Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association

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POSITION STATEMENT

The adoption and maintenance of physical activity are critical foci for blood glucose management and overall health in individuals with diabetes and prediabetes. Recommendations and precautions vary depending on individual characteristics and health status. In this Position Statement, we provide a clinically oriented review and evidence-based recommendations regarding physical activity and exercise in people with type 1 diabetes, type 2 diabetes, gestational diabetes mellitus, and prediabetes.

Physical activity includes all movement that increases energy use, whereas exercise is planned, structured physical activity. Exercise improves blood glucose control in type 2 diabetes, reduces cardiovascular risk factors, contributes to weight loss, and improves well-being (1,2). Regular exercise may prevent or delay type 2 diabetes development (3). Regular exercise also has considerable health benefits for people with type 1 diabetes (e.g., improved cardiovascular fitness, muscle strength, insulin sensitivity, etc.) (4). The challenges related to blood glucose management vary with diabetes type, activity type, and presence of diabetes-related complications (5,6). Physical activity and exercise recommendations, therefore, should be tailored to meet the specific needs of each individual.

TYPES AND CLASSIFICATIONS OF DIABETES AND PREDIABETES

Physical activity recommendations and precautions may vary by diabetes type. The primary types of diabetes are type 1 and type 2. Type 1 diabetes (5%–10% of cases) results from cellular-mediated autoimmune destruction of the pancreatic β-cells, producing insulin deficiency (7). Although it can occur at any age, β-cell destruction rates vary, typically occurring more rapidly in youth than in adults. Type 2 diabetes (90%–95% of cases) results from a progressive loss of insulin secretion, usually also with insulin resistance. Gestational diabetes mellitus occurs during pregnancy, with screening typically occurring at 24–28 weeks of gestation in pregnant women not previously known to have diabetes. Prediabetes is diagnosed when blood glucose levels are above the normal range but not high enough to be classified as diabetes; affected individuals have a heightened risk of developing type 2 diabetes (7) but may prevent/delay its onset with physical activity and other lifestyle changes (8).

TYPES OF EXERCISE AND PHYSICAL ACTIVITY

Aerobic exercise involves repeated and continuous movement of large muscle groups (9). Activities such as walking, cycling, jogging, and swimming rely primarily on aerobic energy-producing systems. Resistance (strength) training includes exercises with free weights, weight machines, body weight, or elastic resistance bands. Flexibility exercises improve range of motion around joints (10). Balance exercises benefit gait and prevent falls (11). Activities like tai chi and yoga combine flexibility, balance, and resistance activities.

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BENEFITS OF EXERCISE AND PHYSICAL ACTIVITY

Aerobic Exercise Benefits

Aerobic training increases mitochondrial density, insulin sensitivity, oxidative enzymes, compliance and reactivity of blood vessels, lung function, immune function, and cardiac output (12). Moderate to high volumes of aerobic activity are associated with substantially lower cardiovascular and overall mortality risks in both type 1 and type 2 diabetes (13). In type 1 diabetes, aerobic training increases cardiorespiratory fitness, decreases insulin resistance, and improves lipid levels and endothelial function (14). In individuals with type 2 diabetes, regular training reduces A1C, triglycerides, blood pressure, and insulin resistance (15). Alternatively, high-intensity interval training (HIIT) promotes rapid enhancement of skeletal muscle oxidative capacity, insulin sensitivity, and glycemic control in adults with type 2 diabetes (16,17) and can be performed without deterioration in glycemic control in type 1 diabetes (18,19).

Resistance Exercise Benefits

Diabetes is an independent risk factor for low muscular strength (20) and accelerated decline in muscle strength and functional status (21). The health benefits of resistance training for all adults include improvements in muscle mass, body composition, strength, physical function, mental health, bone mineral density, insulin sensitivity, blood pressure, lipid profiles, and cardiovascular health (12). The effect of resistance exercise on glycemic control in type 1 diabetes is unclear (19). However, resistance exercise can assist in minimizing risk of exercise-induced hypoglycemia in type 1 diabetes (22). When resistance and aerobic exercise are undertaken in one exercise session, performing resistance exercise first results in less hypoglycemia than when aerobic exercise is performed first (23). Resistance training benefits for individuals with type 2 diabetes include improvements in glycemic control, insulin resistance, fat mass, blood pressure, strength, and lean body mass (24).

Benefits of Other Types of Physical Activity

Flexibility and balance exercises are likely important for older adults with diabetes. Limited joint mobility is frequently present, resulting in part from the formation of advanced glycation end products, which accumulate during normal aging and are accelerated by hyperglycemia (25). Stretching increases range of motion around joints and flexibility (10) but does not affect glycemic control. Balance training can reduce falls risk by improving balance and gait, even when peripheral neuropathy is present (11). Group exercise interventions (resistance and balance training, tai chi classes) may reduce falls by 28%−29% (26). The benefits of alternative training like yoga and tai chi are less established, although yoga may promote improvement in glycemic control, lipid levels, and body composition in adults with type 2 diabetes (27). Tai chi training may improve glycemic control, balance, neuropathic symptoms, and some dimensions of quality of life in adults with diabetes and neuropathy, although high-quality studies on this training are lacking (28).

BENEFITS OF AND RECOMMENDATIONS FOR REDUCED SEDENTARY TIME

Recommendations

- All adults, and particularly those with type 2 diabetes, should decrease the amount of time spent in daily sedentary behavior. **B**
- Prolonged sitting should be interrupted with bouts of light activity every 30 min for blood glucose benefits, at least in adults with type 2 diabetes. **C**
- The above two recommendations are additional to, and not a replacement for, increased structured exercise and incidental movement. **C**

Sedentary behavior—waking behaviors with low energy expenditure (TV viewing, desk work, etc.)—is a ubiquitous and significant population-wide influence on cardiometabolic health (29,30). Higher amounts of sedentary time are associated with increased mortality and morbidity, mostly independent of moderate-to-vigorous physical activity participation (31–35). In people with or at risk for developing type 2 diabetes, extended sedentary time is also associated with poorer glycemic control and clustered metabolic risk (36–39). Prolonged sitting interrupted by brief (≤5 min) bouts of standing (40–42) or light-intensity ambulation (41,43,44) every 20–30 min improves glycemic control in sedentary overweight/obese populations and in women with impaired glucose regulation. In adults with type 2 diabetes, interrupting prolonged sitting with 15 min of postmeal walking (45) and with 3 min of light walking and simple body-weight resistance activities every 30 min (46) improves glycemic control. The longer-term health efficacy and durability of reducing and interrupting sitting time remain to be determined for individuals with and without diabetes.

