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2018 Clinical Practice Guidelines

Physical Activity and Diabetes

Diabetes Canada Clinical Practice Guidelines Expert Committee

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KEY MESSAGES

- Moderate to high levels of physical activity and cardiorespiratory fitness are associated with substantially lower morbidity and mortality in people with diabetes.
- Both aerobic and resistance exercise are beneficial, and it is optimal to do both types of exercise. At least 150 minutes per week of aerobic exercise and at least 2 sessions per week of resistance exercise are recommended, though smaller amounts of activity still provide some health benefits.
- A number of strategies that increase self-efficacy and motivation can be employed to increase physical activity uptake and maintenance, such as setting specific physical activity goals, using self-monitoring tools (pedometers or accelerometers) and developing strategies to overcome anticipated barriers.
- For people with type 2 diabetes, supervised exercise programs have been particularly effective in improving glycemic control, reducing the need for noninsulin antihyperglycemic agents and insulin, and producing modest but sustained weight loss.
- Habitual, prolonged sitting is associated with increased risk of death and major cardiovascular events.

KEY MESSAGES FOR PEOPLE WITH DIABETES

- Physical activity often improves glucose control and facilitates weight loss, but has multiple other health benefits even if weight and glucose control do not change.
- It is best to avoid prolonged sitting. Try to interrupt sitting time by getting up briefly every 20 to 30 minutes.
- Try to get at least 150 minutes per week of aerobic exercise (like walking, bicycling or jogging).
- Using a step monitor (pedometer or accelerometer) can be helpful in tracking your activity.
- In addition to aerobic exercise, try to do at least 2 sessions per week of strength training (like exercises with weights or weight machines).
- If you decide to begin strength training, you should ideally get some instruction from a qualified exercise specialist.
- If you cannot reach these recommended levels of activity, doing smaller amounts of activity still has some health benefits.

Types of Exercise

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (1). Exercise is planned, structured physical activity (1) (see Table 1 for definitions of key exercise terms used in this article.) **Aerobic exercise** (like walking, bicycling, swimming or jogging) involves continuous, rhythmic movements of large muscle groups, normally at least 10 minutes at a time. In this chapter, we will refer to this type of exercise as "aerobic" for simplicity, even though when performed at a very high intensity, such as with high-intensity interval training, it also involves some anaerobic metabolism. **Resistance exercise** involves brief repetitive exercises with weights, weight machines, resistance bands or one's own body weight (e.g. push-ups) to increase muscle strength and/or endurance. **Flexibility exercise** (like lower back or hamstring stretching) aims to enhance the ability to move through fuller ranges of motion. Some types of exercise, such as yoga, can incorporate elements of both resistance and flexibility exercise.

Benefits of Physical Activity

Physical activity can help people with diabetes achieve a variety of goals, including increased cardiorespiratory fitness, increased vigour, improved glycemic control, decreased insulin resistance, improved lipid profile, blood pressure (BP) reduction and maintenance of weight loss (2–5).

Randomized trials have found that supervised exercise interventions improve glycated hemoglobin (A1C) (6–8), triglycerides (TG) and cholesterol (9) in people with type 2 diabetes when compared to no exercise comparison groups (10). Cohort studies have demonstrated that, in people with type 2 (11–13), and with type 1 diabetes (14,15), regular physical activity (11–13) and/or moderate to high cardiorespiratory fitness (16) are associated with reductions in cardiovascular (CV) and overall mortality.

Randomized trials have also demonstrated that aerobic exercise training increases cardiorespiratory fitness in both type 1 and type 2 diabetes (17), and slows the development of peripheral neuropathy (18). A meta-analysis (6) found that supervised exercise interventions improved A1C in people with type 2 diabetes when compared to no exercise comparison groups. In addition, interventions involving exercise durations of more than 150 minutes per week were associated with greater A1C reductions (mean change –0.89%) than interventions involving 150 minutes or less of exercise per week (mean change –0.36%) (6). A meta-analysis of head-to-head trials comparing the effects on A1C of aerobic exercise at higher vs. lower intensity found that the interventions with higher intensity reduced A1C more than those of lower intensity (mean A1C difference –0.22%) (8). It was unclear whether the greater

Conflict of interest statements can be found on page S60.

