

Moving Beyond Cardio: The Value of Resistance Training, Balance Training, and Other Forms of Exercise in the Management of Diabetes

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■ **IN BRIEF** Traditionally, aerobic training has been a central focus of exercise promotion for diabetes management. However, people with diabetes have much to gain from other forms of exercise. This article reviews the evidence and recommendations on resistance, balance, and flexibility training, as well as other, less traditional, forms of exercise such as yoga and Tai Chi.

Health-related physical fitness is “the ability to perform daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and meet unforeseen emergencies” (1). Although cardiorespiratory capacity is a key part of physical fitness, improving and maintaining other components of fitness, such as strength, flexibility, and balance, are also of primary importance to health and longevity. Muscular fitness has tended to receive less attention than cardiorespiratory fitness as a prescription for improving overall and diabetes-related health. Activities that improve muscular fitness can slow the age-related loss of muscle mass (sarcopenia), improve mobility, and enhance functional status, all of which are significant health benefits to the aging population with diabetes (2,3).

American Diabetes Association (ADA) guidelines (4) recommend that people with diabetes accumulate at least 150 minutes/week of aerobic exercise, plus at least two sessions per week of resistance exercise (strength training). Most adults with type 2 diabetes fail to meet the minimum recommended level of aerobic activity, and even fewer are meeting the recommendations for

muscular fitness. For example, in one population-based survey (5), 55% of respondents reported engaging in walking for exercise, whereas only 12% reported engaging in resistance training. The purpose of this article is to highlight the importance and benefits of forms of exercise training other than aerobic exercise, in hopes of moving beyond a cardio-centric view of promoting exercise in adults with diabetes. Muscular fitness activities can include resistance, balance, and flexibility training, as well as other alternative forms of exercise such as yoga and Tai Chi.

Resistance Training

Resistance, or strength, training increases muscular fitness, which includes both muscular strength and muscular endurance. Muscle strength is the ability of the muscle to exert force, whereas muscle endurance is the ability of the muscle to continue to perform without fatigue (1). This form of training includes exercises performed using weights, weight machines, resistance bands, or one’s own body weight as resistance (e.g., pushups and squats). Regular resistance training can increase muscular strength, muscular endurance, and functional capacity and has been shown to improve

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musculoskeletal health, maintain independence in performing daily activities, and reduce the possibility of injury (6–8). Low muscular strength is associated with greater risks of disability, morbidity, and mortality (9). In a large cohort study, men with low muscular strength had increased all-cause mortality (23%) (10), cancer mortality (23%) (10,11), and cardiovascular disease (CVD) mortality (29%) (10) compared to men with higher strength. Moreover, diabetes is an independent risk factor for low muscular strength (12) and for accelerated decline in muscle strength and functional status over time (13), highlighting the need to promote the preservation of strength within this population.

Biological aging is typically associated with a loss of lean body mass, particularly of skeletal muscle. Observational studies indicate that there is a gradual reduction in skeletal muscle and strength starting in the third decade of life, with a more rapid absolute decline after the fifth decade (14,15).

Older patients with type 2 diabetes have an accelerated decline in muscle mass and strength compared to age-matched nondiabetic control subjects (16,17). Resistance training can delay, prevent, and, in some cases, reverse the effects of sarcopenia (18,19). Furthermore, resistance training can promote the maintenance of muscular strength and enhance mobility and functional independence further into old age (3,20). Resistance training has been shown to increase lean muscle mass (21) and prevent or limit the loss of lean body mass in individuals who lose weight (22), and other studies have demonstrated that resistance training can improve bone mineral density (23,24), leading to the prevention of osteoporosis. In a systematic review, Gordon et al. (25) reported that, of seven randomized, controlled trials (RCTs), all but one reported strength improvements of at least 50% in subjects with type

2 diabetes after completing resistance training.

