Type 2 diabetes mellitus (T2DM) affects nearly 26 million US adults aged 20 years or older, with 1.5 million more cases diagnosed in adults each year. By 2050, it is predicted that 1 in 3 US adults will have diabetes mellitus, including 53% of senior citizens. Currently, 79 million US adults have prediabetes, and many of them, if left untreated, will develop diabetes. Not only is diabetes common, but it is also linked to considerable morbidity and mortality. For example, diabetes is a major cause of heart disease and stroke, and it is the seventh leading cause of death in the United States. In light of these statistics, it is inevitable that this disease will eventually come to affect all families and all medical specialties.

Type 2 diabetes mellitus is a chronic disease that is largely preventable and wholly treatable. The largest component of T2DM management is self-care. This type of care includes consuming a well-balanced and whole food diet, participating in regular physical activity, maintaining a healthy weight, and getting proper rest. A healthy lifestyle is even more effective at preventing T2DM. Unfortunately, individuals in the United States continue to gain weight and become more sedentary. Osteopathic physicians have an opportunity to proactively address this disease by implementing the core features of osteopathic principles.

The modern osteopathic practice has changed in many ways as it has been integrated into mainstream medicine (eg, prescribing medications), but the osteopathic tenets (Figure 1) can still be used to advantage in the management of today’s chronic diseases. In the present review, we will discuss how the application of these tenets can be integrated in an osteopathic approach to caring for patients with T2DM.

Psychological and Emotional Aspects of T2DM
The first osteopathic tenet states, “The body is a unit; the person is a unit of body, mind, and spirit.” This tenet is certainly applicable to diabetes and its metabolic effects. In terms of the body, this multisystem disease arises from a complicated polygenic pathophysiology that involves and affects many organ systems. There is strong evidence that the pathophysiologic processes that lead to T2DM start decades before
T2DM diagnosis. The genetic predisposition for T2DM is also affected by environmental factors and comorbid illnesses. Defining T2DM narrowly as a disease of glucose regulation underestimates the role that stress, pain, sleep patterns, and illness play on glucose control.

In terms of mind and spirit, people with T2DM are twice as likely as those without T2DM to be depressed and 1.4 times more likely to have an anxiety disorder. Comorbid depression in patients with T2DM has been associated with worse glycemic control and fewer self-care behaviors when compared to those without depression. These individuals also tend to have increased complications and a poorer quality of life. The longer an individual has T2DM, the more likely it is that he or she will suffer from mood disorders and worse glycemic control, which, in turn, result in additional diabetes-related complications.

As with most chronic diseases, pain can be a provocative and complicating factor for glucose control. Between 40% and 60% of individuals with T2DM experience some type of painful comorbid condition. Types of pain include neuropathic pain and non–diabetes-related pain such as osteoarthritis. In both cases, people with T2DM experience higher glucose levels when they feel acute or chronic pain. Further, for people with T2DM, pain can limit their ability to participate in physical activity and may trigger unscheduled eating as a form of self-medication.

Osteopathic physicians should remember that each patient is composed of a body, a mind, and a spirit and is not simply a body with an illness. Addressing all 3 factors will allow for a truly holistic and patient-centered approach to T2DM.

Self-Management for Prevention and Treatment of T2DM

The second tenet of osteopathic medicine states, “the body is capable of self-regulation, self-healing, and health maintenance.” Rogers et al expanded this tenet to indicate that it is the individual’s responsibility to maintain his or her own health. Ultimately, the environmental stimuli we are subject to are within our own control. If a person with T2DM allows too many harmful events to occur, then the body’s self-regulatory mechanisms will be hindered.

For individuals with T2DM, noxious stimuli such as a poor diet, stress, and lack of physical activity can potentially impair the body’s ability to continue self-regulatory functions and thus make the body susceptible to illnesses. Illness can manifest in the short term as hyperglycemia, hypertension, and dyslipidemia but, if allowed to persist, can result in T2DM-related complications. The noxious stimuli must be eliminated, and much of that responsibility falls to the patient.