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Table 1
Definitions of terms

Physical activity	Any bodily movement produced by skeletal muscles that results in energy expenditure above resting (basal) levels. This term broadly encompasses exercise, sport and physical activities done as a part of daily living, occupation, leisure and active transport.
Exercise	Planned, structured physical activity typically performed with the intent of improving health and/or fitness.
Aerobic exercise	Exercise that involves continuous, rhythmic movements of large muscle groups, such as walking, bicycling, swimming or jogging, normally lasting for at least 10 minutes at a time. This type of exercise depends primarily on the aerobic energy-generating processes in the body (i.e. heart, lungs, cardiovascular system and the oxidation of fuels in skeletal muscle). Moderate-intensity aerobic activities range from 3–6 metabolic equivalents (METS) and include brisk walking, dancing, light cycling, gardening and domestic chores. Vigorous-intensity activities (>6 METS) include running, climbing stairs or hill walking, fast cycling or swimming, aerobics and most competitive sports and games.
Resistance exercise	Brief repetitive exercise using weights, weight machines, resistance bands or one's own body weight (e.g. push-ups) to increase muscle strength and/or endurance.
Flexibility exercise	A form of activity, such as lower back or hamstring stretching, that enhances the ability of joints to move through their full range of motion.
Aerobic training	Exercise training involving periods of predominantly aerobic exercise activities, such as running, cycling or swimming, performed for the purpose of enhancing cardiorespiratory fitness, performance and/or health.
Resistance training	Exercise training, involving brief repetitive exercises with weights, weight machines, resistance bands or one's own body weight (e.g. push-ups) performed for the purpose of increasing muscle mass and strength. This type of exercise uses predominantly anaerobic energy-generating systems in skeletal muscle.
High-intensity interval training	A type of aerobic exercise training based on alternating between short periods of vigorous intensity exertion and periods of rest or lower-intensity exercise; commonly performed using a predominantly aerobic exercise modality, such as running or cycling.
Cardiorespiratory fitness	A health-related component of physical fitness defined as the ability of the circulatory, respiratory and muscular systems to supply oxygen during sustained physical activity. Typically measured via a treadmill or cycle ergometer test and expressed as maximal oxygen uptake (VO_2max) relative to body mass or in metabolic equivalents (METS).
Musculoskeletal fitness	Ability of skeletal and muscular systems to perform work (exercise). Muscular strength and muscular endurance are components of musculoskeletal fitness.
Cardiorespiratory endurance	Ability of the heart, lungs and circulatory system to supply oxygen to working muscles efficiently.
Muscular strength	Maximal force or tension level produced by a muscle or muscle group.
Muscular endurance	Ability of muscle to maintain submaximal force levels for extended periods.
Physical fitness	Ability to perform occupational, recreational and daily activities without undue fatigue. A set of measureable health and skill-related attributes that include cardiorespiratory fitness, muscular strength and endurance, body composition, flexibility, balance, agility, reaction time and power.
Maximum oxygen uptake (VO_2max)	Maximum rate of oxygen utilization during exercise.
METS	The ratio of a person's working (exercising) metabolic rate to the resting metabolic rate. One MET is equivalent to the energy expended while sitting at rest.
Sedentary behaviour	An "activity" that involves little or no movement, with an energy expenditure ranging between 1-1.5 METS. Examples include sitting, watching TV, working on a computer, reclining while awake and driving.

benefits of higher-intensity exercise were limited to studies using high-intensity interval training (see next section on interval training).

In contrast to trials in type 2 diabetes, most clinical trials evaluating exercise interventions in adults with type 1 diabetes have not demonstrated a beneficial effect of exercise on glycemic control (19), but 2 recent meta-analyses found that aerobic training lowered A1C in children and youth with type 1 diabetes by 0.5% and 0.85% respectively (20,21), while also lowering body mass index (BMI), TG and total cholesterol levels. A recent large cross-sectional study of 18,028 adults with type 1 diabetes reported an inverse association between physical activity levels and A1C, diabetic ketoacidosis (DKA), BMI and a number of diabetes-related complications, including dyslipidemia, hypertension, retinopathy and microalbuminuria (22). There are no published trials evaluating the effects of exercise training on quality of life in type 1 diabetes.

Benefits of Interval Training

High-intensity interval training involves alternating between short periods of higher and lower-intensity exercise (see Exercise Prescription Examples). High-intensity interval training leads to greater gains in cardiorespiratory fitness in people with or without diabetes (23,24), and improves glycemic control in some studies of people with type 2 diabetes compared to continuous moderate-intensity exercise (24–26).

In people with type 1 diabetes, high-intensity interval exercise appears to be associated with less risk for hypoglycemia than continuous aerobic exercise, at least during the time of the activity (27,28,29). To date, the risks of high-intensity interval training seem comparable to moderate-intensity continuous exercise in previously screened participants with relatively good glycemic control; however, most studies have been small and underpowered (8). A small trial in women with type 2 diabetes (n=17) found that twice-weekly high-intensity interval training reduced abdominal fat (–8.3%) and visceral fat (–24.2%) significantly, but continuous aerobic exercise did not.