Many types of exercise can acutely improve insulin action in people with diabetes, but resistance training can be particularly beneficial over time because of its ability to increase and maintain muscle mass. The main tissues in the body that are sensitive to insulin are muscles and adipose cells; by increasing the quantity and insulin sensitivity of skeletal muscles with resistance exercise, most individuals can better manage blood glucose levels and body weight (20). Several studies have demonstrated that resistance training can improve glycemic control in people with type 2 diabetes. A systematic review of RCTs concluded that resistance training improves glycemic control (as reflected by reduced A1C), decreases insulin resistance, and increases muscular strength in adults with type 2 diabetes (25). In a more recent meta-analysis, Umpierre et al. (26) reported a 0.57% reduction in A1C in four studies comparing resistance training alone to a control. Such training improves overall glycemic control and insulin sensitivity through a number of training adaptations, including increased levels of glucose transporter 4, insulin receptors, protein kinase B, glycogen synthase, and glycogen synthase total activity in trained muscles after acute training (27,28).

There have been relatively few randomized trials of resistance training in people with type 1 diabetes. D'Hooge et al. (29) randomized 16 children to 20 weeks of combined aerobic and resistance training or no exercise training. They found no impact on A1C, but substantial reductions in insulin dose in the group randomized to exercise. Ramalho et al. (30) randomized 13 adolescents and adults with type 1 diabetes to either aerobic exercise ($n = 7$) or resistance exercise ($n = 6$). A1C decreased 0.6 percentage points in the resistance training group and increased 1.1 percentage points in the

aerobic training group, but the difference was not statistically significant. Insulin doses were reduced in both groups, suggesting decreased insulin resistance. Acutely, resistance exercise causes less hypoglycemia than aerobic exercise (31), and performing resistance exercise before aerobic exercise causes less hypoglycemia than performing aerobic exercise before resistance exercise (32). The article by Jane E. Yardley and Ronald J. Sigal in this *Diabetes Spectrum* From Research to Practice section (p. 32) offers additional details on this topic.

The design of a resistance training program should consider the experience, functional ability, and goals of the individual. Ideally, a strength training program should include several characteristics, including the use of concentric (muscle-shortening contractions), eccentric (during which a muscle lengthens while it is under contraction), and isometric (contraction of a muscle without changing length) muscle actions, along with bilateral and unilateral single- and multiple-joint exercises. To allow for optimal preservation of exercise intensity, large muscle-group exercises should be performed before small muscle-group exercises, multiple-joint exercises should precede single-joint exercises, and higher-intensity exercises should come before lower-intensity exercises (2). Resistance training is recommended to be performed on a minimum of two, and more ideally three, nonconsecutive days per week (4,33–35). In general, resistance training should start at a low intensity and progress slowly enough to prevent injury and motivational issues. Table 1 outlines a sample resistance training program.

Combined Resistance and Aerobic Exercise Training

There is evidence to suggest that performing both resistance training and aerobic training (i.e., “combined training”) is the most beneficial type of training for people with type 2 diabetes. The combination of aero-

TABLE 1. Sample Resistance Training Program

Mode	Free weights, weight or resistance machines, resistance bands, isometric exercises, or calisthenics using body weight as resistance
Intensity	Moderate to vigorous (50–80% of one-repetition maximum)
Duration	One to three sets of 8–15 repetitions per set, including at least 5–10 exercises that work the major muscle groups
Frequency	At least two, but ideally three, nonconsecutive days per week
Progression	One set of 10–15 repetitions to fatigue initially, progressing to 8–10 harder repetitions, and finally to three sets of 8–10 repetitions to fatigue
Sample Weight Exercises	
<ul style="list-style-type: none"> • Seated row • Bench press • Leg press • Triceps extension • Seated biceps curl • Leg curls • Leg extension • Shoulder press • Abdominal crunches 	

Adapted from Ref. 37.

bic and resistance exercise improves glycemic control and reduces several cardiovascular risk factors more than either type of exercise alone. An early meta-analysis (36) reported that aerobic, resistance, and combined training reduced A1C levels by 0.7, 0.5, and 0.8%, respectively. Subsequent to this, the effect of combined training has been demonstrated in two large trials (22,37). In the Diabetes Aerobic and Resistance Exercise (DARE) trial (37), 251 previously inactive adults with type 2 diabetes and a median baseline A1C of 7.5% were randomized to aerobic exercise training, resistance exercise training, combined aerobic and resistance training, or a waiting-list control group. The combined training group performed the full aerobic training program plus the full resistance training program, thereby undergoing more weekly time in exercise than the other groups. Absolute A1C changes compared to control were –0.51% in the aerobic training group, –0.38% in the resistance training group, and –0.97% in the combined aerobic and resistance training group. Resistance

exercise training, either alone or in combination with aerobic exercise training, reduced levels of atherogenic remnant-like particles (38) and also significantly improved vitality and mental health dimensions of quality of life compared to either aerobic exercise training alone or the nonexercise control condition (39). Combined exercise was also superior to aerobic or resistance exercise alone in its impact on quality-adjusted life expectancy (40), according to the U.K. Prospective Diabetes Study Outcomes Model (41).