PHYSICAL ACTIVITY AND TYPE 2 DIABETES

Recommendations

- Daily exercise, or at least not allowing more than 2 days to elapse between exercise sessions, is recommended to enhance insulin action. **B**
- Adults with type 2 diabetes should ideally perform both aerobic and resistance exercise training for optimal glycemic and health outcomes. **C**
- Children and adolescents with type 2 diabetes should be encouraged to meet the same physical activity goals set for youth in general. **C**
- Structured lifestyle interventions that include at least 150 min/week of physical activity and dietary changes resulting in weight loss of 5%–7% are recommended to prevent or delay the onset of type 2 diabetes in populations at high risk and with prediabetes. **A**

Insulin Action and Physical Activity

Insulin action in muscle and liver can be modified by acute bouts of exercise and by regular physical activity (47). Acutely, aerobic exercise increases muscle glucose uptake up to fivefold through insulin-independent mechanisms. After exercise, glucose uptake remains elevated by insulin-independent (∼2 h) and insulin-dependent (up to 48 h) mechanisms if exercise is prolonged (48), which is linked with muscle glycogen repletion (49,50). Improvements in insulin action may last for 24 h following shorter duration activities (∼20 min) if the intensity is elevated to near-maximal effort intermittently (51,52). Even low-intensity aerobic exercise lasting ≥60 min enhances insulin action in obese, insulin-resistant adults for at least 24 h (53). If enhanced insulin action is a primary goal, then daily moderate- or high-intensity exercise is likely optimal (54).

Regular training increases muscle capillary density, oxidative capacity, lipid metabolism, and insulin signaling proteins (47), which are all reversible with detraining (55). Both aerobic and resistance training promote adaptations in skeletal muscle, adipose tissue, and liver associated with enhanced insulin action, even without weight loss (56,57). Regular aerobic training increases muscle insulin sensitivity in individuals with prediabetes (58) and type 2 diabetes (59) in proportion to exercise volume (60). Even low-volume training (expending just 400 kcal/week) improves insulin action in previously sedentary adults (60). Those with higher baseline insulin resistance have the largest improvements, and a dose response is observed up to about 2,500 kcal/week (60). Resistance training enhances insulin action similarly (56), as do HIIT and other modes (2,15–17). Combining endurance exercise with resistance exercise may provide greater improvements (61), and HIIT may be superior to continuous aerobic training in adults with diabetes (16).

Physical Activity in Adults With Type 2 Diabetes

The Look AHEAD (Action for Health in Diabetes) trial (62) was the largest randomized trial evaluating a lifestyle intervention in older adults with type 2 diabetes compared with a diabetes support and education control group. The intensive lifestyle intervention group targeted weight loss of at least 7% through a modest dietary energy deficit and at least 175 min/week of unsupervised exercise. Major cardiovascular events were the same in both groups, possibly in part due to greater use of cardioprotective medications in the diabetes support and education group (62). However, as reviewed by Pi-Sunyer (63), the intensive lifestyle intervention group achieved significantly greater sustained improvements in weight loss, cardiorespiratory fitness, blood glucose control, blood pressure, and lipids with fewer medications; less sleep apnea, severe diabetic kidney disease and retinopathy, depression, sexual dysfunction, urinary incontinence, and knee pain; and better physical mobility maintenance and quality of life, with lower overall health care costs. This trial provided very strong evidence of profound health benefits from intensive lifestyle intervention. Moreover, aerobic exercise clearly improves glycemic control in type 2 diabetes, particularly when at least 150 min/week are undertaken (64). Resistance exercise (free weights or weight machines) increases strength in adults with type 2 diabetes by about 50% (24) and improves A1C by 0.57% (64). A meta-analysis of 12 trials in adults with type 2 diabetes reported a greater reduction (difference of −0.18%) in A1C following aerobic compared with resistance training but no difference in cardiovascular risk marker reduction (65). For glycemic control, combined training is superior to either type of training undertaken alone (61,66). Therefore, adults with type 2 diabetes should ideally perform both aerobic and resistance exercise training for optimal glycemic and health outcomes.

Physical Activity in Youth With Type 2 Diabetes

Randomized trials evaluating exercise interventions in youth with type 2 diabetes are limited and inconclusive, although benefits are likely similar to those in adults. In the Treatment Options for Type 2 Diabetes in Adolescents and Youth (TODAY) study (67), youth aged 10–17 years with type 2 diabetes were stabilized on metformin and then randomized to metformin plus placebo, metformin plus rosiglitazone, or metformin plus lifestyle intervention and followed for a mean of 3.86 years. The lifestyle intervention included modest weight loss achieved through dietary energy restriction and increased physical activity (minimum 200 min/week of moderate to vigorous activity for most; >300 min/week for already active youth), along with metformin use. The rate of glycemic failure (A1C >8.0% or need to initiate insulin) was not significantly reduced in the lifestyle plus metformin group compared with metformin only or metformin plus rosiglitazone. Given the limited data in youth with type 2 diabetes, it is recommended that children and adolescents with type 2 diabetes meet the same physical activity goals set for youth in general (http://www.cdc.gov/physicalactivity/basics/children): a minimum 60 min/day of moderate-to-vigorous physical activity, including strength-related exercise at least 3 days/week.

Prevention and Treatment of Type 2 Diabetes With Lifestyle Intervention

Structured lifestyle intervention trials that include physical activity at least 150–175 min/week and dietary energy restriction targeting weight loss of 5%−7% have demonstrated reductions of 40%–70% in the risk of developing type 2 diabetes in people with impaired glucose tolerance (66). A recent systematic review of 53 studies (30 of diet and physical activity promotion programs vs. usual care, 13 of more intensive vs. less intensive programs, and 13 of single programs) that evaluated 66 lifestyle intervention programs reported that, compared with usual care, diet and physical activity promotion programs reduced type 2 diabetes incidence, body weight, and fasting blood glucose while improving other cardiometabolic risk factors (68). Trials evaluating less resource-intensive lifestyle interventions have also shown effectiveness (3), and adherence to guidelines is associated with a greater weight loss (69).