Benefits of Resistance Exercise

Resistance training in adults with type 2 diabetes improves glycemic control (as reflected by reduced A1C), decreases insulin resistance and increases muscular strength (30), lean muscle mass (31) and bone mineral density (32,33), leading to enhanced functional status and prevention of sarcopenia and osteoporosis. The optimal resistance training program has not been clearly established in terms of frequency, intensity, type and volume (34). The greatest impact on A1C is typically seen in studies that had participants progress to 3 sets (with approximately 8 repetitions per set) of resistance-type exercises at moderate to high intensity (i.e. the maximum weight that can be lifted 8 times while maintaining proper form), 3 times per week (35,36) or more (37,38). However, significant reductions in A1C and body fat have been achieved with twice-weekly resistance exercise in combination with regular aerobic exercise (39–41). The effects of resistance exercise and aerobic exercise on glycemic control are additive (42).

Resistance exercise in most of these studies was carried out using weight machines and/or free weights, and these findings cannot necessarily be generalized to other types of resistance exercise, such as resistance bands or exercises utilizing one's own body weight. For example, a recent meta-analysis found that exercise training with resistance bands in people with type 2 diabetes increased strength but had no significant effect on A1C (43). The benefits of resistance exercise in type 1 diabetes are less clear, but small clinical trials suggest improved body composition and strength, enhanced insulin sensitivity and possibly modest reductions in A1C (44). Compared to aerobic exercise, resistance exercise is associated with less hypoglycemia risk for individuals with type 1 diabetes (45,46).

Benefits of Other Types of Exercise

To date, evidence for the beneficial effects of other types of exercise is not as extensive or as supportive as the evidence for aerobic and resistance exercise. Two systematic reviews found that tai chi had no effect on A1C, compared to either sham exercise or usual care in people with diabetes (47,48). Systematic reviews of yoga as an intervention for type 2 diabetes (49–51) have reported reductions in A1C. However, the quality of the studies was generally low and results were highly heterogeneous, limiting any conclusions that may be drawn (see Complementary and Alternative Medicine for Diabetes chapter, p. S154).

No published study has demonstrated any impact of a pure flexibility program on metabolic control, injury risk or any diabetes-related outcome.

Since osteoarthritis can be a barrier to physical activity (52), water-based physical activities, such as swimming, walking or running in a pool, or aquatic fitness classes have been encouraged for people with such comorbidities (53,54). While few high-quality trials exist, a recent meta-analysis suggests aquatic exercise improves A1C compared to no exercise comparison groups and that the improvements are comparable to those obtained with land-based exercise (55).

Supervised vs. Unsupervised Exercise

A systematic review and meta-analysis found that supervised programs involving aerobic or resistance exercise improved glycemic control in adults with type 2 diabetes, whether or not they included dietary co-intervention (6). The same meta-analysis found that unsupervised exercise improved glycemic control only if there was concomitant dietary intervention. A meta-analysis found that trials evaluating resistance exercise with less supervision showed less beneficial impact on glycemic control, insulin resistance and body composition than studies with greater supervision (30). A 1-year randomized trial compared exercise counselling plus twice-weekly supervised aerobic and resistance exercise vs. exercise counselling alone in people with type 2 diabetes and the metabolic syndrome (39). Although self-reported total physical activity increased substantially in both groups, the group receiving the supervised aerobic and resistance exercise training had significantly better results, including greater reductions in A1C, blood pressure (BP), BMI, waist circumference and estimated 10-year CV risk, and greater increases in aerobic fitness, muscle strength and high-density lipoprotein cholesterol (HDL-C) (39).

The Look-AHEAD Trial

The Look AHEAD (Action for Health in Diabetes) trial was the largest randomized trial to date evaluating the efficacy of a physical activity and dietary control intervention (targeting a ≥7% weight loss), in older adults with type 2 diabetes (56). In this study, at least 175 min/week of unsupervised exercise was targeted as part of the intense lifestyle intervention (ILI), while the control group (Diabetes Support and Education—DSE group) received usual care. Major CV event rates were not significantly different in the 2 groups (56). However, the ILI group achieved significantly greater and more sustained improvements in many important secondary outcomes, including weight loss; improved cardiorespiratory fitness; improved glycemic control, BP and lipids with fewer medications; as well as decreased rate of sleep apnea, severe diabetic chronic kidney disease and retinopathy, depression, sexual dysfunction, urinary incontinence and knee pain; as well as better physical mobility maintenance and quality of life, with lower overall health-care costs (57).