In the second study, the Health Benefits of Aerobic and Resistance Training in Individuals With Type 2 Diabetes (HART-D) trial (22), participants with type 2 diabetes who were 30–75 years of age were randomized to thrice-weekly aerobic training, resistance training, combined training, or a control condition. Unlike in the DARE trial, the combined group performed smaller amounts of aerobic and resistance exercise than those performing just one type of exercise, such that the total amount of weekly exercise time was similar among the

three groups, and no efforts were made to minimize dietary or medication co-intervention. The absolute reduction in A1C in HART-D was significantly lower for the combined group compared to the control group (–0.34%), but not when compared to aerobic (–0.24%) or resistance (–0.16%) exercise. The combined group also had the greatest decrease in the use of antidiabetic medication. This trial provided additional support for combined aerobic and resistance exercise rather than either type of exercise alone, when total exercise time was equivalent.

However, if strength gains are an individual's primary goal, undertaking combined training may not be as effective as strength training alone. For example, muscular strength gains were assessed in the DARE trial in individuals performing resistance training or resistance plus aerobic training (42). Those doing only resistance training experienced greater increases in upper- and lower-body strength. Thus, although both types of training can lead to improved strength over 6 months, strength gains are greater with resistance training alone. It has been suggested that the aerobic component of combined training may induce an acute state of local fatigue (43), leading to an insufficient training stimulus when performing aerobic and resistance training on the same day. Fatigue effects have been shown whether aerobic training is performed before or after resistance training (44). Additionally, studies in healthy individuals have suggested that alterations in neural recruitment patterns (45) and differences in cortisol responses (46,47) leading to attenuation effects on anabolic hormones (e.g., testosterone and growth hormone) may also play a role in the differences in strength improvements.

Another form of combined training is “circuit training,” one form of which occurs when aerobic training and resistance training are alternated, and each is usually performed for a

given amount of time (e.g., 45–60 seconds). To date, there have not been many studies evaluating this mode of training, although one study by Maiorana et al. (48) evaluated the effects of an 8-week circuit training program in 16 subjects with type 2 diabetes. They reported significant improvements in heart rate response, cardiorespiratory fitness, body composition, and A1C. Although these results are promising, more studies of longer duration and with larger sample sizes of people with diabetes are needed.

Other Forms of Resistance Exercise

To date, the majority of published studies have carried out resistance exercise using weight machines or free weights. Accordingly, the evidence is much more robust for these types of training and cannot necessarily be generalized to other types of resistance exercise such as resistance bands or exercises using only one's own body weight. In real-world practice, training with elastic resistance bands is attractive because of lower associated costs and minimal equipment requirements. In addition, resistance bands offer easier access to strength training and greater feasibility of home-based training.

Although the use of resistance bands is appealing, their efficacy within the diabetes population is unclear. In a recent meta-analysis (49), we identified seven trials evaluating the use of resistance bands in people with type 2 diabetes. Most studies reported increases in strength with resistance band training, but A1C changes were variable. The overall A1C change between resistance band training and the control condition was nonsignificant (−0.18%). In the identified studies, resistance band training did not significantly affect upper-extremity or hand-grip strength, but significantly increased strength in the lower extremities. There were several serious limitations to the identified

studies, including small sample sizes, inadequate durations of the training protocol, and limited room for progression. Given the limitations in the evidence, the current widespread adoption of resistance band training in exercise programs designed for people with diabetes may be premature. However, the low cost and easy accessibility of resistance band exercise make it attractive, if it is indeed effective. There is, therefore, a need for additional, higher-quality research evaluating resistance band exercise training.