As previously stated, the largest component of T2DM management is self-care. Self-care includes regulating dietary

<table>
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<td>When healthy, the musculoskeletal system is central to glucose and insulin regulation; it can provide information about systemic disease. When it is not functioning optimally, it can contribute to worsening disease and complications.</td>
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<td>Rational treatment is based upon an understanding of the basic principles of body unity, self-regulation, and the interrelationship of structure and function.</td>
<td>A rational treatment approach to T2DM is based upon the understanding of the previous 3 tenets. Thus, osteopathic physicians have the opportunity to educate and engage their patients in self-care and diabetes self-management. In addition, they may be able to use osteopathic manipulative treatment to help manage some complications when they arise.</td>
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Figure 1. Tenets of osteopathic medicine applied to type 2 diabetes mellitus (T2DM).
intake, physical activity, sleep, and stress in addition to checking glucose measurements, taking medication, and problem solving when glucose is out of range. Further, self-care involves the prevention and treatment of complications, which include but are not limited to daily skin and foot checks, routine medical care, screening examinations, and early intervention if a problem arises.

It has been estimated that it takes 2 to 3 hours per day to complete the recommended diabetes self-care activities.\textsuperscript{15,16} Having diabetes can affect every decision a person makes in a day. Because of the time requirements and complexity of T2DM management, it is not surprising that estimates of self-care adherence rates are low.\textsuperscript{17-19} One study\textsuperscript{20} found that 57% to 70% of individuals adhere to blood glucose monitoring routines, 65% adhere to dietary routines, and 19% to 30% adhere to exercise routines. As these studies show, physical activity is one of the most difficult areas of self-care adherence for individuals with T2DM, despite the proven benefits.

The body possesses the ability to self-heal, and for patients with T2DM who adhere to all self-care goals and treatment regimens, the body’s self-regulation mechanism could be minimally blunted. With incomplete self-care, noxious stimuli can overwhelm the body’s defenses, usually in a slowly progressing manner that will ultimately lead to complications. It is the job of healthcare providers to assist and to encourage their patients to strive for complete self-care to maximize the body’s self-healing process.

**Musculoskeletal Aspects of T2DM**

The third tenet states, “structure and function are reciprocally interrelated.”\textsuperscript{16} Directly related to this tenet is the musculoskeletal system, which substantially influences the individual’s ability to maintain homeostasis and therefore wellness.

**Physical Activity**

There is ample evidence that physical activity is critical to normal glucose metabolism.\textsuperscript{21-26} However, most individuals with T2DM do not engage in physical activity.\textsuperscript{20}

Physical activity leads to an increase of blood glucose uptake. Under normal conditions, blood glucose levels are maintained by glucose production by means of liver glycogenolysis and gluconeogenesis and mobilization of free fatty acids. Several factors influence metabolic substrate use during physical activity, but the most important factors are the intensity and duration of activity.\textsuperscript{21} As duration of physical activity increases, the body shifts from predominant reliance on free fatty acids at rest to a blend of fat, glucose, and muscle glycogen along with a small amount of amino acids.\textsuperscript{21} As intensity of physical activity increases, the body shifts to a greater reliance on carbohydrates.\textsuperscript{22} Initially, glycogen provides the bulk of fuel for muscles during exercise, but as these stores become depleted, muscles increase uptake and use of circulating blood glucose and adipose free fatty acids.\textsuperscript{22} Glucose production also shifts from hepatic glycogenolysis to enhanced gluconeogenesis as duration increases.\textsuperscript{24}

Glucose transport into skeletal muscle is accomplished by means of glucose transporter proteins (GLUT-4) and is modulated by insulin and muscle contractions.\textsuperscript{25,27} Both aerobic and resistance exercise will increase GLUT-4 transporter expression and blood glucose uptake.\textsuperscript{23,27} In those with T2DM, moderate exercise will cause the blood glucose levels to decline.\textsuperscript{28} The amount of reduction in the glucose is related to the duration and intensity of exercise, as well as the pre-exercise glucose control and overall state of fitness.\textsuperscript{29,30} A combination of aerobic and resistance training may be more effective for glucose management than either one alone.\textsuperscript{31}

**Chronic Effects of Exercise**—Even as little as 1 week of aerobic training can improve whole-body insulin sensitivity in T2DM.\textsuperscript{32} Both moderate and vigorous aerobic physical activity improve insulin sensitivity for hours to days.\textsuperscript{20,32} Further training can enhance the responsiveness of skeletal muscles to insulin with increased expression and activity of proteins involved in glucose metabolism and insulin signaling.\textsuperscript{24} Resistance exercise also helps glucose control and insulin action in T2DM.\textsuperscript{26,33} In a randomized trial,\textsuperscript{34} 16 weeks of 2 bouts per week in older men with newly diagnosed T2DM resulted in a 46.3% increase in insulin action and a 7.1% reduction in blood glucose levels.