PHYSICAL ACTIVITY AND TYPE 1 DIABETES

Recommendations

- Youth and adults with type 1 diabetes can benefit from being physically active, and activity should be recommended to all. **B**
- Blood glucose responses to physical activity in all people with type 1 diabetes are highly variable based on activity type/timing and require different adjustments. **B**
- Additional carbohydrate intake and/or insulin reductions are typically required to maintain glycemic balance during and after physical activity. Frequent blood glucose checks are required to implement carbohydrate intake and insulin dose adjustment strategies. **B**
- Insulin users can exercise using either basal-bolus injection regimens or insulin pumps, but there

are advantages and disadvantages to both insulin delivery methods. **C**

- Continuous glucose monitoring during physical activity can be used to detect hypoglycemia when used as an adjunct rather than in place of capillary glucose tests. **C**

Physical Activity and Sports in Youth and Adults With Type 1 Diabetes

Youth experience many health benefits from physical activity participation (9). A meta-analysis of 10 trials in youth <18 years of age with type 1 diabetes found significant improvements in A1C in exercisers (70), and exercising more than three sessions/week for longer (>1 h/session) and doing both aerobic and resistance exercise may be beneficial (70). In adults, regular physical activity has been associated with decreased mortality (71). There is insufficient evidence on the ideal type, timing, intensity, and duration of exercise for optimal glycemic control.

Effects of Activity Type and Timing on Glycemic Balance

Blood glucose responses to physical activity in type 1 diabetes are highly variable (72). In general, aerobic exercise decreases blood glucose levels if performed during postprandial periods with the usual insulin dose administered at the meal before exercise (73), and prolonged activity done then may cause exaggerated decreases (74–76). Exercise while fasting may produce a lesser decrease or a small increase in blood glucose (77). Very intense activities may provide better glucose stability (22) or a rise in blood glucose if the relative intensity is high and done for a brief duration (≤10 min) (78). Mixed activities, such as interval training or team/individual field sports, are associated with better glucose stability than those that are predominantly aerobic (18,79–82), although variable results have been reported for intermittent, high-intensity exercise (80).

Management of Food and Insulin With Physical Activity

Variable glycemic responses to physical activity (72) make uniform recommendations for management of food intake and insulin dosing difficult. To prevent hypoglycemia during prolonged (≥30 min), predominantly aerobic exercise, additional carbohydrate intake and/or reductions in insulin are typically required. For low- to moderate-intensity aerobic activities lasting 30−60 min undertaken when circulating insulin levels are low (i.e., fasting or basal conditions), ~10−15 g of carbohydrate may prevent hypoglycemia (83). For activities performed with relative hyperinsulinemia (after bolus insulin), 30−60 g of carbohydrate per hour of exercise may be needed (84), which is similar to carbohydrate requirements to optimize performance in athletes with (85) or without (86) type 1 diabetes.

As recommended in Table 1, blood glucose concentrations should always be checked prior to exercise undertaken by individuals with type 1 diabetes. The target range for blood glucose prior to exercise should ideally be between 90 and 250 mg/dL (5.0 and 13.9 mmol/L). Carbohydrate intake required will vary with insulin regimens, timing of exercise, type of activity, and more (87), but it will also depend on starting blood glucose levels. As an alternative or a complement to carbohydrate intake, reductions in basal and/or bolus insulin dose should be considered for exercise-induced hypoglycemia prevention; lowering insulin levels adequately during activity may reduce or eliminate the need for carbohydrate intake. For example, a 20% reduction in basal insulin for individuals on multiple daily injections (MDI) can be made for doses both before and after exercise, but this strategy may not fully attenuate the decline in glucose during the activity (89). Continuous subcutaneous insulin infusion (CSII) users can reduce (90) or suspend (91) insulin delivery at the start of exercise, but this strategy does not always prevent hypoglycemia (91,92). Performing basal rate reductions 30−60 min before exercise may reduce hypoglycemia due to pharmacokinetics of rapid-acting insulin analogs used in CSII (93). For exercise performed within 2−3 h after bolus insulin via CSII or MDI, 25%−75% reductions in insulin may limit hypoglycemia (Table 2). Frequent blood glucose checks are required when implementing insulin and carbohydrate adjustments.

Table 1—Suggested carbohydrate intake or other actions based on blood glucose levels at the start of exercise

Pre-exercise blood glucose	Carbohydrate intake or other action
<90 mg/dL (<5.0 mmol/L)	• Ingest 15–30 g of fast-acting carbohydrate prior to the start of exercise, depending on the size of the individual and intended activity; some activities that are brief in duration (<30 min) or at a very high intensity (weight training, interval training, etc.) may not require any additional carbohydrate intake. • For prolonged activities at a moderate intensity, consume additional carbohydrate, as needed (0.5–1.0 g/kg body mass per h of exercise), based on blood glucose testing results.
90–150 mg/dL (5.0–8.3 mmol/L)	• Start consuming carbohydrate at the onset of most exercise (~0.5–1.0 g/kg body mass per h of exercise), depending on the type of exercise and the amount of active insulin.
150–250 mg/dL (8.3–13.9 mmol/L)	• Initiate exercise and delay consumption of carbohydrate until blood glucose levels are <150 mg/dL (<8.3 mmol/L).
250–350 mg/dL (13.9–19.4 mmol/L)	• Test for ketones. Do not perform any exercise if moderate-to-large amounts of ketones are present. • Initiate mild-to-moderate intensity exercise. Intense exercise should be delayed until glucose levels are <250 mg/dL because intense exercise may exaggerate the hyperglycemia.
≥350 mg/dL (≥19.4 mmol/L)	• Test for ketones. Do not perform any exercise if moderate-to-large amounts of ketones are present. • If ketones are negative (or trace), consider conservative insulin correction (e.g., 50% correction) before exercise, depending on active insulin status. • Initiate mild-to-moderate exercise and avoid intense exercise until glucose levels decrease.

