipidemia and family history is so imperious. Asking for the other symptoms of neuropathic complications such as numbness, joint pain and muscle weakness will also help to evaluate the biopsychosocial context, severity and nature of the patients' current DM state [21, 22].

### 2.2.2. Objective measurement

Objective assessment should be done routinely to test and objectify the patient identified problems by using appropriate equipments and outcome measurement tools. In physiotherapy,

physical assessment findings, or objective data of diabetes mellitus patients can be obtained through the use of three specific diagnostic techniques: Observation, palpation and physical examination. An assessor physiotherapist has to quantify levels of impairment, physical activity limitation and participation restrictions of DM patients. The active and passive range of motion, the sensory integrity, the muscle power, balance, walking pattern and other gross motor activities of diabetes mellitus patients should also be evaluated and objectified.

### 3. Physical rehabilitation in diabetes mellitus patients

#### 3.1. Physical activity for persons at higher risk of developing type 2 diabetes mellitus

Different clinical practice guidelines and systematic reviews agreed that participation in lifestyle therapy that includes regular physical activity should be the first line of defense against T2D development from a state of pre diabetes [23–26]. Both *aerobic* and *anaerobic* forms of physical activity have also various beneficial effects on metabolism in a number of tissues and organs, including skeletal muscle, adipose, liver, pancreas and even brain. Exercise may increase body's response to intrinsic insulin, by multiple mechanisms including [27, 28].

The American Diabetes Association states that simple lifestyle measures have been shown to be effective in preventing or delaying the onset of type 2 diabetes. To help prevent type 2 diabetes and its complications, people should be physically active at least 30 minutes of regular, moderate-intensity activity on most days [16, 17, 29].

Several large-scale clinical trials have established that about 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic physical activity per week, such as brisk walking, with no more than 1 or 2 days off in a row, reduces the risk of developing type 2 diabetes regardless of the degree of adiposity [30–34].

People with prediabetes can be taught physical activities to use their body weight as resistance. They can also use mechanical devices like machines. Major muscle groups of both the upper and lower extremities such as the quadriceps, hamstrings, calves, abdominals, biceps, triceps and forearms should be trained to build their girth and strength. Physical activity guidelines vary on intensity and frequency of prescribing such exercises. The frequency and intensity of exercises should be designed based on an individual's observed capacity to continue the program [16, 35].

Resistance exercise can be performed 2 or 3 times per week for 30–60 min per session. It increases muscle mass, elevates resting metabolic rate, enhances muscular endurance, increases insulin sensitivity and attenuates muscle mass loss during caloric restriction and aging [31, 36].

A systematic review done on the effectiveness of combined diet and physical activity for the prevention of type 2 diabetes stated that combined diet and physical activity promotion programs are effective at decreasing diabetes incidence and improving cardio metabolic risk factors in persons at increased risk. It stated that the more the intensive programs are the more effective will be [37].

Safety should be a major consideration for both health-care professionals and patients before initiating a new program of physical activity.

Therefore physiotherapists should encourage patients who are at high risk of developing diabetes mellitus type 2 to do the following.

1. Increase their physical activities and reduce their sedentary time
2. Start a regular physical activity program: 3–4 days per week for 10–15 minutes per session.
3. Start with a preliminary resistance exercise: It can be done for 1–2 days per week, and for 15–30 minutes per session.
4. Practicing an aerobic exercise for a minimum of 30 minutes per session of 5 days per week.
5. Doing a regular resistance exercise for a minimum of 30 minutes per session of up to 2 or more days per week.

### **3.2. Physiotherapy management of physical impairments and associated complications with diabetes mellitus**

#### *3.2.1. Both aerobic and resistance exercises help to improve metabolic control*

Clinical trials have provided strong evidence that a combination of both aerobic and resistance exercise has a significant effect in glycemic control than either aerobic exercise only or resistance exercise only [27, 37]. These two studies added that both aerobic exercise and resistance training have better outcomes in glycemic control than advice through phone call and maintaining present life style. Progressive resistance training was also found to be helpful in improving glycemic control [38, 39].