Minimizing Risk of Exercise-Related Adverse Events

Identifying individuals for whom medical evaluation should be considered prior to initiating an exercise program

For most people with and without diabetes, being sedentary is associated with far greater health risks than exercise would be**.** Most people with diabetes who have no symptoms of coronary ischemia do not require medical clearance before starting a low-to-moderate intensity exercise program. However, middle-aged and older individuals with diabetes who wish to undertake very vigorous or prolonged exercise, such as competitive racing, high-intensity interval training with intervals at maximal effort, or long-distance running should be assessed for conditions that may place them at increased risk for an adverse event. Preproliferative or proliferative retinopathy should be treated and stabilized prior to commencement of vigorous exercise. People with severe peripheral neuropathy should be instructed to inspect their feet daily, especially on days they are physically active, and to wear appropriate footwear. Although previous guidelines stated that persons with severe peripheral neuropathy should avoid weight-bearing activity, more recent studies indicate that individuals with peripheral neuropathy may safely participate in moderate weight-bearing exercise provided they do not have active foot ulcers (58–60). Studies also suggest that people with peripheral neuropathy in the feet, who participate in daily weight-bearing activity, are at decreased risk of foot ulceration compared with those who are less active (59).

A resting ECG should be performed, and an exercise ECG stress test should be considered, for individuals with typical or atypical chest discomfort, unexplained dyspnea, peripheral arterial disease, carotid bruits or history of angina, myocardial infarction (MI), stroke or transient ischemic attacks (see Screening for the Presence of Cardiovascular Disease chapter, p. S170) who wish to undertake exercise more intense than brisk walking, especially if considering very intense, prolonged aerobic exercise.

The value and utility of medical screening procedures prior to exercise, such as resting ECG and exercise stress testing in asymptomatic individuals has been the subject of much debate (61). There is now an increased appreciation that exercise testing is a poor predictor of future cardiovascular disease (CVD) events because such testing detects flow-limiting coronary lesions while sudden cardiac arrest is usually produced by the rapid progression of a previously non-obstructive lesion (62). Nevertheless, identifying individuals who are symptomatic remains very important. People with diabetes should be screened for signs and symptoms consistent with myocardial ischemia, such as chest pain, severe shortness of breath upon exertion and/or syncope. People who are symptomatic, either before or during exercise, should be referred for ECG stress testing and further cardiac evaluation prior to participating or continuing in an exercise program (see Screening for the Presence of Cardiovascular Disease chapter, p. S170).

Minimizing risk of heat-related illness

Performing physical activity, especially in the heat, places individuals at risk for heat-related injuries. The increase in metabolic heat production augments the rate at which heat must be dissipated to the environment to prevent dangerous increases in core temperature. However, relative to young adults, healthy active adults ≥40 years of age (63) and individuals with diabetes (64,65) have a restricted capacity to lose heat. This is a result of reductions in the heat loss responses of sweating and skin blood flow, which occur even during short duration and/or light-to-moderate intensity exercise (63,66–70). Reduced physical fitness (70) and the presence of metabolic, CV and neurologic dysfunctions, which are often associated with diabetes (71), further exacerbate an already compromised ability to dissipate heat.

People with diabetes should be aware that heat stress is associated with a reduction in exercise capacity and an increase in disease-related symptoms (71). Combined with greater levels of dehydration due to hyperglycemia and/or medication use (71), individuals with type 2 diabetes have an augmented risk of heat-related morbidity. Whenever possible, exercise should be performed indoors in a cool and/or dry and well-ventilated environment (e.g. an air-conditioned training centre, room with fans) if it is very hot outdoors. If activities (e.g. gardening, cycling, etc.) must be performed outdoors when the weather is hot, the activities should be conducted in the early or later hours of the day when the temperatures are cooler and the sun is not at its peak. When possible, prolonged exercise (>15 min) should be interspersed with adequate rest or break periods in a shaded or cool location. Middle-aged and older people with diabetes should try to avoid performing exercise in hot humid conditions as these conditions restrict the evaporation of sweat which is necessary to cool the body. Staying well hydrated will help ensure that the body can maintain an adequate cooling capacity during exercise (by maintaining sweat production at normal levels) especially in the heat, and prevent fluctuations in blood glucose levels (71,72), and is likely to reduce the risk for heat-related complications, such as heat exhaustion or heat stroke.

Minimizing risk of exercise-induced hypoglycemia in type 1 diabetes

Prolonged aerobic exercise increases insulin sensitivity in recovery for up to 48 hours (73). In type 1 diabetes, there is little or no endogenous insulin secretion, and achieving the appropriate balance of exogenous insulin and carbohydrate intake for the different forms and intensities of exercise can be challenging (74). If exogenous insulin and/or carbohydrate ingestion is not adjusted accordingly, hypo- or hyperglycemia occurs. Fear of hypoglycemia is an important barrier to exercise in people with type 1 diabetes (75) and advice on physical activity to people with type 1 diabetes should include strategies to reduce risk of hypoglycemia.