Resistance Training Precautions

There are several precautions to consider when prescribing resistance training to patients with diabetes. For people with diabetes who want to begin resistance training workouts, no clear evidence is available to determine whether a pre-exercise evaluation involving graded exercise stress testing is necessary or beneficial before participation in this type of exercise. Moreover, coronary ischemia is less likely to occur during resistance training than during aerobic exercise eliciting the same heart rate, and resistance exercise may not induce ischemia at all (50,51). For example, even in men in cardiac rehabilitation programs and with known coronary ischemia and electrocardiogram (ECG) changes inducible by moderate aerobic exercise, no evidence of angina, ST depression, abnormal hemodynamics, ventricular dysrhythmias, or other complications was documented during high-intensity resistance workouts (52). A study of 12 men with known coronary ischemia and ECG changes inducible by moderate aerobic exercise found that even maximal-intensity resistance exercise did not induce ECG changes (50).

Until the mid-1990s, resistance training was generally not prescribed to anyone with CVD because it was feared that increases in blood pressure would put the individual at increased risk for an adverse cardiac

event. Resistance training, however, is now recommended for individuals with known CVD, including even those who have suffered a myocardial infarction or stroke. Such individuals experience less angina (chest pain due to ischemia) during resistance training than during aerobic treadmill training (50). During resistance work, both systolic and diastolic blood pressures rise in parallel, possibly helping to maintain coronary perfusion, whereas in aerobic exercise, systolic pressure rises significantly more than diastolic pressure. There is also a lesser rise in cardiac output with resistance training and more rest between resistance sets compared to continuous aerobic exercise bouts (53). Thus, for individuals who are diagnosed with coronary artery disease, moderate weight training actually may be a safer activity than most high-intensity aerobic exercise. In addition, a randomized trial demonstrated that resistance training increased quality of life in patients undergoing cardiac rehabilitation (54).

With regard to glycemic balance, in individuals whose diabetes is controlled by lifestyle modification or oral antidiabetic agents, the risk of developing hypoglycemia during resistance exercise is minimal, and most individuals will not need supplemental carbohydrates or other regimen changes. Although resistance training has a long-term impact on glycemic control similar to that of aerobic exercise, the acute effects of a single bout of this type of exercise result in a lower risk for both post-exercise and late-onset hypoglycemia than aerobic training in adults with type 2 (55) or type 1 diabetes (31). Because the risk of hypoglycemia is low, monitoring blood glucose levels before and after a resistance training session is most likely unnecessary. However, if an individual on insulin or insulin secretagogues is new to this type of training, it may be useful to monitor blood glucose levels for initial sessions because individual glycemic responses may vary.

Retinopathy is a concern, and those with pre-proliferative or proliferative retinopathy should be treated and stabilized before starting a resistance exercise regimen.

Balance Training

Normal aging is associated with slower cognitive processing (56), slower postural reactions (57), and decreased muscle strength (58), all of which are essential for optimal balance (59). The ability to optimally control one's balance is essential for mobility, avoidance of disability, and preservation of independence in older people. Maintaining balance and preventing falls is a significant concern in older adults, particularly those with diabetes, and balance training is an important intervention to reduce the risk of falling (60).

Causes of Loss of Balance and Falls in Diabetes

Older people with diabetes must contend with both age-related declines in balance control and health-related issues associated with diabetes. Older adults with type 2 diabetes, on average, have impaired balance, slower reactions, impairments in gait, and, consequently, a higher risk of falling than their nondiabetic counterparts (60–62). Diabetes-related complications such as peripheral neuropathy, visual deficits, cognitive impairments, autonomic dysfunction with orthostatic hypotension, and the use of various medications that can cause lightheadedness and instability can all have an additive effect on the risk of falling.

Diabetic neuropathy and its associated decline in sensory function are major contributing factors to the overall increase in falls risk in people with diabetes. Neuropathy develops as the result of chronic hyperglycemia, microvascular insufficiency, oxidative stress, and advancing age (63). One of the most common forms of neuropathy is distal symmetric diabetic polyneuropathy, which affects sensation and balance at the ankles and feet. The loss of nerve functioning

can have dramatic implications for standing and walking tasks; people with diabetic neuropathy can exhibit increased postural motion and slower gait speed, with increased stride time variability (64–67). Additionally, there is slowing of reaction time, loss of ability to prevent progression to a fall after its initiation, and dorsiflexion weakness, all of which increase susceptibility to falls (60,68).