A RCT comparing aerobic exercise and resistance training found that both exercises have similar effects in reducing HbA1c. However, there is a chance of potential increase in late-onset hypoglycemia risk after aerobic exercise [40]. It is also been found that physical activities using Physio ball among type 2 diabetes has also its own result in improving glycemic control and blood pressure [41].

Generally, the major benefits of resistance training in individuals with diabetes are:

1. improved **blood cholesterol profiles**,
2. increased heart function,
3. decreased blood pressure,
4. improved insulin sensitivity and blood glucose control,

#### *3.2.2. Both aerobic and resistance training helps to improve muscular strength*

An evidence done on the comparison of muscle strength and short-term endurance in the different periods of type 2 diabetes suggested that patients suffering from diabetes mellitus

have less muscular strength than people without type 2 DM [42]. This further leads to reduced physical activity unless it is properly managed. However, physical activities in form of aerobic/resistance or combination of both resulted in increase in strength in persons with diabetes mellitus.

### *3.2.3. Exercises can improve gait and balance of patients with diabetes mellitus*

Individuals with diabetic peripheral neuropathy (DPN) are 15 times more likely to experience fall compared to the healthy subjects. Falls are marked as a dangerous health issue in DPN especially in the geriatric population. Therefore, knowledge of the factors that influence falls such as postural control deficit and gait instability in DPN patients is essential. Tailored preventive programs including specific gait and balance exercises and cognitive training might be beneficial in reducing fall risk in older adults suffering from diabetes.

A growing number of studies have shown that exercises have some effect on gait and balance. Multisensory exercise and specific gait and balance training programs combined with functional orientated strengthening activities can improve gait speed and balance, and increase both muscle strength and joint mobility of diabetic patients [43, 44].

Task-oriented motor gait training for DPN patients can be used to enhance performance during walking, balance and foot mechanics during walking. Changes in the provided sensorimotor information and enhanced muscle abilities can be regarded as reliable contributions for gait responses in DPN patients [44].

As evidenced by a review on the effectiveness of balance training in the intervention of fall risk in elderly with DPN, Proprioception training, vestibular training, lower limb strength training and mixed sports training enhance balance and reduce its risk of falling in elderly with DPN [45]. When the therapist applies the balance training to elderly patients with DPN, they should focus on the features of different kinds of balance training.

Proprioceptive training can be applied to moderate to severe neuropathy in elderly patients due to the safety and its effectiveness. Vestibular training is more suitable for younger DPN patients. When we apply it to elderly patients, we should pay attention to their safety and should choose low-intensity training. Weight training could significantly improve the lower limbs of patients with DPN walking ability, and relatively more effective than non-weight training [44].

### **3.3. Physical therapy for diabetic peripheral neuropathy**

Peripheral neuropathy is the most common complication of diabetes mellitus (DM) both in developed and developing countries. It is found in about 10% of diabetic patients at diagnosis and in the majority of patients 25 years later on. In diabetic peripheral neuropathy peripheral nerves are unable to function optimally as a result of high blood sugar levels. This condition affects almost half of patients with type 1 and type 2 DM. It involves the presence of symptoms or signs of peripheral nerve dysfunction in people with diabetes after other possible causes have been excluded. Thus, decreasing blood glucose levels can help inhibit and possibly reverse some of the consequences of diabetic peripheral neuropathy.

In type 1 diabetes mellitus, distal lower extremity peripheral neuropathy typically becomes symptomatic after many years of chronic extended hyperglycemia. However, it will be usually obvious after only a few years of well-known poor glycemic control in patients with type 2 DM. Sometimes it may even be recognized at diagnosis. Clinical features of peripheral neuropathy can be categorized in three: sensory, motor and autonomic symptoms.