**Prevention**—Physical activity may be even better at preventing T2DM than managing it.\textsuperscript{4,5,31} In the Da Qing IGT and Diabetes Study,\textsuperscript{35} 20 minutes of moderate, 10 minutes of strenuous, or 5 minutes of very strenuous exercise twice daily reduced T2DM risk by 46%. In the Diabetes Prevention Program,\textsuperscript{4} physical activity reduced the risk of T2DM even when weight loss goals were not achieved. A systematic review of 10 cohort studies\textsuperscript{36} showed that moderate physical activity provided a relative risk reduction of 0.7 for individuals with new-onset T2DM who were walking more than 2.5 hours per week. It is clear that a healthy lifestyle as described in the above studies can prevent or delay this serious disease.

**Musculoskeletal Complications**

Late complications of T2DM include microvascular complications (eg, retinopathy, neuropathy, nephropathy) and macrovascular complications (eg, cardiovascular disease, stroke, peripheral arterial disease). Other long-term complications often overlooked and underappreciated include limited joint mobility syndrome (eg, diabetic cheiroarthropathy,
adhesive capsulitis, carpal tunnel syndrome) and other musculoskeletal manifestations. When compared to the general population, patients with T2DM are 5 times more likely to have adhesive capsulitis, and they have an increased risk for bilateral carpal tunnel syndrome. The musculoskeletal complication of limited joint mobility has even been linked to a greater risk for microvascular complications. In addition, these musculoskeletal complications can contribute to less physical activity and contribute to worsening of the disease state.

**Osteopathic Palpatory Diagnosis and T2DM**
Osteopathic physicians are trained to palpate and seek information from the musculoskeletal system. Knowledge of autonomic innervations allows for monitoring of T2DM via visceral somatic reflexes. A recent pilot case-control study attempted to determine the reflective cord levels for patients with T2DM. They did not confirm osteopathic palpatory findings at spinal levels T5 through T11 (visceral somatic innervation for the pancreas), but they did find an association between T2DM and tissue changes at spinal levels T11 through L2 on the right side.

These findings support the argument that T2DM is not merely a pancreatic disease but a multisystem disease that will manifest somatically throughout the body. Changes in the soft tissue and fascial structures over time may initiate somatic manifestations. Specifically, one study found that patients with T2DM have increased tissue edema and bogginess in their posterior cervical spine, which is theorized to be due to an increase in extracellular fluid caused by elevated glucose levels. This area needs further study and elucidation.

When healthy, the musculoskeletal system is central to glucose and insulin regulation, and it can provide information about systemic disease. When the body is overwhelmed with disease, it can be deleterious to a person’s overall health and well-being.

**People with T2DM are unlikely to experience hypoglycemia as a result of physical activity alone.**

When physicians take the time to recommend physical activity, it can be effective in stimulating behavioral change. Pedometer-based programs specifically have been shown to be effective. In addition, motivational interviewing in conjunction with a weight loss program have been shown to be beneficial toward weight loss in women with T2DM. Motivational interviewing involves individual sessions focused on ambivalence to change where the counselor employs reflective listening and objective feedback. Such strategies can be very effective in the management of chronic disease. Central to the success of motivational interviewing is willingness of physicians to spend a few minutes of a patient’s appointment listening to physical activity goals and providing appropriate feedback.

**Promoting Patient Behavior Change**
As stated in the fourth tenet, a rational treatment approach to a disease, including T2DM, is based upon the understanding of the first 3 osteopathic tenets. Thus, osteopathic physicians have the opportunity to educate and engage their patients in self-care and diabetes self-management. Despite knowledge of the beneficial effects of physical activity, most people with T2DM are not physically active, and physicians do not recommend physical activity often enough. Seventy-three percent of patients with T2DM ever receive counseling from a physician on physical activity, and those who do receive counseling receive it during a minority of patient visits.

