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Physical activity: the forgotten tool for type 2 diabetes management

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Individuals who are currently sedentary, unfit, or overweight can benefit metabolically from simply taking breaks from sitting. Since avoidance of sedentary behavior appears to have a large impact on glycemic management, all individuals with type 2 diabetes should be encouraged to minimally engage in greater daily movement to better manage their diabetes and body weight. In addition, engaging in physical activity of any intensity (including low-intensity ones) likely positively impacts insulin action and blood glucose control acutely. Moreover, as long as total caloric expenditure during exercise is matched (i.e., total exercise dose), daily exercise may be done every other day instead with the same glycemic results, although at least 150 min of weekly physical activity is recommended. Both aerobic and resistance training are important for individuals with diabetes, and ideally a program that combines the two types of training should be undertaken to achieve maximal glycemic and other benefits. Once individuals have successfully implemented more daily movement into their lifestyle, they will be more likely to participate in structured forms of physical activity to gain additional benefits. All clinicians working with individuals with either type 2 diabetes or prediabetes should consider incorporating these suggestions into care plans to improve their patients' glycemic management.

Keywords: type 2 diabetes, physical activity, exercise, sedentary behavior, physical inactivity, glycemic control

INTRODUCTION

For individuals who are currently sedentary, unfit, or overweight, the research is now compellingly clear that they can benefit metabolically from simply taking breaks from sitting regardless of whether they undertake other forms of physical activity (Healy et al., 2008; Cooper et al., 2012; Dunstan et al., 2012). Of course, they can additionally benefit from engaging in other types of activity (Boulé et al., 2001; Irvine and Taylor, 2009; Dube et al., 2012). The treatment goal for individuals with type 2 diabetes is to achieve and maintain optimal blood glucose, lipid, and blood pressure levels to prevent or delay chronic complications of diabetes (American Diabetes Association, 2012). Consequently, the purpose of this review is to reinforce how sedentary individuals with type 2 diabetes can greatly improve their metabolic health by taking small steps away from sedentary behavior toward greater physical activity participation.

TAKING BREAKS IN SEDENTARY TIME AND DOING MORE DAILY MOVEMENT

“Physical activity” includes any bodily movement that substantially increases energy expenditure, whereas “exercise” is the subset of planned, structured, and repetitive movements done to develop or maintain physical fitness, which includes cardiovascular, strength, and flexibility training options (Haskell et al., 2007; Nelson et al., 2007). Individuals with diabetes are frequently deconditioned and live a sedentary lifestyle (Church et al., 2005; Zhao et al., 2008; Larose et al., 2011). Therefore, the first major step in becoming regularly physically active is incorporation of more activities of daily living and other unstructured

physical activity into their lifestyles (Levine et al., 2005; Johannsen et al., 2008).

Standing up and moving around more can by themselves lower metabolic risk, and health benefits result from concurrently reducing total time engaged in sedentary pursuits and interspersing frequent, short bouts of standing and physical activity between periods of sedentary activity, even in physically active adults (Garber et al., 2011; Dunstan et al., 2012). Making small changes in daily activity levels, such as taking a 5-min walking break every hour, also likely benefits weight management. An individual will theoretically expend an additional 24, 59, or 132 kcal during an 8-h workday by walking around at a normal, self-selected pace for 1, 2, or 5 min every hour, respectively, compared with sitting for that whole time (Swartz et al., 2011). Even modest amounts of exercise in the absence of weight loss positively affect markers of glucose and fat metabolism in previously sedentary adults (Duncan et al., 2003). Taking breaks from sedentary time is a potential way to lose weight and prevent weight gain, and it may assist in preventing the onset of type 2 diabetes.

In middle-aged adults without diabetes, sedentary time predicts higher levels of fasting insulin independent of the amount of time spent doing moderate- and vigorous-intensity activity levels (Helmerhorst et al., 2009). For anyone with diabetes, inclusion of more daily, unstructured physical activity is likely to bestow even greater glycemic benefits. Participants in the Australian Diabetes, Obesity, and Lifestyle study wore accelerometers to measure sedentary time for seven consecutive days. Independent of total sedentary time and moderate- to vigorous-intensity activity, taking more frequent breaks in sedentary time was beneficially

associated with waist circumference, body mass index, triglyceride levels, and 2-h postmeal plasma glucose, highlighting the importance of avoiding prolonged uninterrupted periods of sedentary time (Healy et al., 2008). Frequent breaks from sitting may also assist in controlling postprandial spikes prevalent throughout the day in many individuals with type 2 diabetes, even in those with a glycated hemoglobin (HbA1c) level well below 7.0% (van Dijk et al., 2011).

In newly diagnosed adults with type 2 diabetes (ages 30–80 years), more time spent in sedentary pursuits has been associated with a larger waist circumference (Cooper et al., 2012), likely reflective of a greater amount of deleterious visceral fat (Amati et al., 2012). However, non-exercise activity thermogenesis (i.e., activities of daily living) can create a large daily caloric deficit to prevent excessive weight gain, which can facilitate body weight and glycemic management (Levine et al., 2005, 2008). Even standing counts as unstructured activity. Obese individuals sit for about 2.5 h more and walk 3.5 miles less per day than their lean counterparts (Levine et al., 2005). Furthermore, most of the activity done by lean individuals consists of walks of short-duration (<15 min) and low-velocity (1 mile/h). How long individuals sit each day or include movement during periods of prolonged inactivity is critical to metabolic health and diabetes management.

HOW DOES PHYSICAL ACTIVITY ACUTELY AFFECT GLYCEMIA?