- **Sensory:** Sensory symptoms like burning pain, tingling sensation, numbness, pain and paresthesia appears symmetrically and commonly at the nerve endings of the longest nerves. It is prevalent in the lower extremities and feet. These symptoms usually develop before motor symptoms such as weakness.
- **Motor:** characterized by flaccid paralysis, diminished deep tendon reflex, muscle weakness and loss of balance and coordination.
- **Autonomic:** It is manifested by features of cardiovascular, gastrointestinal and genitourinary systems dysfunction.

Physical therapy can improve the overall quality of life of DM patients with peripheral neuropathy and alleviate them from the symptoms of diabetic neuropathy. It is also improve muscle strength, joint mobility, balance, coordination and physical function.

### 3.3.1. *The goals of physiotherapy treatment*

To maintain and improve functions by using a range of motion

- To improve and increase the muscle strength, endurance and power
- To improve balance and stability
- To prevent falls and fall related injury

Physical therapists can also recommend assistive devices such as braces and splints to enhance balance and posture. Splinting is often used in the treatment of compression mononeuropathies, such as carpal tunnel syndrome. Research has shown that strengthening exercises for peripheral neuropathy moderately improve muscle strength in people with DPN. In addition, exercises to help peripheral neuropathy, when done regularly, may reduce neuropathic pain and can help control blood sugar levels. A combination of aerobic and strength exercises are shown to be effective to improve both the strength and balance of individuals with diabetic peripheral neuropathy [45].

### 3.3.2. *Aerobic exercise*

It is suggested that increasing energy expenditure by **aerobic exercise** will decrease heart rate, blood pressure and increase **exercise** tolerance. For the majority of individuals, it will be noble to plan for a 30 minutes per day exercise for about 3–5 days a week. It is advisable that you can exercise for 5–10 minutes a day, and work up to more time each week if you have not been very active recently. They can also vary their activity for the . A 10-minute walk exercise after each meal is also marvelous.



Here are some useful aerobic exercises:

- Walking for 30–60 minutes, three times per week is a great and easy way to increase physical activity.
- Participating in a low-impact aerobics class is also very important
- Swimming helps to stretch and relax muscles
- Though it is not easily accessible for all diabetics individuals, stationary bicycling indoors is another useful form aerobics exercise

### 3.3.3. *Strengthening exercises*

There are different forms of strengthening exercises that can be done by diabetic patients. Resistance exercises are commonly applied in physical rehabilitation programs to improve muscular strength, power and endurance of diabetic's patients. Many newly recognized type 2 diabetics may not have exercised in years. Therefore, there should be an awareness rising program together with health promotion and disease prevention campaigns about the clinical advantages of exercises with weights or other forms of mechanical resistance [46]. Then it will be imperative if they check in with their doctor first. After asking if there are any contraindicated moves they should avoid, they can start learning the right way to do each strengthening exercise. However, strengthening exercises have different requirements depending upon the treatment goals or function [28, 47]. The strengthening exercise programs need to be personalized to each patient's chief complaint, functional problems and goals. The workout variables such as speed, the intensity, the frequency and the type of muscle contraction used or the amount of muscles recruited in each contraction all effect the outcome of the program. Physiotherapists are experts who can guide and supervise patients with DPN. In addition to muscle strength, which can involve power, endurance and speed of contraction, the timing and balance of muscle contractions is very important. There are many different benefits of strengthening exercises for people with diabetes. Some of the benefits of working out a strengthening exercise are:

- It helps them to respond better to insulin
- It Improves the way it uses blood sugar
- It helps to lose weight
- It helps to lower the risk for heart disease

In addition, the American College of Sports Medicine recommends that people with type 2 diabetes should start practicing a strength training program to reduce the risk of further injury, to improve muscle strength, to improve the quality and range of movement and overall quality of functional mobility [35].