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**Hyperglycemia and Hypoglycemia and Consideration With Physical Activity**
Many people with diabetes are told not to exercise when their glucose level is high (>250 mg/dL). This advice is sound for patients with type 1 diabetes, as there can be a paradoxical increase in the glucose level with exercise. However, this glucose increase is much less likely to occur in patients with T2DM. In fact, exercise with hyperglycemia is likely to be beneficial (as long as the person is not acutely symptomatic with polyuria and polydipsia). The American Diabetes Association and the American College of Sports Medicine recommend that exercise is permitted in a person with T2DM who is not acutely symptomatic (Figure 2).

People with T2DM are unlikely to experience hypoglycemia as a result of physical activity alone. A normal response to glucose lowering is a reduction in endogenous insulin secretion and an increase in glucagon secretion. The primary mechanisms are further supported by increases in epinephrine, cortisol, and growth hormone if the glucose continues to drop lower. The risk of hypoglycemia is higher if the person is receiving a sulfonylurea or insulin. In this scenario, physical activity is still recommended, but the person is advised to monitor glucose before and after exercise and ingest adequate carbohydrates during and after exercise to prevent hypoglycemia.

**Physical Activity in People With T2DM Complications**
The benefits of physical activity extend into even the later stages of diabetes. People who have cardiovascular disease and T2DM can continue to participate in physical activity, but those who have moderate to high risk should first be enrolled in a cardiac rehabilitation program. In fact, physical activity is specifically advised for people with T2DM and peripheral arterial disease. There are no limitations to physical activity in those with nephropathy, provided that the blood pressure...
is reasonably controlled. Exercise is even helpful in people with advanced renal disease, including those undergoing dialysis.47

Even people with T2DM and peripheral neuropathy (without active ulceration) can participate in moderate physical activity. Moderate walking will not increase risk of foot ulceration or return of ulcers in those who have had these conditions before.48 However, those with uncontrolled proliferative retinopathy and accelerated hypertension should avoid activities that increase intraocular pressure and could potentially increase the risk of hemorrhage.

**Osteopathic Manipulation and the Management of T2DM**

Treatment with osteopathic manipulative treatment (OMT) can serve as an adjunct to the current methods of T2DM management. Overall, osteopathic medical literature is limited regarding evidence of OMT and management of T2DM. However, the evidence that has been published is encouraging.

One small study49 indicated that OMT may be beneficial in lowering glucose levels as well as increasing insulin secretion from the pancreas. In addition, OMT can reduce diabetes-related complications, including adhesive capsulitis.50 The current standard of care for adhesive capsulitis is corticosteroid injection, physiotherapy, or both, and surgical manipulation with refractory cases.51 A comparative study is needed to determine the true importance of OMT for the management of this condition.

Bilateral carpal tunnel syndrome can also be a complication of diabetes, with a greater prevalence in individuals with diabetes compared to the healthy population.37,52 One small study53 indicated that OMT to the wrist increases the length of the transverse carpal ligament and thus is indicated for carpal tunnel syndrome. Therefore, OMT can potentially prevent adhesive capsulitis and carpal tunnel syndrome by maintaining mobility and range of motion in the upper extremity. The Spencer technique specifically has been shown to increase overall range of motion in elderly patients with common shoulder problems.54

**Conclusion**

Andrew Taylor Still, MD, DO, once said, “To find health should be the object of the doctor. Anyone can find disease.”55 An osteopathic approach to T2DM should focus on helping patients live a healthy lifestyle (limiting noxious stimuli), encouraging physical activity (to help disease prevention and maximizing physical function), and early identification of complications (with adjunctive assistance with osteopathic palpatory diagnosis).

**References**


**Figure 2. Evidence statements on exercise and type 2 diabetes mellitus.**46 The American College of Sports Medicine (ACSM) evidence levels are as follows: A, randomized controlled trials (overwhelming evidence) with consistent pattern of findings; B, few randomized controlled trials (limited evidence) with limited or inconsistent data; C, nonrandomized, observational trials; D, panel consensus judgment. The American Diabetes Association (ADA) evidence levels are as follows: A, well-conducted, generalizable, randomized controlled trials that are adequately powered; B, well-conducted cohort studies; C, poorly controlled or uncontrolled studies; E, expert consensus or clinical experience. **Abbreviation:** NA, not available.


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