Several small studies have explored several types of strategies for the prevention of hypoglycemia in type 1 diabetes, including the consumption of extra carbohydrates for exercise (76), limiting preprandial bolus insulin doses (77–79) or reducing the basal insulin rate for continuous subcutaneous insulin infusion (CSII) (insulin pump) users (80). These strategies can be used alone or in combination (81,82). Increasing carbohydrate intake just before, during and immediately after exercise is a simple and effective way to prevent hypoglycemia, although the optimal carbohydrate intake rate varies based on the duration and intensity of the activity and the amount of insulin in the circulation at the time of exercise (78,83,84). For activities less than 2 hours after a meal, reductions in prandial insulin by 25% to 75% are effective in limiting hypoglycemia (77). However, heavy reductions in mealtime insulin before (by 75%) and after exercise (by 50%) may cause hyperglycemia (85).

Basal insulin reduction before exercise may also offer some protection for children (86) and for those people on CSII (79,87). In 1 study, a 50% basal rate reduction performed 60 minutes before the onset of 30 minutes of moderate-intensity exercise does not reduce insulin level enough during the activity to adequately attenuate hypoglycemia risk (88). A more aggressive basal rate reduction, such as basal rate suspension at exercise onset is somewhat effective, although blood glucose levels may still drop markedly at the start of exercise (79). As such, additional carbohydrates may still be needed even following basal rate reductions. For people on insulin injections, in addition to lowering the mealtime bolus before exercise, exercise-associated hypoglycemia can be attenuated by reducing total daily basal insulin by 20% for days when they are physically active (89). Another strategy to avoid hypoglycemia is to perform intermittent, brief (10 seconds), maximal-intensity sprints either at the beginning (90) or end (91) or intermittently during a moderate-intensity exercise session (92). Performing resistance exercise immediately prior to aerobic exercise also helps reduce hypoglycemia risk, rather than performing aerobic exercise alone or aerobic exercise followed by resistance exercise (46).

Exercise performed late in the day or in the evening can be associated with increased risk of overnight hypoglycemia in people with type 1 diabetes (76). To reduce this risk, the bedtime intermediate or long-acting injected insulin dose, or overnight basal insulin infusion rate may be reduced by approximately 20% from bedtime to 3 AM for CSII users.

Minimizing risks related to hyperglycemia

Glucose levels can rise with brief intense exercise, such as sprinting (90–92), resistance training (93), 10 to 15 minutes of maximal-intensity aerobic exercise to exhaustion (94,95) or high-intensity interval training (96) in individuals with type 1 diabetes. If this occurs, it can be addressed by giving a small bolus of a rapid-acting insulin in exercise recovery (97), or by temporarily increasing the basal insulin infusion in CSII users.

Individuals with type 2 diabetes generally do not need to postpone exercise because of high blood glucose, provided they feel well. If capillary blood glucose levels are elevated >16.7 mmol/L, it is important to ensure proper hydration and monitor for signs and symptoms of dehydration (e.g. increased thirst, nausea, severe fatigue, blurred vision or headache), especially for exercise to be performed in the heat.

In individuals with type 1 diabetes who are severely insulin deficient (e.g. due to insulin omission or illness), hyperglycemia can worsen with exercise. In people with type 1 diabetes, if CBG is >16.7 mmol/L and the person does not feel well, urine or blood ketones should be tested. If ketone levels are elevated in the blood (≥1.5 mmol/L) or in the urine (2 + or ≥4 mmol/L), it is suggested that vigorous exercise be postponed until insulin is given (with carbohydrate, if necessary) and ketones are no longer elevated. If ketones are negative or “trace” and the person feels well, it is not necessary to defer exercise due to hyperglycemia.

Reduction of Sedentary Behaviour

Sedentary behaviours involve prolonged sitting or reclining while awake, including television viewing, working on a computer and driving. Systematic reviews of observational studies (98,99) have demonstrated positive associations between the amount of sitting and the risk of premature mortality within the general population and in people with diabetes (100,101) even after adjusting for time spent in moderate-to-vigorous physical activity (98–101). Several recent studies in people with diabetes have documented harmful associations between objectively measured sedentary time and cardiometabolic risk factors, such as A1C, central adiposity, BMI, fasting TG, systolic BP, C-reactive protein, and hyperglycemia (102–107). Studies in people with and without type 2 diabetes have demonstrated that interrupting sitting by light walking or light resistance training can attenuate postprandial increases in BG, insulin and TG (108–110).

Given the evidence that sedentary behaviour is associated with adverse health outcomes, even after statistically adjusting for levels of moderate-to-vigorous exercise, physical activity levels and sedentary behaviours should be considered distinct and potentially independent behaviours. When discussing activity patterns with people with diabetes in clinical practice, it is reasonable, therefore, to promote both the reduction of prolonged sitting and the accumulation of moderate-to-vigorous physical activity in the person's daily routine.