Strengthening exercise programs will include a variety of exercises designed to target specific groups or individual muscles. These exercises will begin easier and progress as strength is developed. Some of the exercises may involve the following:

- Exercising against gravity
- Exercising against the resistance of water
- Exercising against a resistance band
- Exercising with weight
- Exercising using your own body weight as the load

### 3.3.4. Muscle tone and joint flexibility exercises

Muscle tone and joint flexibility exercises are also called stretching exercises. There are two main types of stretching exercises: therapeutic stretching and self-stretching. While the first is indicated for therapeutic purposes, the second is used in bodybuilding, athletic training, dance and certain ritual exercises. The therapeutic stretching can be implemented on the desired muscle groups *either* by the therapist *or* by the patient himself. It is believed that stretching stimulates the body-mind complex to resolve injury, stress and pain. Gradual therapeutic stretching helps to keep the joints flexible and reduce the chances of injury during other activities. Thus gentle stretching for 5–10 minutes helps our body warm up and get ready for aerobic activities such as walking or swimming. Diabetes patients and prediabetes can do the following flexibility exercises of major muscle groups of both upper and lower limbs bilaterally. These exercises can be done either individually or in groups.

- Calf stretching exercise
- Sitting hamstring stretch exercise
- Plantar fascia stretching exercise.
- Hip flexors and adductors stretch exercise
- Biceps and triceps stretching exercise

## 4. Guidelines for a sound exercise program

If the blood glucose level is less than 100 mg/dl or greater than 250 mg/dl, do not exercise.

It is recommended to exercise indoor instead of outdoor to minimize the risk of integumentary and musculoskeletal trauma. It is also helpful for the patient to have an immediate access to necessary things to address hypoglycemia, hyperglycemia or diabetic ketoacidosis.

When patients plan to come out of their house to go somewhere else, they are highly advised to wear the medical tag for diabetics.

During prolonged exercise duration, 10–15 g of carbohydrate snack is recommended for every 30 minutes.

They are recommended to have a carbohydrate snack such as a glass of orange juice or milk at every exercise session. Exercising in a comfortable temperature is worthwhile. Never exercise in extreme temperatures.

For type 1 (insulin-dependent) patients, it is not allowed to exercise during the peak times of insulin. Before a physiotherapist asks a patient to do exercise, he should coordinate with the referring physician or nurse in charge for the patient regarding the stability of the patient and the type of insulin administered.

Type 2 diabetics are advised to have an average of 30 minutes of exercise duration per session.

Always wear proper footwear and exercise in a safe environment.

Menstruating women should have to boost insulin during menses, especially if they are not active.

It is not reasonable to inject insulin close to the muscles to be exercised within 1 hour of exercise.

Patients ought to eat 2 hours before they go for exercise. If they plan to exercise after meal, they should have to wait 1 hour prior to start. They should always bring their own portable blood glucose monitor. They should keep an eye on their glucose levels before and after exercise.

It is also important to drink adequate amount of fluid before exercise. If blood glucose level is between 70 and 100 mg/dl, the physical therapist can be allowed to provide carbohydrate snack and then reassess the glucose level after 15 minutes.

Make sure exercise does not contribute an unnecessary stress to the patient. Stress increases insulin requirements. A gradual progression from aerobic and resistance exercises is the key.

Avoid exercising late at night. Thus, exercising five times a week as maintenance is preferred. Any known DM patient must not exercise alone as much as possible so as to call someone to help in unexpected situations.

## **5. Summary and conclusion**

Majority of diabetes mellitus patients have physical impairments, activity limitations and associated complications. Physical therapy has an important role to improve physical function, activities of daily living and quality of life of diabetic patients. Persons who are at risk of developing diabetes mellitus should also be involved in appropriate levels of daily physical activity based on personal preference and anticipated physical limitations.

It is recommended that people with DM ought to have a regular aerobic exercise and strength training to reassure positive adaptations in the control of blood glucose concentration, insulin action, muscular strength and exercise tolerance. Blood glucose levels should be monitored before and after exercise to prevent hypoglycemia. A medical screening and evaluation is essential to distinguish diabetes-related complications affecting cardiovascular function, which may be aggravated by an exercise program.