Adapted from Zaharieva and Riddell (88).

Table 2—Suggested initial pre-exercise meal insulin bolus reduction for activity started within 90 min after insulin administration

Exercise intensity	Exercise duration	
	30 min	60 min
Mild aerobic (~25% VO_{2max})	−25%*	−50%
Moderate aerobic (~50% VO_{2max})	−50%	−75%
Heavy aerobic (70%−75% VO_{2max})	−75%	N-A
Intense aerobic/anaerobic (>80% VO_{2max})	No reduction recommended	N-A

Recommendations compiled based on four studies (94–97). N-A, not assessed as exercise intensity is too high to sustain for 60 min. *Estimated from study (95).

Use of CSII and MDI for Activity

Individuals using CSII or MDI as a basal-bolus regimen can exercise with few restrictions. CSII offers some advantages over MDI due to greater flexibility in basal rate adjustments and limiting postexercise hyperglycemia (98), with some limitations. For example, aerobic exercise may accelerate basal insulin absorption from the subcutaneous depot (74), whereas basal insulin glargine absorption is largely unaffected (99). Skin irritation, pump tubing, and wearing a pump that is visible to others can be concerns (100). In certain sports, such as basketball or contact sports, wearing pumps and other devices may be prohibited during competition. Frustration with CSII devices and exercise may lead to discontinuation of pump therapy (100).

Use of Continuous Glucose Monitoring With Activity

Continuous glucose monitoring (CGM) may decrease the fear of exercise-induced hypoglycemia in type 1 diabetes by providing blood glucose trends that allow users to prevent and treat hypoglycemia sooner (83). Although a few studies have found acceptable CGM accuracy during exercise (101–104), others have reported inadequate accuracy (105) and other problems, such as sensor filament breakage (103,104), inability to calibrate (102), and time lags between the change in blood glucose and its detection by CGM (106). Differences in sensor performance have also been noted (107–109). Although it is a potentially useful tool during and after exercise (110), CGM values have traditionally required confirmation by fingerstick glucose testing prior to making regimen changes, but approval of nonadjunctive use is likely forthcoming in the near future.

RECOMMENDED PHYSICAL ACTIVITY PARTICIPATION FOR PEOPLE WITH DIABETES

Recommendations

- Pre-exercise medical clearance is generally unnecessary for asymptomatic individuals prior to beginning low- or moderate-intensity physical activity not exceeding the demands of brisk walking or everyday living. **B**
- Most adults with diabetes should engage in 150 min or more of moderate-to-vigorous intensity activity weekly, spread over at least 3 days/week, with no more than 2 consecutive days without activity. Shorter durations (minimum 75 min/week) of vigorous-intensity or interval training may be sufficient for younger and more physically fit individuals. **B** for type 2 diabetes, **C** for type 1 diabetes
- Children and adolescents with type 1 or type 2 diabetes should engage in 60 min/day or more of moderate or vigorous intensity aerobic activity, with vigorous, muscle-strengthening, and bone-strengthening activities included at least 3 days/week. **C**
- Adults with diabetes should engage in 2–3 sessions/week of resistance exercise on nonconsecutive days. **B** for type 2 diabetes, **C** for type 1 diabetes
- Flexibility training and balance training are recommended 2–3 times/week for older adults with diabetes. Yoga and tai chi may be included based on individual preferences to increase flexibility, muscular strength, and balance. **C**
- Individuals with diabetes or prediabetes are encouraged to increase their total daily incidental (nonexercise) physical activity to gain additional health benefits. **C**
- To gain more health benefits from physical activity programs, participation in supervised training is recommended over nonsupervised programs. **B**

Pre-exercise Health Screening and Evaluation

The American College of Sports Medicine (ACSM) recently proposed a new model for exercise preparticipation health screening on the basis of *1*) the individual's current physical activity levels; *2*) the presence of signs or symptoms and/or known cardiovascular, metabolic, or renal disease; and *3*) the desired exercise intensity, all of which are risk modulators of exercise-related cardiovascular events (111). The ACSM no longer includes risk factor assessment in the exercise preparticipation health screening process. However, their recommendation is that anyone with diabetes who is currently sedentary and desires to begin physical activity at any intensity (even low intensity) should obtain prior medical clearance from a health care professional (111). We believe this recommendation is excessively conservative.

Physical activity does carry some potential health risks for people with diabetes, including acute complications like cardiac events, hypoglycemia, and hyperglycemia. In low- and moderate-intensity activity undertaken by adults with type 2 diabetes, the risk of exercise-induced adverse events is low. In individuals with type 1 diabetes (any age) the only common exercise-induced adverse event is hypoglycemia. No current evidence suggests that any screening protocol beyond usual diabetes care reduces risk of exercise-induced adverse events in asymptomatic individuals with diabetes (112,113). Thus, pre-exercise medical clearance is not necessary for asymptomatic individuals receiving diabetes care consistent with guidelines who wish to begin low- or moderate-intensity physical activity not exceeding the demands of brisk walking or everyday living.

However, some individuals who plan to increase their exercise intensity or who meet certain higher-risk criteria may benefit from referral to a health care provider for a checkup and possible exercise stress test before starting such activities (6). In addition, most adults with diabetes may also benefit from working with a diabetes-knowledgeable exercise physiologist or certified fitness professional to assist them in formulating a safe and effective exercise prescription. A combination of careful consideration of multiple factors and sound clinical judgment based on the individual's medical history and physical examination will determine their degree of risk of acute complications and identify the most appropriate physical activities to avoid or limit.

Aerobic Exercise Training

People with diabetes should perform aerobic exercise regularly. Aerobic activity bouts should ideally last at least 10 min, with the goal of ~30 min/day or more, most days of the week for adults with type 2 diabetes. Daily exercise, or at least not allowing more than 2 days to elapse between exercise sessions, is recommended to decrease insulin resistance, regardless of diabetes type (16,19). Over time, activities should progress in intensity, frequency, and/or duration to at least 150 min/week of moderate-intensity exercise. Adults able to run at 6 miles/h (9.7 km/h) for at least 25 min can benefit sufficiently from shorter-duration vigorous-intensity activity (75 min/week). Many adults, including most with type 2 diabetes, would be unable or unwilling to participate in such intense exercise and should engage in moderate exercise for the recommended duration (Table 3).