The Use of Adjunct Motivational Interventions to Improve Physical Activity Uptake

There are a number of barriers and facilitators to physical activity in people with diabetes (111–114). Interventions targeting these barriers and facilitators are needed to initially engage people with diabetes in, and then maintain, sufficient physical activity.

Behaviour-change focused interventions added to exercise-based interventions have tended to focus on increasing physical activity self-efficacy (i.e. an individual's belief or confidence in his/her ability to undertake physical activity) (115) and motivation (i.e. an individual's desire or willingness to do physical activity) (116). Such interventions have been shown to increase self-reported and/or objectively assessed physical activity when compared to usual care or equivalent comparison groups (115,117–122), although it is unclear if these improvements in physical activity are associated with improved A1C. For example, a recent meta-analysis suggested that the use of motivational interviewing-based interventions (see description below) not only improved physical activity but also decreased A1C by about 0.65% 6 months after the intervention when compared to usual care (119). However, it should be noted that some other studies found this kind of intervention did not reduce A1C (123,124).

The vast majority of the studies have examined motivational interviewing (125) or motivational communication (126) as the behaviour change intervention. Motivational interviewing is a goal-oriented, client-centred counselling style, which helps to explore and resolve ambivalence and increase intrinsic motivation in individuals in order to change behaviour (125). Motivational communication represents a collection of evidence-based strategies drawn from motivational interviewing, cognitive-behavioural techniques and behaviour change theories (e.g. self-determination theory, social-cognitive theory, theory of planned behaviour and the transtheoretical model) that are used as a communication strategy to engage individuals in changing their behaviour (126).

For people with type 2 diabetes, evidence suggests that goal setting, problem solving, providing information on where and when to exercise, and self-monitoring (e.g. use of objective monitoring with pedometers) have some efficacy to increase physical activity and improve A1C (114,127–131).

Newer evidence is starting to accumulate on the potential benefits of other motivational tools and techniques. Examples of these include reinforcement, such as providing direct, instantaneous rewards (monetary or token-based) for goal completion (132), text-messaging (133,134), mobile applications, social media and video games (116,135). However, further higher level evidence is needed to demonstrate their benefits for both physical activity and diabetes-related outcomes (129,136–138).

Objective Monitoring of Physical Activity

A pedometer is a wearable device that detects and counts each step a person takes. An accelerometer is a device that measures non-gravitational acceleration. Pedometers and accelerometers are well suited to measuring walking or jogging, but not bicycling or swimming. Pedometers measure steps but not speed, whereas accelerometers can measure both steps and speed.

Large-scale cohort studies consistently demonstrate an inverse relationship between higher self-reported walking with CV events and both CV and all-cause mortality in type 2 diabetes, even with adjustments for other CV risk factors. In a cohort analysis (9,306 participants in 40 countries) in people with prediabetes (139), 2,000 more steps/day at baseline was associated with a 10% reduction in CVD events at a median of 6 years and increasing counts by 2,000 steps/day in the first year of follow up was associated with an 8% reduction in CVD event rates at 6 years.

In a randomized controlled trial examining the effect of a pedometer-based prescription in people with type 2 diabetes, the change in A1C at the end of the 1-year step count prescription intervention was 0.38% lower in the active arm compared to the control arm (140). Active arm participants reviewed step count logs with their physicians at each clinic visit over a 1-year period, set step targets and received a written step count prescription. Those in the control arm were encouraged to be active 30 to 60 minutes daily. The change in steps over the 1-year intervention was 1,200 steps/day higher in the active compared to the control arm (140) (see Appendix 4. Smarter Step Count Prescription).

Two meta-analyses of clinical trials in type 2 diabetes demonstrated that pedometer-based facilitator-led group programs increase step counts by about 2,000 steps/day over 3 to 6 months (141,142). In these trials, the active arms engaged in pedometer-based interventions with monitoring and recording of daily step counts often complemented by support from a facilitator with or without peers in a group.

Exercise Prescription Examples

The following are practical examples illustrating how exercise can be prescribed:

Aerobic exercise

- Start by walking at a comfortable pace for as little as 5 to 15 minutes at one time.
- Gradually progress over 12 weeks to up to 50 minutes per session (including warm-up and cool down) of brisk walking.
- Alternatively, shorter exercise sessions in the course of a day, e.g. 10 minutes 3 times a day after meals, can replace a single longer session of equivalent length and intensity (143) (Table 2).

Resistance exercise

- Choose approximately 6 to 8 exercises that target the major muscle groups in the body.