## Author details

Asmare Yitayeh Gelaw

Address all correspondence to: [asmphysio@gmail.com](mailto:asmphysio@gmail.com)

Department of Physiotherapy, School of Medicine, College of Medicine and Health Sciences, University of Gondar, Gondar, Ethiopia

## References

- [1] Alberti KGMM, Zimmet P. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: Diagnosis and classification of diabetes mellitus. Provisional report of a WHO consultation. *Diabetic Medicine*. 1998;**15**(7):539-553
- [2] Boulton AJ, Vileikyte L, Ragnarson-Tennvall G, Apelqvist J. The global burden of diabetic foot disease. *The Lancet*. 2005;**366**(9498):1719-1724
- [3] Chen L, Magliano DJ, Zimmet PZ. The worldwide epidemiology of type 2 diabetes mellitus—Present and future perspectives. *Nature Reviews. Endocrinology*. 2012;**8**(4):228-236
- [4] Goh SY, Ang SB, Bee YM, Chen RY, Gardner D, Ho E, et al. Ministry of health clinical practice guidelines: Diabetes mellitus. *Singapore Medical Journal*. 2014;**55**(6):334
- [5] Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *The New England Journal of Medicine*. 2001;**344**(18):1343-1350
- [6] Kujala UM. Evidence on the effects of exercise therapy in the treatment of chronic disease. *British Journal of Sports Medicine*. 2009;**43**(8):550-555
- [7] NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in diabetes since 1980: A pooled analysis of 751 population-based studies with 4.4 million participants. *Lancet* (London, England). 2016 Apr 9;**387**(10027):1513-1530
- [8] Nathan DM, Buse JB, Davidson MB, Ferrannini E, Holman RR, Sherwin R, et al. Medical management of hyperglycemia in type 2 diabetes: A consensus algorithm for the initiation and adjustment of therapy a consensus statement of the American Diabetes Association and the European Association for the Study of diabetes. *Diabetes Care*. 2009;**32**(1):193-203
- [9] Anderson RM, Funnell MM, Butler PM, Arnold MS, Fitzgerald JT, Feste CC. Patient empowerment: Results of a randomized controlled trial. *Diabetes Care*. 1995;**18**(7):943-949
- [10] Keers JC, Blaauwweikel EE, Hania M, Bouma J, Scholten-Jaegers SM, Sanderman R, et al. Diabetes rehabilitation: Development and first results of a multidisciplinary intensive education program for patients with prolonged self-management difficulties. *Patient Education and Counseling*. 2004;**52**(2):151-157

- [11] Balk EM, Earley A, Raman G, Avendano EA, Pittas AG, Remington PL. Combined diet and physical activity promotion programs to prevent type 2 diabetes among persons at increased risk: A systematic review for the community preventive services task force. *Annals of Internal Medicine*. 2015 Sep 15;**163**(6):437
- [12] Kitchiner D, Bundred P. Integrated care pathways increase use of guidelines. *BMJ*. 1998;**317**(7151):147
- [13] Ouwens M, Wollersheim H, Hermens R, Hulscher M, Grol R. Integrated care programmes for chronically ill patients: A review of systematic reviews. *International Journal for Quality in Health Care*. 2005;**17**(2):141-146
- [14] Waller SL, Delaney S, Strachan MWJ. Does an integrated care pathway enhance the management of diabetic ketoacidosis? *Diabetic Medicine*. 2007;**24**(4):359-363
- [15] Bakker K, Apelqvist J, Schaper NC. Practical guidelines on the management and prevention of the diabetic foot 2011. *Diabetes/Metabolism Research and Reviews*. 2012;**28**(S1): 225-231
- [16] American Diabetes Association. Standards of medical care in diabetes—2007. *Diabetes Care*. 2007;**30**(suppl 1):S4-S41
- [17] Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes. *Diabetes Care*. 2010 Dec;**33**(12):e147-e167
- [18] Thomas D, Elliott EJ, Naughton GA. Exercise for type 2 diabetes mellitus. In: *Cochrane Database of Systematic Reviews* [Internet]. John Wiley & Sons, Ltd; 2006 [cited 2016 Sep 7]. Available from: <http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD002968.pub2/abstract>
- [19] Orozco LJ, Buchleitner AM, Gimenez-Perez G, Roqué i Figuls M, Richter B, Mauricio D. Exercise or exercise and diet for preventing type 2 diabetes mellitus. *Cochrane Library* [Internet]. 2008 [cited 2016 Sep 1]. Available from: <http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD003054.pub3/full>
- [20] Bohn B, Herbst A, Pfeifer M, Krakow D, Zimny S, Kopp F, et al. Impact of physical activity on glycemic control and prevalence of cardiovascular risk factors in adults with type 1 diabetes: A cross-sectional multicenter study of 18,028 patients. *Diabetes Care*. 2015 Aug 1;**38**(8):1536-1543
- [21] Waryasz GR, McDermott AY. Exercise prescription and the patient with type 2 diabetes: A clinical approach to optimizing patient outcomes. *Journal of the American Academy of Nurse Practitioners*. 2010;**22**(4):217-227
- [22] Umpierre D, Ribeiro PB, Kramer CK, et al. Physical activity advice only or structured exercise training and association with hba1c levels in type 2 diabetes: A systematic review and meta-analysis. *Journal of the American Medical Association*. 2011 May 4;**305**(17):1790-1799
- [23] Meltzer S, Leiter L, Daneman D, Gerstein HC, Lau D, Ludwig S, et al. 1998 clinical practice guidelines for the management of diabetes in Canada. *Canadian Diabetes Association. Canadian Medical Association Journal*. 1998;**159**:S1-29

