



## Review Article

## Exercise and Diabetes: A Narrative Review

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## ABSTRACT

Persons with diabetes might experience significant benefits through regular exercise. Not unlike the general population, those with diabetes could also lack motivation to participate in an exercise program. Often, those treating persons with diabetes lack training and/or interest in exercise prescription and are therefore unable to provide the needed information and encouragement. In many cases, reluctance to exercise could result from an inability to find an enjoyable exercise activity. Attempts to find activities that, not only provide effective aerobic challenges, but are also enjoyable to participate in are fraught with difficulty. Three electronic databases were searched in January 2017. Evidence for the merits of exercise for those with diabetes was robust. Numerous reports have addressed the degree of noncompliance to exercise recommendations and the barriers reported for this nonadherence. Additional studies concluded that most medical providers are deficient in formal training in the prescription of an exercise program. Newer studies are evaluating the effects of exercise and vitamin D supplementation and their interplay with diabetic peripheral neuropathy and ulceration. Exercise confers remarkable benefits to those with diabetes; however, the challenges to compelling patients with diabetes to exercise are formidable. An improved focus on exercise prescription and related motivation during provider training must be undertaken.

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Diabetes mellitus (DM) is one of today's greatest health concerns, with serious effects, not only for the person afflicted, but also for society. Along with an alarming increase in the diagnosed cases of DM and prediabetes, a concurrent increase in DM-related manifestations such as diabetic peripheral neuropathy (DPN), diabetic foot ulcers (DFUs), and amputations has occurred.

Exercise has been found to profoundly improve the physiologic and psychological conditions of those with DM. Therefore, the incorporation of a modality (exercise) that has been found to significantly improve the health status for those with DM by health care providers is imperative. However, those with DM are often unwilling to participate in exercise because of barriers, both real and perceived. In addition, many providers are poorly equipped, not only to devise an exercise prescription, but also to encourage and motivate their patients to participate in an exercise program. Those providers caring for persons with DM must become better educated regarding the importance of exercise prescription and its delivery and to consider their patients' needs for an achievable, safe, and enjoyable activity.

The present review has delineated many of the challenges encountered both by those with DM and health care providers that impede exercise participation despite the benefits. Additionally, updates on the effect of exercise as it relates to the risk of ulceration in those with DPN and the interplay of exercise, development of DFUs, neuropathy, and vitamin D supplementation are provided owing to the significant importance to foot and ankle specialists.

**Materials and Methods**

Three electronic databases (PubMed, UpToDate, and Google Scholar) were searched from their inception to January 2017. The search strategy was diabetes + exercise; diabetes + neuropathy; exercise + diabetic ulcers; and exercise + vitamin D + diabetes. The preferred citations were meta-analyses and systematic reviews on the given topics. The search yields were transferred to Endnote™, version 8 (Clarivate Analytics, Boston, MA). Citation tracking was completed for all identified studies included in the refined library, using Google Scholar. No restriction was placed on the year of publication for the included reports.

**Results**

Our search yielded 97 reports about which we comment, below.

*Seriousness of DM*

The American Diabetes Association (ADA) reported that DM mellitus afflicted 9.3% of the U.S. population in 2012 (about 29.1 million) (1). From 1980 through 2011, the number of Americans with

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DM diagnosed more than tripled (from 5.6 million to 20.9 million) (2). The total economic burden of diagnosed DM in the United States in 2012 exceeded \$245 billion. Also, if one includes the undiagnosed cases and cases of prediabetes and gestational diabetes, this number increases to \$322 billion (1). Ten percent of all spending on health care is the result of treating DM and DM-related complications, and health care costs are 2.3 times greater for those with DM compared with those without (1). In addition, the cost of managing DFUs exceeds the cost of treatment for the 5 costliest forms of cancer (3).

Of great concern to foot and ankle surgeons is the significant association of nontraumatic lower limb amputations and the presence of DM. The ADA has reported that persons with DM undergo roughly 60% of all nontraumatic lower limb amputations, resulting in approximately 73,000 amputations annually (1). This high rate of amputation is further compounded by an alarming correlation of a higher rate of death for persons with DM who undergo a major (below-the-knee or above-the-knee) nontraumatic lower limb amputation (4,5). Major amputations resulting from DM have been notably correlated with a 5-year mortality rate of 40% to 82% after below-the-knee amputation and 40% to 90% after above-the-knee amputation (5). Given that premature death can be directly influenced by the amputation or is simply a manifestation of the patient's severe disease state underscores the point that preventing patients with DM from reaching a status that requires amputation is paramount. Therefore, any intervention, such as exercise, that is capable of improving the management of DM or preventing DM will be a useful treatment adjunct for both current and future patients.