Table 2
Aerobic exercise

Definition and recommended frequency	Intensity	Examples
Rhythmic, repeated and continuous movements of the same large muscle groups for at least 10 minutes at a time.	Moderate: 64%–76% of person's maximum heart rate	• Biking • Brisk walking • Continuous swimming • Dancing • Raking leaves • Water aerobics
Moderate-to-vigorous intensity aerobic exercise is recommended for a minimum of 150 minutes per week, no more than 2 consecutive days without exercise. Performance of smaller amounts of exercise is also beneficial, but to a lesser extent than the recommended amount. Higher-intensity interval training can increase aerobic fitness gains compared to continuous moderate-intensity exercise	Vigorous: >76% of person's maximum heart rate	• Brisk walking up an incline • Jogging • Aerobics • Hockey

Table 3
Resistance exercise*

Definition	Recommended frequency	Examples
Activities of brief duration involving the use of weights, weight machines or resistance bands to increase muscle strength and endurance	**2–3 times per week** • Start with 1 set using a weight with which you can perform 15 to 20 repetitions while maintaining proper form. • Progress to 2 sets and decrease the number of repetitions to 10–15 while increasing the weight slightly. If you cannot complete the required repetitions while maintaining proper form, reduce the weight. • Progress to 3 sets of 8 repetitions performed using an increased weight, ensuring proper form is maintained.	• Exercise with weight machines • Exercise with free weights

* Initial instruction and periodic supervision are recommended.
Note: The evidence supporting exercise with resistance bands is not as strong as the evidence for free weights or weight machines.

- Gradually increase the resistance until you can perform 3 sets of 8 to 12 repetitions for each exercise, with 1 to 2 minutes of rest between sets (113).
- The best evidence supports strength training with weight machines or free weights. Resistance bands may not be as effective to improve glycemic control, but they can help increase strength and can be a starting point to progress to other forms of resistance training.
- If you wish to begin resistance exercise, you should receive initial instruction and periodic supervision by a qualified exercise specialist to maximize benefits, while minimizing risk of injury, at least for the initial sessions (Table 3).

Interval exercise
- Exercise performed in intervals, alternating between higher intensity and lower intensity, can be used by participants who have trouble sustaining continuous aerobic exercise, or can be used to shorten total exercise duration or increase variety. Try alternating between 3 minutes of faster walking and 3 minutes of slower walking (144).
- Another form of interval training, high-intensity interval training (HIIT), can be performed through shorter intervals of higher-intensity exercise (e.g. 30 seconds to 1 minute at near-maximal intensity alternating with 1–3 minutes of lower-intensity activity) and can be performed with walking/running or other modalities, such as stationary cycling (8,26).
- Start with just a few intervals and progress to longer durations by adding additional intervals.

Other types of exercise
- Aquatic exercise can have similar benefits as other forms of exercise and help minimize barriers from conditions, such as osteoarthritis. Aquatic exercise can include walking briskly in the water, swimming or classes that include a variety of exercises.
- Other types of exercise or exercise classes, such as yoga, may be appealing for reasons, such as stress management.

Using pedometers or accelerometers
- Encourage people with diabetes to self-monitor physical activity with a pedometer or accelerometer. Ask them to record values, review at visits, set step count targets and formalize recommendations with a written prescription (see Appendix 4. Smarter Step Count Prescription).

Breaking up sedentary time
- It is best to avoid prolonged sitting. Try to interrupt sitting time by getting up briefly every 20 to 30 minutes.

Physical Activity in Children with Type 2 Diabetes: see Type 2 Diabetes in Children and Adolescents chapter, p. S247.

RECOMMENDATIONS

1. People with diabetes should ideally accumulate a minimum of 150 minutes of moderate- to vigorous-intensity aerobic exercise each week, spread over at least 3 days of the week, with no more than 2 consecutive days without exercise, to improve glycemic control [Grade B, Level 2, for adults with type 2 diabetes (2,4,6) and children with type 1 diabetes (20)]; and to reduce risk of CVD and overall mortality [Grade C, Level 3, for adults with type 1 diabetes (14) and type 2 diabetes (10)]. Smaller amounts (90–140 minutes/week) of exercise or planned physical activity can also be beneficial but to a lesser extent [Grade B, Level 2 (6,7) for glycemic control in type 2 diabetes; Grade C, Level 3 for mortality in type 2 diabetes (10) and type 1 diabetes (14)].

2. Interval training (short periods of vigorous exercise alternating with short recovery periods at low-to-moderate intensity or rest from 30 seconds to 3 minute each) can be recommended to people willing and able to perform it to increase gains in cardiorespiratory fitness in type 2 diabetes [Grade B, Level 2 (144)] and to reduce risk of hypoglycemia during exercise in type 1 diabetes [Grade C, Level 3 (28,29)].

3. People with diabetes (including elderly people) should perform resistance exercise at least twice a week (39) and preferably 3 times per week [Grade B, Level 2 (30)] in addition to aerobic exercise [Grade B, Level 2 (39–42)]. Initial instruction and periodic supervision by an exercise specialist can be recommended [Grade C, Level 3 (30)].