- [24] Evenson KR, Mottola MF, Owe KM, Rousham EK, Brown WJ. Summary of international guidelines for physical activity following pregnancy. *Obstetrical & Gynecological Survey*. 2014 Jul;**69**(7):407-414
- [25] Aune D, Norat T, Leitzmann M, Tonstad S, Vatten LJ. Physical activity and the risk of type 2 diabetes: A systematic review and dose-response meta-analysis. *European Journal of Epidemiology*. 2015 Jul 1;**30**(7):529-542
- [26] Smith AD, Crippa A, Woodcock J, Brage S. Physical activity and incident type 2 diabetes mellitus: A systematic review and dose-response meta-analysis of prospective cohort studies. *Diabetologia*. 2016 Dec 1;**59**(12):2527-2545
- [27] Yavari A, Najafipour F, Aliasgarzadeh A, Niafar M, Mobasser M. Effect of aerobic exercise, resistance training or combined training on glycaemic control and cardiovascular risk factors in patients with type 2 diabetes. *Biology of Sport*. 2012;**29**(2):135
- [28] Sigal RJ, Kenny GP, Boulé NG, Wells GA, Prud'homme D, Fortier M, et al. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: A randomized trial effects of aerobic and resistance training on glycemic control in type 2 diabetes. *Annals of Internal Medicine*. 2007;**147**(6):357-369
- [29] American Diabetes Association. Physical activity/exercise and diabetes mellitus. *Diabetes Care*. 2003;**26**(suppl 1):s73-s77
- [30] Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH. A prospective study of exercise and incidence of diabetes among US male physicians. *Journal of the American Medical Association*. 1992;**268**(1):63-67
- [31] Kriska AM, LaPorte RE, Pettitt DJ, Charles MA, Nelson RG, Kuller LH, et al. The association of physical activity with obesity, fat distribution and glucose intolerance in Pima Indians. *Diabetologia*. 1993;**36**(9):863-869
- [32] Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS Jr. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. *The New England Journal of Medicine*. 1991;**325**(3):147-152
- [33] FB H, Sigal RJ, Rich-Edwards JW, Colditz GA, Solomon CG, Willett WC, et al. Walking compared with vigorous physical activity and risk of type 2 diabetes in women: A prospective study. *Journal of the American Medical Association*. 1999;**282**(15):1433-1439
- [34] Espeland M. Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: One-year results of the look AHEAD trial. *Diabetes Care* [Internet]. 2007 [cited 2017 Aug 1]. Available from: <http://care.diabetesjournals.org/content/diacare/early/2007/03/15/dc07-0048.full.pdf>
- [35] American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription [Internet]. Lippincott Williams & Wilkins; 2013 [cited 2017 Aug 4]. Available from: <https://books.google.com/books?hl=en&lr=&id=hhosAwwAAQBAJ&oi=fnd&pg=PP1&dq=guidelines+on+strengthening+and+aerobic+exercies++for+diabetic+patients&ots=ljA36D3VTC&sig=frKt4F6MZzRWE-AzReDjMk-sNok>