Cognitive decline resulting from aging and diabetes is another factor contributing to instability, particularly when it is related to executive functioning, which is defined as a set of cognitive skills that are necessary to plan, monitor, and execute a sequence of goal-directed complex actions (69). Studies have reported an increased risk of cognitive impairment and dementia in older patients with diabetes (70), and diabetes itself has been recognized as an independent risk factor for the development of cognitive impairment in large, prospective, population-based studies with follow-up durations of up to 18 years (71). Changes in executive functioning have been shown to be associated with gait performance (72), and falls in older people have been associated with changes in the pre-frontal cortex, leading to failures of executive control (69).

Another significant risk factor for falls is the use of medication, and particularly the use of psychotropic medications and polypharmacy (i.e., the use of four or more medications simultaneously). The American Geriatric Society states that evidence supports withdrawal of psychotropic medication to reduce falls (73). Although some clinicians believe that selective serotonin reuptake inhibitors (SSRIs) are generally safer to use in older adults than tricyclic antidepressants with regard to falls prevention, SSRIs may increase falls risk as much as, or even more than, the older tricyclic antidepressants (74). Reducing psychotropic medication as a single intervention has been found to reduce the fall rate by 66% (75). Assessment,

adjustment, and discontinuation of some medications as part of a multifactorial intervention have also been found to be effective in reducing falls (73).

Benefits of Balance Training

Unfortunately, many people who are at risk of falling develop a fear of falling, which results in a further limitation of activity, leading to reduced mobility and decreased physical fitness (76). Although older individuals with diabetes often exhibit an increased risk of falling, exercise training interventions can significantly improve their balance and gait and reduce their risk of falling (77). Morrison et al. (60) demonstrated that a 6-week program of thrice-weekly, supervised balance and resistance training (Table 2) had positive effects on balance, proprioception, lower-limb strength, and reaction time. This program resulted in a decreased falls risk in older individuals with type 2 diabetes, regardless of whether they had neuropathy. An updated Cochrane review (78) included 59 studies evaluating the effectiveness of exercise in reducing falls risk and reported a 29% reduction in the rate of falls when comparing group exercise interventions (mostly resistance and balance training) to a nonexercise control group. This review also reported a 28% reduction in falls with Tai Chi exercise classes. Overall, the authors concluded that home-based, group-based, and Tai Chi exercise programs reduce the rate of falls and the risk of falling. Accordingly, most older adults are advised to undertake exercises that maintain or improve balance two to three times per week (2,73). Many lower-body and core-strengthening exercises concomitantly improve balance and may be included as a part of both resistance and balance training.

Flexibility Training

Flexibility, the ability to move a joint through a complete range of motion, is considered by the American College of Sports Medicine to be an important

TABLE 2. Sample Balance Training Program

Lower-limb stretches	
Bilateral calf raises	Two sets of 20 repetitions
Single-leg calf raises	Two sets of 10–15 repetitions
Abdominal crunches	One to three sets of 10–15 repetitions
Lower back extensions and bilateral single-leg extensions, or “Supermans” (lying prone)	Two to three repetitions
Standing balance exercises	
Tandem standing (one foot in front of the other) with eyes closed on firm surface	Two sets, 15 seconds each
Single-leg standing with eyes closed on a firm surface	Two sets, 15 seconds each
Forward-leaning activity that involves standing on one leg with hands on hips and leaning forward	Two sets of 10 repetitions, 15 seconds each
Frequency	Three times per week

*Adapted from Ref. 60. Participants in this study were 50–75 years of age.

ant part of physical fitness (2). Some types of physical activity, along with various activities of daily living, require more flexibility than others. In the elderly and people with all types of diabetes, limited joint mobility is frequently observed, likely resulting from formation of advanced glycation end-products (AGEs), which accumulate in the plasma and tissues during the normal aging process, but to an accelerated degree in diabetes (79). The most extensive accumulation of AGEs occurs in tissues that contain proteins with low turnover such as the collagen in the extracellular matrix of articular capsule, ligaments, and muscle-tendon units. An increase in collagen cross-linking alters the mechanical properties of these tissues, resulting in a decrease in elasticity and tensile strength and an increase in mechanical stiffness. Because of the potential for AGE-related damage with fluctuations in blood glucose levels, people with diabetes are more prone to developing structural changes to joints that can limit movement. These include shoulder adhesive capsulitis (“frozen shoulder”), carpal tunnel syndrome, metatarsal fractures, and neuropathy-related joint disorders (e.g.,

Charcot foot), among others. Aging itself also results in a reduction in flexibility and joint movement (79).