4. In addition to achieving physical activity goals, people with diabetes should minimize the amount of time spent in sedentary activities and periodically break up long periods of sitting [Grade C, Level 3 (100)].

5. Setting specific exercise goals, problem solving potential barriers to physical activity, providing information on where and when to exercise, and self-monitoring should be performed collaboratively between the person with diabetes and the health-care provider to increase physical activity and improve A1C [Grade B, Level 2 (128,129)].

6. Step count monitoring with a pedometer or accelerometer can be considered in combination with physical activity counselling, support and goal-setting to support and reinforce increased physical activity [Grade B, Level 2 (140,141)].

7. To reduce risk of hypoglycemia during and after exercise in people with type 1 diabetes, the following strategies can be considered alone or in combination:
   a. Reduce the bolus dose of the insulin that is most active at the time of exercise [Grade B, Level 2 (85)]
   b. Significantly reduce, or suspend (only if the activity is ≤45 minutes), basal insulin for the exercise duration [Grade B, Level 2 (79,87)], and lower the basal rate overnight after exercise by ~20% [Grade B, Level 2 (86)]
   c. Increase carbohydrate consumption prior to, during and after exercise, as necessary [Grade C, Level 3 (78,83,84)]
   d. Perform brief (10 seconds), maximal-intensity sprints at the start of exercise [Grade D, Level 4 (90)], periodically during the activity [Grade D, Level 4 (92)], or at the end of exercise [Grade D, Level 4 (91)]
   e. Perform resistance exercise before aerobic exercise [Grade D, Level 4 (46)].

8. People with diabetes ≥40 years of age who wish to undertake very vigorous or prolonged exercise, such as competitive running, long-distance running, or high-intensity interval training, should be assessed for conditions that might place them at increased risk for an adverse event with history, physical examination (including fundoscopic exam, foot exam and neuropathy screening), resting ECG and, possibly, exercise ECG stress testing [Grade D, Consensus].

9. Structured exercise programs supervised by qualified trainers should be implemented when feasible for people with type 2 diabetes to improve glycemic control, CV risk factors and physical fitness [Grade B, Level 2 (6,39)].

Abbreviations:
A1C, glycated hemoglobin*; BG*, blood glucose; *BP*, blood pressure; *BMI*, body mass index; *CV*, cardiovascular; *CVD*, cardiovascular disease; *ECG*, electrocardiogram; *FPG*, fasting plasma glucose; *HDL-C*; high-density lipoprotein cholesterol; *LDL-C*, low-density lipoprotein cholesterol.

Other Relevant Guidelines

Monitoring Glycemic Control, p. S47
Glycemic Management in Adults with Type 1 Diabetes, p. S80
Hypoglycemia, p. S104
Screening for the Presence of Cardiovascular Disease, p. S170
Type 2 Diabetes in Children and Adolescents, p. S247

Relevant Appendix

Appendix 4. Smarter Step Count Prescription

Author Disclosures

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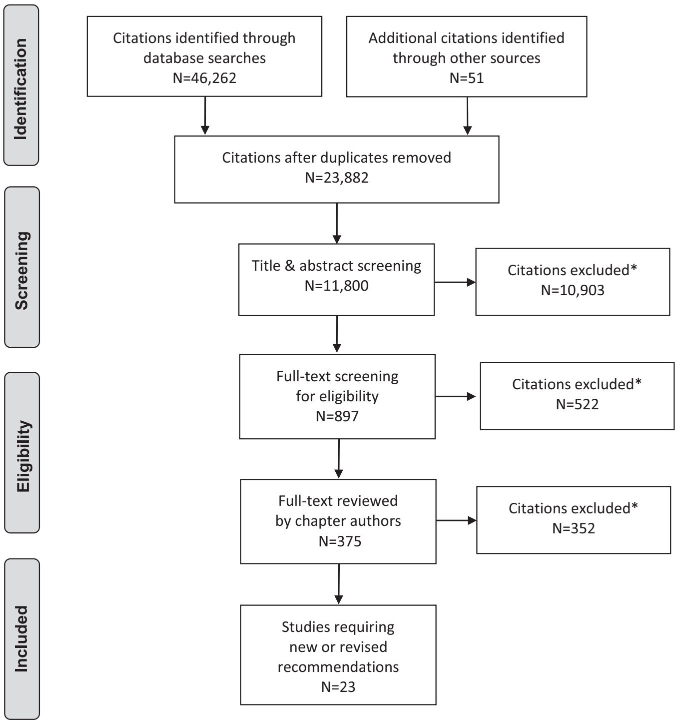
Literature Review Flow Diagram for Chapter 10: Physical Activity and Diabetes



*Excluded based on: population, intervention/exposure, comparator/control or study design

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