- [36] Irvine C, Taylor NF. Progressive resistance exercise improves glycaemic control in people with type 2 diabetes mellitus: A systematic review. *The Australian Journal of Physiotherapy*. 2009;**55**(4):237-246
- [37] Sigal RJ, Alberga AS, Goldfield GS, Prud'homme D, Hadjiyannakis S, Gougeon R, et al. Effects of aerobic training, resistance training, or both on percentage body fat and cardio-metabolic risk markers in obese adolescents: The healthy eating aerobic and resistance training in youth randomized clinical trial. *JAMA Pediatrics*. 2014;**168**(11):1006-1014
- [38] Bweir S, Al-Jarrah M, Almalty A-M, Maayah M, Smirnova IV, Novikova L, et al. Resistance exercise training lowers HbA1c more than aerobic training in adults with type 2 diabetes. *Diabetology and Metabolic Syndrome*. 2009;**1**(1):1
- [39] Bacchi E, Negri C, Trombetta M, Zanolin ME, Lanza M, Bonora E, et al. Differences in the acute effects of aerobic and resistance exercise in subjects with type 2 diabetes: Results from the RAED2 randomized trial. *PLoS One*. 2012;**7**(12):e49937
- [40] Subramanian SS, Venkatesan P, Deepa S. Impact of Physioball exercises among type II diabetes on glycaemic control and hypertension. *IOSR Journal of Nursing and Health Science (IOSR-JNHS)*. 2016;**5**(1):34-36
- [41] Hatf B, Bahrpeyma F, Tehrani MRM. The comparison of muscle strength and short-term endurance in the different periods of type 2 diabetes. *Journal of Diabetes and Metabolic Disorders*. 2014;**13**(1):22
- [42] Kutty NAM, Majida NAL. Effects of multisensory training on balance and gait in persons with type 2 diabetes: A randomised controlled trial. *Disability, CBR & Inclusive Development*. 2013 Jul 28;**24**(2):79-91
- [43] Salsabili H, Bahrpeyma F, Esteki A. The effects of task-oriented motor training on gait characteristics of patients with type 2 diabetes neuropathy. *Journal of Diabetes and Metabolic Disorders*. 2016 May 25;**15**:14
- [44] Pan X, Bai J. Balance training in the intervention of fall risk in elderly with diabetic peripheral neuropathy: A review. *Int J. Nursing Science*. 2014 Dec 1;**1**(4):441-445
- [45] Maronesi CTP, Cecagno-Zanini SC, Oliveira de LZ, Bavaresco SS, Leguisamo CP, Maronesi CTP, et al. Physical exercise in patients with diabetic neuropathy: Systematic review and meta-analysis of randomized clinical trials. *Fisioterapia e Pesquisa* 2016 Jun;**23**(2):216-223
- [46] Brooks N, Layne JE, Gordon PL, Roubenoff R, Nelson ME, Castaneda-Sceppa C. Strength training improves muscle quality and insulin sensitivity in Hispanic older adults with type 2 diabetes. *International Journal of Medical Sciences*. 2007;**4**(1):19
- [47] Castaneda C, Layne JE, Munoz-Orians L, Gordon PL, Walsmith J, Foldvari M, et al. A randomized controlled trial of resistance exercise training to improve glycemic control in older adults with type 2 diabetes. *Diabetes Care*. 2002;**25**(12):2335-2341