Many guidelines (2,7,80,81) recommend flexibility training as an adjunct to aerobic and resistance training. However, it is unknown whether flexibility training reduces the risk of acute, exercise-related injury (82,83). Stretching exercises are effective in increasing flexibility and thereby may allow people to more easily do activities that require greater flexibility. However, unlike aerobic and resistance training, the benefits, if any, of flexibility training on diabetes management are not clear. We are not aware of any studies in people with diabetes demonstrating a beneficial impact of a pure stretching program on metabolic control, injury risk, or any diabetes-related outcome. The ADA recommendation regarding flexibility training is that it may be included as part of a physical activity program, but not as a substitute for other training (4).

Flexibility exercises, combined with resistance training, have been shown to increase joint range of movement in individuals with type 2 diabetes (84), and a more recent study suggests that flexibility as a

component of a balance training program can reduce the risk of falls in older individuals with diabetes (60). One study in nondiabetic older adults comparing an aerobic and resistance training program to a pure flexibility program reported that the flexibility group reported better bodily pain scores, whereas the aerobic and strength group had better endurance and strength scores (85). Regular stretching can be considered an option to include in the fitness plan, in particular for older adults. However, time spent on flexibility exercise should not be counted toward meeting the aerobic or muscle-strengthening guidelines.

Alternative Forms of Fitness Training: Yoga and Tai Chi

Nontraditional exercises have become increasingly popular in recent years, both in practice and in the literature. Both yoga and Tai Chi are multifaceted and involve varying combinations of flexibility, balance, and resistance exercise as part of the instruction. Gentle movement such as that undertaken during both of these exercise modalities can benefit flexibility, and both activities can assist adults in meeting the recommended levels of participation in flexibility exercise.

Benefits of Yoga

Yoga has been investigated for its potential to improve blood glucose management. In a recent systematic review and meta-analysis (86), 11 studies were identified evaluating the effects of yoga in people with type 2 diabetes. In meta-analysis of seven of these studies, relative to usual care, yoga improved A1C, with a mean difference of -0.49% (95% CI -1.03 to -0.05). It should be noted that the quality of these studies was low, there was significant heterogeneity, and the risk of bias using the Cochrane risk of bias tool (87) was high or unclear. Within the identified studies, the training regimens varied greatly, with many involving practice 5–7 days/week for >60 min-

utes per session. Other systematic reviews of trials evaluating yoga as an intervention for type 2 diabetes found modest reductions in A1C and fasting glucose (88,89) but stated that the limitations characterizing most yoga studies preclude drawing firm conclusions.

Participation in yoga may provide other health benefits. A recent Cochrane review of yoga for the primary prevention of CVD (90) reported that small, beneficial effects were seen in HDL cholesterol, triglycerides, and diastolic blood pressure, yet the effect on LDL cholesterol was uncertain. Again, the trials included were at risk of bias, and larger, more methodologically rigorous trials are needed. Given the limited evidence to date, the authors of that review were unable to determine the effects of yoga in CVD prevention.

The metabolic cost of yoga also has been investigated in several studies. Exercise intensity can be expressed in metabolic equivalents (METs), with 1 MET being the energy expenditure while sitting quietly at rest. One study reported that the average metabolic cost for the majority of yoga poses was 1–2 METs in young male Hatha yoga instructors (91), and another study found that Hatha yoga required ~55% lower metabolic costs than walking at 3.5 mph on a treadmill (92). Another study concluded that the metabolic cost of Hatha yoga averaged across the entire session was similar to walking at 1.9 mph (93), much less than the moderate level of intensity recommended by guidelines. All of these studies concluded that Hatha yoga was a low-intensity activity and would not contribute to cardiovascular fitness.

The health benefits of yoga may lie more in its muscular fitness and flexibility effects, as well as in its relaxation and stress management properties. However, the wide array of yoga styles, practices, and applications makes it hard to

draw firm conclusions regarding its effectiveness.