Youth with type 1 or type 2 diabetes should follow general recommendations for children and adolescents. These include 60 min/day or more of moderate- or vigorous-intensity aerobic activity, with vigorous, muscle-strengthening, and bone-strengthening activities at least 3 days/week (9).

Low-volume HIIT, which involves short bursts of very intense activity interspersed with longer periods of recovery at low to moderate intensity, is an alternative approach to continuous aerobic activity (16,19). However, its safety and efficacy remain unclear for some adults with diabetes (114,115). Those who wish to perform HIIT should be clinically stable, have been participating at least in regular moderate-intensity exercise, and likely be supervised at least initially (116). The risks with advanced disease are unclear (116), and continuous, moderate-intensity exercise may be safer (117). The optimal HIIT training protocol has yet to be determined.

Resistance Exercise Training

Adults with diabetes should engage in 2−3 sessions/week of resistance exercise on nonconsecutive days (Table 3) (9). Although heavier resistance training with free weights and weight

Table 3—Exercise training recommendations: types of exercise, intensity, duration, frequency, and progression

	Aerobic	Resistance	Flexibility and Balance
Type of exercise	• Prolonged, rhythmic activities using large muscle groups (e.g., walking, cycling, and swimming) • May be done continuously or as HIIT	• Resistance machines, free weights, resistance bands, and/or body weight as resistance exercises	• Stretching: static, dynamic, and other stretching; yoga • Balance (for older adults): practice standing on one leg, exercises using balance equipment, lower-body and core resistance exercises, tai chi
Intensity	• Moderate to vigorous (subjectively experienced as "moderate" to "very hard")	• Moderate (e.g., 15 repetitions of an exercise that can be repeated no more than 15 times) to vigorous (e.g., 6–8 repetitions of an exercise that can be repeated no more than 6–8 times)	• Stretch to the point of tightness or slight discomfort • Balance exercises of light to moderate intensity
Duration	• At least 150 min/week at moderate to vigorous intensity for most adults with diabetes • For adults able to run steadily at 6 miles per h (9.7 km/h) for 25 min, 75 min/week of vigorous activity may provide similar cardioprotective and metabolic benefits	• At least 8–10 exercises with completion of 1–3 sets of 10–15 repetitions to near fatigue per set on every exercise early in training	• Hold static or do dynamic stretch for 10−30 s; 2−4 repetitions of each exercise • Balance training can be any duration
Frequency	• 3–7 days/week, with no more than 2 consecutive days without exercise	• A minimum of 2 nonconsecutive days/week, but preferably 3	• Flexibility: ≥2−3 days/week • Balance: ≥2−3 days/week
Progression	• A greater emphasis should be placed on vigorous intensity aerobic exercise if fitness is a primary goal of exercise and not contraindicated by complications • Both HIIT and continuous exercise training are appropriate activities for most individuals with diabetes	• Beginning training intensity should be moderate, involving 10−15 repetitions per set, with increases in weight or resistance undertaken with a lower number of repetitions (8−10) only after the target number of repetitions per set can consistently be exceeded • Increase in resistance can be followed by a greater number of sets and finally by increased training frequency	• Continue to work on flexibility and balance training, increasing duration and/or frequency to progress over time

machines may improve glycemic control and strength more (118), doing resistance training of any intensity is recommended to improve strength, balance, and ability to engage in activities of daily living throughout the life span.

Flexibility, Balance, and Other Training

Completing flexibility exercises for each of the major muscle-tendon groups on 2 or more days/week maintains joint range of movement (Table 3) (12). Although flexibility training may be desirable for individuals with all types of diabetes, it should not substitute for other recommended activities (i.e., aerobic and resistance training), as flexibility training does not affect glucose control, body composition, or insulin action (6). Adults with diabetes (ages 50 years and older) should do exercises that maintain/improve balance 2−3 times/week (Table 3) (11,12), particularly if they have peripheral neuropathy (11). Many lower-body and core-strengthening exercises concomitantly improve balance and may be included. Yoga and tai chi can be included based on individual preferences to increase flexibility, strength, and balance.

Daily Movement

Increasing unstructured physical activity (e.g., errands, household tasks, dog walking, or gardening) increases daily energy expenditure and assists with weight management (119–121). Unstructured activity also reduces total daily sitting time. Increasing nonexercise activity, even in brief (3−15 min) bouts, is effective in acutely reducing postprandial hyperglycemia and improving glycemic control in those with prediabetes and type 1 and type 2 diabetes, most prominently after meals (41,43–46,75,122–124). Increasing unstructured physical activity should be encouraged as part of a whole-day approach, or at least initially as a stepping stone for individuals who are sedentary and unable/reluctant to participate in more structured exercise.

Supervised Versus Nonsupervised Training

Supervised aerobic or resistance training reduces A1C in adults with type 2 diabetes whether or not they include dietary cointervention, but unsupervised exercise only reduces A1C with a concomitant dietary intervention (64). Similarly, individuals undertaking supervised aerobic and resistance exercise achieve greater improvements in A1C, BMI, waist circumference, blood pressure, fitness, muscular strength, and HDL cholesterol (125). Thus, supervised training is recommended when feasible, at least for adults with type 2 diabetes.

PHYSICAL ACTIVITY AND PREGNANCY WITH DIABETES

Recommendations

- Women with preexisting diabetes of any type should be advised to engage in regular physical activity prior to and during pregnancy. **C**
- Pregnant women with or at risk for gestational diabetes mellitus should be advised to engage in 20–30 min of moderate-intensity exercise on most or all days of the week. **B**

Physical activity and exercise during pregnancy have been shown to benefit most women by improving cardiovascular health and general fitness while reducing the risk of complications like preeclampsia and cesarean delivery (126). Regular physical activity during pregnancy also lowers the risk of developing gestational diabetes mellitus (127,128). Exercise programs including at least 20−30 min of moderate-intensity exercise on most or all days of the week are recommended (126). Once gestational diabetes mellitus is diagnosed, either aerobic or resistance training can improve insulin action and glycemic control (129). In women with gestational diabetes mellitus, particularly those who are overweight and obese, vigorous-intensity exercise during pregnancy may reduce the odds of excess gestational weight gain (130). Ideally, the best time to start physical activity is prior to pregnancy to reduce gestational diabetes mellitus risk (131), but it is safe to initiate during pregnancy with very few contraindications (126). Any pregnant women using insulin should be aware of the insulin-sensitizing effects of exercise and increased risk of hypoglycemia, particularly during the first trimester (129).