#### *Exercise and Patients With DM*

##### *Exercise Is Good for Those With DM*

Physical exercise has been shown to dramatically improve the physiologic and psychological state of persons with and without DM (6–9). Therefore, it is imperative that those caring for patients with DM become versed, not only in the creation of a physical exercise prescription, but also in the mechanisms for providing encouragement and motivation.

##### *Physiologic Benefits*

Exercise confers beneficial physiologic effects to patients both with and without DM. Weight loss, improved muscle tone, and improved heart rate and respiratory function are well-known attributes of exercise. Furthermore, fitness for the patient with DM not only leads to those outcomes, but also has remarkable and specific effects in controlling their disease metabolically. This is clinically relevant for physicians who desire nonpharmacologic interventions for their patients with DM.

The following list reflects the evidence supporting the profound physiologic and metabolic benefits seen in patients with DM who undertake an exercise program:

1. Insulin receptors and glucose transporters, which are insufficient in those with type 2 DM (T2DM), are enhanced by long-term exercise (>6 weeks), resulting in a reduction of the insulin resistance associated with T2DM (7,8).
2. Extended exercise improves glycemic control, represented by reduced hemoglobin A1c (HbA1c) values (7,8,10,11).
3. In and of itself, aerobic exercise has a verifiable benefit in improving glycemic control, but, when combined with resistance exercise, the beneficial effects might be synergistic or at least additive (12–17). In fact, improved lean body mass and greater overall weight loss occurs, with a resultant reduction in HbA1c

when aerobic and resistance exercise are performed concomitantly (12).

4. The maximum rate of oxygen consumption (VO<sub>2</sub> max) will increase as a result of exercise (18).
5. Some recent studies have suggested that the improved glycemic control (reduction in HbA1c) seen with exercise could very well be enhanced when the intensity of the exercise is increased (19–23).
6. Persons with DM who exercise will experience changes such as reduced blood pressure and improved lipid profiles and body mass index (BMI) (24). Also, cardiovascular mortality rates decreased in persons with DM who exercised (25,26).

##### *Psychological Benefits*

Many people who exercise report doing so for the positive mental health benefits. The results from the meta-analysis by Gillison et al (9) support this claim. They found that exercise enhances the self-reported quality of life in healthy individuals (9). However, as Reid et al (27) noted, the evidence for self-reported quality of life improvement in patients with T2DM has been lacking or inconsistent. Dixit et al (28) found that a moderate-intensity aerobic exercise program improved the quality of life of patients with T2DM and peripheral neuropathy. Nicolucci et al (29) reported a relationship between changes in physical and mental health-related quality of life measures and the volume of physical activity or exercise performed. They also reported that supervised exercise training seemed to augment these benefits (29).

Regardless of what DM-specific research discovers in the future, exercise has known effects on diseases that are likely to be comorbid in patients with DM, including major depressive disorder (30). Exercise can also instill habits of self-discipline in patients with DM, which will enhance their compliance with treatment regimens. Additionally, exercise can enhance patients' self-image of their body through the resulting weight loss and improvement in body composition and appearance.

##### *Why Do Patients Not Exercise?*

Although the evidence of the numerous health benefits resulting from regular physical exercise to those patients with DM is overwhelming, patients continue to have great reluctance in engaging in an exercise program (31). For instance, no exercise is performed by more than one half of adolescents (58% of females and 52% of males) with T2DM—a sobering statistic—considering that a diagnosis of DM limits the quality and duration of an individual's potential life span (26). Additionally, Mu et al (32) reported that only 12% of persons with DM met the ADA standard for resistance exercise, a value 9% less than that for the general population.

Even if a satisfactory exercise program has been recommended by a health care provider, nonadherence to participation in exercise has been considerable, ranging from 35% to 86% (33–39). Other components of the treatment recommendation fared better than exercise regarding patient compliance. Morrison et al (40) reported that changing dietary habits seemed easier for those patients with DM who described themselves as “motivated to change lifestyle” compared with making changes to their exercise routine. Likewise, a systematic review by Coyle et al (41) found that self-management compliance was markedly better with medication usage than with following an exercise program.

A significant area of investigation has centered on what barriers, both physical and psychological, are dissuading patients with DM from exercising (42). Many of these barriers have been covered in the present review. However, these barriers are not unique to persons with DM.

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