Benefits of Tai Chi

Tai Chi originated in China and evolved from a form of martial arts. It involves a series of movements performed in a slow, focused manner and accompanied by deep breathing and is considered a form of moving meditation (94). The effects of Tai Chi on glucose control in people with type 2 diabetes have been mixed. Some studies have reported reductions in A1C, whereas others have not. Recent systematic reviews (95,96) found that Tai Chi had no significant effects on glycemic control. Yan et al. (96) pooled four RCTs and five nonrandomized, controlled trials and reported a nonsignificant weighted mean difference of -0.19% ($P = 0.09$) A1C for the RCTs, whereas the pooled change in A1C for the nonrandomized trials was -0.41% and significant. Because most Tai Chi studies have had small sample sizes, larger and better-designed randomized trials are needed to clarify its potential health effect for people with diabetes.

A recent Cochrane systematic review (97) concluded that, although some beneficial effects of Tai Chi on CVD risk factors may exist, they were inconsistent across studies, and no conclusions could be drawn regarding its effectiveness. Of note, in 374 nondiabetic subjects, a 12-week Tai Chi or walking exercise intervention (98) produced similar and significant beneficial effects on body composition, aerobic fitness, and fasting blood glucose. However, this study also reported that, although Tai Chi and walking both elicited significant cardiorespiratory responses and energy expenditures, walking elicited an ~46% higher metabolic cost than Tai Chi. Another meta-analysis (99) reported a wide range of exercise intensities associated with Tai Chi, ranging from 1.5 to 4.6 METs, which may explain some of the variance in outcomes.

Tai Chi has been reported to be beneficial for balance, mobility, and falls prevention in some studies. In one 6-month study, weekly Tai Chi training improved plantar sensation and balance in elderly adults with and without diabetes who had a large plantar sensation loss (100). In another study (101), diabetic participants with peripheral neuropathy were assigned (not randomized) to a Tai Chi group or a control group. After 12 weeks of training, the Tai Chi group showed improvement in balance and neuropathic symptoms, as well as glucose control and quality of life. However, the dropout rate was high (34%).

In an attempt to consolidate the overall evidence on Tai Chi, a systematic review of systematic reviews (102) was performed. The authors concluded that the evidence for Tai Chi was contradictory for many outcomes. However, for reducing the risk of falls and improving psychological health, particularly in the elderly, the evidence was convincingly positive. The aforementioned Cochrane review supported this and found that Tai Chi was effective in reducing falls in older individuals (78).

To date, evidence for the beneficial effects of yoga and Tai Chi is not as extensive or as supportive as for aerobic and resistance exercise. Current diabetes and exercise guidelines (4,35) are unable to conclusively support the inclusion of yoga or Tai Chi because of the variable results with regard to glycemic benefits. Such exercises can be included based on individual preferences to increase flexibility, muscular strength, and balance, as well as for the psychological benefits, including stress reduction and relaxation. However, their effects on aerobic fitness are likely minimal, and their impact on glycemic control is variable.

Conclusion

Many different forms of exercise offer distinctive and substantial health benefits for people with diabetes.

Given that adults with diabetes are a heterogeneous group, ranging from fit and well to frail with many comorbidities and functional disabilities, many will need to start at a low dose and intensity of exercise training and gradually progress from there. An exercise regimen that promotes the accumulation of at least 150 minutes of moderate to vigorous aerobic activity per week, together with activities that build muscular strength two to three times per week, is recommended by most guidelines (4,33–35) to promote health.

Muscular fitness is a vital component of healthy aging and key for maintaining functional independence with age. Resistance training, ideally with free weights or weight machines, is an essential component of healthy living that helps to maintain muscle mass and functional independence. It should be recommended and promoted for most adults with diabetes. In discussing exercise goals with adults with diabetes, it is important to endorse exercise training that builds and sustains muscular fitness and to not solely promote aerobic activities. For older individuals, it may be advisable to also encourage exercises to improve balance. It is also important that individuals find activities that are at least acceptable to them, and hopefully enjoyable, so that they are more likely to sustain their exercise regimen over the long term.

Duality of Interest

No potential conflicts of interest relevant to this article were reported.

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