MINIMIZING EXERCISE-RELATED ADVERSE EVENTS IN PEOPLE WITH DIABETES

Recommendations

- Insulin regimen and carbohydrate intake changes should be used to prevent exercise-related hypoglycemia. Other strategies involve including short sprints, performing resistance exercise before aerobic exercise in the same session, and activity timing. **B**
- Risk of nocturnal hypoglycemia following physical activity may be mitigated with reductions in basal insulin doses, inclusion of bedtime snacks, and/or use of continuous glucose monitoring. **C**
- Exercise-induced hyperglycemia is more common in type 1 diabetes but may be modulated with insulin administration or a lower-intensity aerobic cooldown. Exercising with hyperglycemia and elevated blood ketones is not recommended. **C**
- Some medications besides insulin may increase the risks of exercise-related hypoglycemia and doses may need to be adjusted based on exercise training. **C**
- Older adults with diabetes or anyone with autonomic neuropathy, cardiovascular complications, or pulmonary disease should avoid exercising outdoors on very hot and/or humid days to prevent heat-related illnesses. **C**
- Exercise training should progress appropriately to minimize risk of injury. **C**

Hypoglycemia

Exercise-induced hypoglycemia is common in people with type 1 diabetes and, to a lesser extent, people with type 2 diabetes using insulin or insulin secretagogues. In addition to insulin regimen and carbohydrate intake changes, a brief (10 s) maximal intensity sprint performed before (132) or after (133) a moderate-intensity exercise session may protect against hypoglycemia (134). Performing high-intensity bouts intermittently during moderate aerobic exercise also slows blood glucose declines (81,135,136), as can resistance exercise done immediately prior to aerobic (23).

Exercise-induced nocturnal hypoglycemia is a major concern (137). Hypoglycemic events occur typically within 6−15 h postexercise (138), although risk can extend out to 48 h (139). The risk of nocturnal hypoglycemia may be minimized through ~20% reductions of daily basal insulin dose with reduced prandial bolus insulin and low glycemic index carbohydrate feeding following evening exercise for those on MDI (89). For CSII users, basal rate reductions of 20% at bedtime for 6 h after afternoon exercise may limit nocturnal hypoglycemia (140). Inclusion of a bedtime snack, glucose checks overnight, and/or use of CGM with alarms and automatic pump suspension may also be warranted (141,142).

Hyperglycemia

Exercise-induced hyperglycemia is more common in type 1 diabetes. Purposeful insulin omission before exercise can promote a rise in glycemia, as can malfunctioning infusion sets (143). Individuals with type 2 diabetes may also experience increases in blood glucose after aerobic or resistance exercise, particularly if they are insulin users and administer too little insulin for meals before activity (144). Overconsumption of carbohydrates before or during exercise, along with aggressive insulin reduction, can promote hyperglycemia during any exercise (89).

Very intense exercise such as sprinting (134), brief but intense aerobic exercise (145), and heavy powerlifting (146,147) may promote hyperglycemia, especially if starting blood glucose levels are elevated (145). Hyperglycemia risk is mitigated if intense activities are interspersed between moderate-intensity aerobic ones (82,148). Similarly, combining resistance training (done first) with aerobic training (second) optimizes glucose stability in type 1 diabetes (23). To correct postexercise hyperglycemia, a conservative (50% of usual) correction can be administered (77) or an aerobic cooldown may be done to lower it (I.S. Millán, personal communication). Excessive insulin corrections after exercise increase nocturnal hypoglycemia risk, which can result in mortality (149).

Individuals with type 1 diabetes should test for blood ketones if they have unexplained hyperglycemia (≥250 mg/dL). Exercise should be postponed or suspended if blood ketone levels are elevated (≥1.5 mmol/L), as blood glucose levels and ketones may rise further with even mild activity.

Medication Effects

Adults with diabetes are frequently treated with multiple medications for diabetes and other comorbid conditions. Some medications (other than insulin) may increase exercise risk and doses may need to be adjusted (150,151). Although appropriate changes should be individualized, Table 4 lists general considerations and guidelines for medications.

Heat-Related Illness During Physical Activity

Physical activity increases bodily heat production and core temperature, leading to greater skin blood flow and sweating. In relatively young adults with type 1 diabetes, temperature regulation is only impaired during high-intensity exercise (152,153). With increasing age, poor blood glucose control, and neuropathy, skin blood flow and sweating may be impaired in adults with type 1 (152,154) and type 2 (155) diabetes, increasing the risk of heat-related

Table 4—Exercise considerations for diabetes, hypertension, and cholesterol medications and recommended safety and dose adjustments

Type/class of medication	Exercise considerations	Safety/dose adjustments
Diabetes		
Insulin	• Deficiency: hyperglycemia, ketoacidosis • Excess: hypoglycemia during and after exercise	• Increase insulin dose pre- and postexercise for deficiency • Decrease prandial and/or basal doses for excess insulin
Insulin secretagogues	• Exercise-induced hypoglycemia	• If exercise-induced hypoglycemia has occurred, decrease dose on exercise days to reduce hypoglycemia risk
Metformin	• None	• Generally safe; no dose adjustment for exercise
Thiazolidinediones	• Fluid retention	• Generally safe; no dose adjustment for exercise
Dipeptidyl peptidase 4 inhibitors	• Slight risk of congestive heart failure with saxagliptin and alogliptin	• Generally safe; no dose adjustment for exercise
Glucagon-like peptide 1 receptor agonists	• May increase risk of hypoglycemia when used with insulin or sulfonylureas but not when used alone	• Generally safe; no dose adjustment for exercise but may need to lower insulin or sulfonylurea dose
Sodium–glucose cotransporter 2 inhibitors	• May increase risk of hypoglycemia when used with insulin or sulfonylureas but not when used alone	• Generally safe; no dose adjustment for exercise
Hypertension		
β-Blockers	• Hypoglycemia unawareness and unresponsiveness; may reduce maximal exercise capacity	• Check blood glucose before and after exercise; treat hypoglycemia with glucose
Other agents	• Regular exercise training may lower blood pressure; some agents increase risk of dehydration	• Doses may need to be adjusted to accommodate the improvements from training and avoid dehydration
Cholesterol		
Statins	• Muscle weakness, discomfort, and cramping in a minority of users	• Generally safe; no dose adjustment for exercise
Fibric acid derivatives	• Rare myositis or rhabdomyolysis; risk increased with gemfibrozil and statin combination	• Avoid exercise if these muscle conditions are present

Table 5—Physical activity consideration, precautions, and recommended activities for exercising with health-related complications

Health complication	Exercise considerations	Physical activity recommendations/precautions
Cardiovascular diseases		
Coronary artery disease	• Coronary perfusion may actually be enhanced during higher-intensity aerobic or resistance exercise.	• All activities okay. • Consider exercising in a supervised cardiac rehabilitation program, at least initially.
Exertional angina	• Onset of chest pain on exertion, but exercise-induced ischemia may be silent in some with diabetes.	• All activities okay, but heart rate should be kept ≥10 bpm below onset of exercise-related angina.
Hypertension	• Both aerobic and resistance training may lower resting blood pressure and should be encouraged. • Some blood pressure medications can cause exercise-related hypotension.	• Ensure adequate hydration during exercise. • Avoid Valsalva maneuver during resistance training.
Myocardial infarction	• Stop exercise immediately should symptoms of myocardial infarction (such as chest pain, radiating pain, shortness of breath, and others) occur during physical activity and seek medical attention.	• Restart exercise after myocardial infarction in a supervised cardiac rehabilitation program. • Start at a low intensity and progress as able to more moderate activities. • Both aerobic and resistance exercise are okay.
Stroke	• Diabetes increases the risk of ischemic stroke. • Stop exercise immediately if symptoms of a stroke (occurring suddenly and often affecting only one side of the body) happen during exercise.	• Restart exercise after stroke in a supervised cardiac rehabilitation program. • Start at a low intensity and progress as able to more moderate activities. • Both aerobic and resistance exercise are okay.
Congestive heart failure	• Most common cause is coronary artery disease and frequently follows a myocardial infarction.	• Avoid activities that cause an excessive rise in heart rate. • Focus more on doing low- or moderate-intensity activities.
Peripheral artery disease	• Lower-extremity resistance training improves functional performance (161).	• Low- or moderate-intensity walking, arm ergometer, and leg ergometer preferred as aerobic activities (162). • All other activities okay.
Nerve disease		
Peripheral neuropathy	• Regular aerobic exercise may also prevent the onset or delay the progression of peripheral neuropathy in both type 1 and type 2 diabetes (163).	• Proper care of the feet is needed to prevent foot ulcers and lower the risk of amputation (6). • Keep feet dry and use appropriate footwear, silica gel or air midsoles, and polyester or blend socks (not pure cotton). • Consider inclusion of more non–weight-bearing activities, particularly if gait altered.
Local foot deformity	• Manage with appropriate footwear and choice of activities to reduce plantar pressure and ulcer risk (164).	• Focus more on non–weight-bearing activities to reduce undue plantar pressures. • Examine feet daily to detect and treat blisters, sores, or ulcers early.
Foot ulcers/amputations	• Moderate walking is not likely to increase risk of foot ulcers or reulceration with peripheral neuropathy (165).	• Weight-bearing activity should be avoided with unhealed ulcers. • Examine feet daily to detect and treat blisters, sores, or ulcers early. • Amputation sites should be properly cared for daily. • Avoid jogging.
Autonomic neuropathy	• May cause postural hypotension, chronotropic incompetence, delayed gastric emptying, altered thermoregulation, and dehydration during exercise (6). • Exercise-related hypoglycemia may be harder to treat in those with gastroparesis.	• With postural hypotension, avoid activities with rapid postural or directional changes to avoid fainting or falling. • With cardiac autonomic neuropathy, obtain physician approval and possibly undergo symptom-limited exercise testing before commencing exercise (166). • With blunted heart rate response, use heart rate reserve and ratings of perceived exertion to monitor exercise intensity (167). • With autonomic neuropathy, avoid exercise in hot environments and hydrate well.

Continued on p. 2074

Table 5—Continued

Health complication	Exercise considerations	Physical activity recommendations/precautions
Eye diseases		
Mild to moderate nonproliferative retinopathy	• Individuals with mild to moderate nonproliferative changes have limited or no risk for eye damage from physical activity.	• All activities okay with mild, but annual eye exam should be performed to monitor progression. • With moderate nonproliferative retinopathy, avoid activities that dramatically elevate blood pressure, such as powerlifting.
Severe nonproliferative and unstable proliferative retinopathy	• Individuals with unstable diabetic retinopathy are at risk for vitreous hemorrhage and retinal detachment.	• Avoid activities that dramatically elevate blood pressure, such as vigorous activity of any type. • Avoid vigorous exercise; jumping, jarring, and head-down activities; and breath holding (6). • No exercise should be undertaken during a vitreous hemorrhage.
Cataracts	• Cataracts do not impact the ability to exercise, only the safety of doing so due to loss of visual acuity.	• Avoid activities that are more dangerous due to limited vision, such as outdoor cycling. • Consider supervision for certain activities.
Kidney diseases		
Microalbuminuria	• Exercise does not accelerate progression of kidney disease even though protein excretion acutely increases afterward (6,159). • Greater participation in moderate-to-vigorous leisure time activity and higher physical activity levels may actually moderate the initiation and progression of diabetic nephropathy (168–170).	• All activities okay, but vigorous exercise should be avoided the day before urine protein tests are performed to prevent false positive readings.
Overt nephropathy	• Both aerobic and resistance training improve physical function and quality of life in individuals with kidney disease. • Individuals should be encouraged to be active.	• All activities okay, but exercise should begin at a low intensity and volume if aerobic capacity and muscle function are substantially reduced.
End-stage renal disease	• Doing supervised, moderate aerobic physical activity undertaken during dialysis sessions may be beneficial and increase compliance (171).	• Exercise should begin at a low intensity and volume if aerobic capacity and muscle function are substantially reduced. • Electrolytes should be monitored when activity done during dialysis sessions.
Orthopedic limitations		
Structural changes to joints	• Individuals with diabetes are more prone to structural changes to joints that can limit movement, including shoulder adhesive capsulitis, carpal tunnel syndrome, metatarsal fractures, and neuropathy-related joint disorders (Charcot foot) (25).	• In addition to engaging in other activities (as able), do regular flexibility training to maintain greater joint range of motion (10,12). • Stretch within warm-ups or after an activity to increase joint range of motion best (172). • Strengthen muscles around affected joints with resistance training. • Avoid activities that increase plantar pressures with Charcot foot changes.
Arthritis	• Common in lower-extremity joints, particularly in older adults who are overweight or obese. • Participation in regular physical activity is possible and should be encouraged. • Moderate activity may improve joint symptoms and alleviate pain.	• Most low- and moderate-intensity activities okay, but more non–weight-bearing or low-impact exercise may be undertaken to reduce stress on joints. • Do range-of-motion activities and light resistance exercise to increase strength of muscles surrounding affected joints. • Avoid activities with high risk of joint trauma, such as contact sports and ones with rapid directional changes.

illness. Chronic hyperglycemia also increases risk through dehydration caused by osmotic diuresis, and some medications that lower blood pressure may also impact hydration and electrolyte balance. Older adults with diabetes or anyone with autonomic neuropathy, cardiovascular complications, or pulmonary disease should avoid exercising outdoors on very hot and/or humid days.

Orthopedic and Overuse Injuries

Active individuals with type 1 diabetes are not at increased risk of tendon injury (156), but this may not apply to sedentary or older individuals with diabetes. Given that diabetes may lead to exercise-related overuse injuries due to changes in joint structures related to glycemic excursions (157), exercise training for anyone with diabetes should progress appropriately to avoid excessive aggravation to joint surfaces and structures, particularly when taking statin medications for lipid control (158).

MANAGING PHYSICAL ACTIVITY WITH HEALTH COMPLICATIONS

Recommendations

- Physical activity with vascular diseases can be undertaken safely but with appropriate precautions. **B**
- Physical activity done with peripheral neuropathy necessitates proper foot care to prevent, detect, and prevent problems early to avoid ulceration and amputation. **B**
- The presence of autonomic neuropathy may complicate being active; certain precautions are warranted to prevent problems during activity. **C**
- Vigorous aerobic or resistance exercise; jumping, jarring, head-down activities; and breath holding should be avoided in anyone with severe nonproliferative and unstable proliferative diabetic retinopathy. **E**
- Exercise does not accelerate progression of kidney disease and can be undertaken safely, even during dialysis sessions. **C**
- Regular stretching and appropriate progression of activities should be done to manage joint changes and diabetes-related orthopedic limitations. **C**

Macrovascular and microvascular diabetes-related complications can develop and worsen with inadequate blood glucose control (159,160). Vascular and neural complications of diabetes often cause physical limitation and varying levels of disability requiring precautions during exercise, as recommended in Table 5.

PROMOTING THE ADOPTION AND MAINTENANCE OF PHYSICAL ACTIVITY

Recommendations

- Targeted behavior-change strategies should be used to increase physical activity in adults with type 2 diabetes. **B**
- When using step counters, adults with type 2 diabetes should initially set tolerable targets for steps/day before progressing toward higher goals. **C**
- For adults with type 2 diabetes, Internet-delivered interventions for physical activity promotion may be used to improve outcomes. **C**

Behavior-Change Strategies

Behavioral interventions can significantly increase physical activity in adults with type 2 diabetes (173), and A1C reductions produced by such interventions have been sustained to 24 months (174). Five key techniques have been identified: *1*) prompt focus on past success, *2*) barrier identification/problem-solving, *3*) use of follow-up prompts, *4*) provision of information on where/when to perform the behavior, and *5*) prompt review of behavioral goals (175). However, motivational interviewing is not significantly better than usual care (176), and other intervention factors associated with weight loss, such as number and duration of contacts, have been inconsistent or not associated with greater participation (177).

Step counters/pedometers have been widely studied as a behavior-change tool. Wearing the device may prompt activity, and it provides feedback for self-monitoring. Pedometer use in adults with type 2 diabetes increased their daily steps by 1,822, but did not improve A1C (178). Using a daily steps goal (e.g., 10,000) was predictive of increased participation, even using self-selected step goals (178). Thus, adults with type 2 diabetes should initially set feasible/achievable targets for steps/day before progressing toward higher goals. Adults should avoid taking $<$5,000 steps/day (179–181) and to strive for $\geq$7,500 steps/day (182). The positive findings for pedometers are not universal (175), however, and some individuals may require greater support to realize benefits. Longer-term efficacy and determination of which populations can benefit from pedometers and other wearable activity trackers (183) require further evaluation.

Technology-Based Strategies

Given that the majority of individuals with type 2 diabetes have access to the Internet, technology-based support is appealing for extending clinical intervention reach. For adults with type 2 diabetes, Internet-delivered physical activity promotion interventions may be more effective than usual care (184). Effective Internet-based programs included monitoring of physical activity, feedback, goal setting, and support from a coach via phone/e-mail (184). More evidence is needed regarding social media approaches, given the importance of social and peer support in diabetes self-management (185).

CONCLUSIONS

Physical activity and exercise should be recommended and prescribed to all individuals with diabetes as part of management of glycemic control and overall health. Specific recommendations and precautions will vary by the type of diabetes, age, activity done, and presence of diabetes-related health complications. Recommendations should be tailored to meet the specific needs of each individual. In addition to engaging in regular physical activity, all adults should be encouraged to decrease the total amount of daily sedentary time and to break up sitting time with frequent bouts of activity. Finally, behavior-change strategies can be used to promote the adoption and maintenance of lifetime physical activity.

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