Previously, the assumption was that aging underlies the reductions in insulin action common in the elderly; however, insulin resistance may not be a normal characteristic of aging, but rather associated with obesity and physical inactivity (Amati et al., 2009). Engaging in almost any type of physical activity facilitates glucose uptake, improves insulin sensitivity, and aids in glucose homeostasis by enhancing resting insulin action and lowering blood glucose levels for 2–72 h after the last bout of activity, depending on the exercise duration, intensity, and subsequent food intake (King et al., 1995; Boulé et al., 2001, 2005; O’Gorman et al., 2006). Exercised muscles take up more blood glucose during the ensuing rest period with the contraction-mediated pathway persisting for several hours (Ivy and Holloszy, 1981; Garetto et al., 1984) and insulin-mediated uptake for longer (Richter et al., 1982; Cartee et al., 1989; King et al., 1995; Bajpeyi et al., 2009). In adults with type 2 diabetes who exercise moderately, muscular uptake of blood glucose use usually exceeds hepatic glucose production, and blood glucose levels decline during the activity (Minuk et al., 1981). Plasma insulin levels concomitantly fall, making the risk of exercise-induced hypoglycemia low as long as the individual is not taking insulin or insulin secretagogues (Koivisto and DeFronzo, 1984). Muscular contractions increase blood glucose uptake to supplement muscular glycogen use (Ploug et al., 1984; Richter et al., 1985). Since this uptake pathway is contraction-induced and distinct from the one triggered by insulin (Khayat et al., 2002), glucose uptake into working muscle is normal even when insulin-mediated uptake is impaired (Colberg et al., 1996; Zierath et al., 1996; Braun et al., 2004).

Daily movement by itself apparently has a large impact on how well the body handles carbohydrate intake. In a recent study,

healthy normally active adults cut their physical activity levels (as monitored with daily steps) from over 10,000 a day to less than 5,000, which is considered a sedentary level (Mikus et al., 2012). The result over a 3-day period was that despite their release extra insulin in response to a glucose load, postprandial glucose spikes increased significantly and progressively over the 3 days, which reinforces the importance of daily physical activity as a mediator of glycemic control even without diabetes. In older individuals with type 2 diabetes, simply undertaking 20 min of self-paced walking after the dinner meal has been shown to be effective at lowering its glycemic impact compared with pre-meal walking or no exercise (Colberg et al., 2009).

Moreover, a single bout of moderate aerobic exercise can have a more lasting effect on diabetes management than previously thought. In a recent study, individuals with impaired glucose tolerance or type 2 diabetes engaged in a single session of either 30 min of moderate aerobic exercise or 45 min of moderate resistance training (van Dijk et al., 2012a). A single bout of either exercise substantially reduced the prevalence of hyperglycemia (blood glucose levels >10 mmol/L) for the following 24 h using continuous glucose monitoring. It also appears that total exercise need not be completed in a single session to be effective since in elderly men with type 2 diabetes, moderate- to high-intensity training performed more frequently (done as three, 10-min sessions daily) resulted in more beneficial effects on glycemic control than doing a single, 30-min session, even though cardiorespiratory fitness increased similarly (Eriksen et al., 2007).

DOES EXERCISE HAVE TO BE INTENSE?

Blood glucose decreases during any physical activity are related to the intensity and duration of the exercise, pre-exercise control, and state of physical training (Colberg et al., 1996; Boulé et al., 2001, 2005; Sigal et al., 2007). Although prior physical activity of any intensity generally enhances uptake of circulating glucose for glycogen synthesis (Christ-Roberts et al., 2003; Galbo et al., 2007), and stimulates fat oxidation and storage in muscle (Duncan et al., 2003; Goodpaster et al., 2003; Boon et al., 2007), more prolonged or intense activity usually enhances acute insulin action for longer (Braun et al., 1995; Larsen et al., 1999; Houmard et al., 2004; Evans et al., 2005; Sigal et al., 2007; Bajpeyi et al., 2009). During brief, intense aerobic exercise, plasma catecholamine levels rise markedly, driving a major increase in blood glucose production (Marliss and Vranic, 2002). As a consequence, hyperglycemia can result and persist for up to 1–2 h, likely because plasma catecholamine levels and glucose production do not return to normal immediately with cessation of the intense activity (Marliss and Vranic, 2002).

Recently, low-volume, high-intensity training (HIT) was shown to rapidly improve glucose control and induce adaptations in skeletal muscle that are linked to improved metabolic health in adults with type 2 diabetes (Little et al., 2011). In that study, participants undertook 2 weeks of thrice weekly exercise that consisted of ten 60-s sessions separated by 1 min of rest done at 90% of maximal heart rate. Training reduced blood glucose by 13% over the 24-h period following training, as well as postprandial glucose spikes for several days afterwards. However, given the intensity of such training, each individual’s fitness level and cardiovascular

risk factors should be carefully considered before HIT is prescribed.

Conversely, physical activity need not be intense to be beneficial. Acute improvements in insulin sensitivity in women with type 2 diabetes have been found for equivalent energy expenditures whether they engaged in low-intensity or high-intensity walking (Braun et al., 1995). Reduction in coronary risk factors and other benefits can be obtained by incorporating frequent bouts of moderate-intensity activity on most days of the week even if not a traditional, structured one (McBride et al., 2008; Loimaala et al., 2009). Moreover, even light-intensity physical activity is associated with blood glucose reductions, whereas sedentary time is unfavorably associated with increased levels (Healy et al., 2007). Adults with type 2 diabetes who performed an isoenergetic bout of endurance-type exercise for 60 min at a low intensity or 30 min at a high intensity reduced their prevalence of hyperglycemia by 50 and 19%, respectively, for 24 h afterwards (Manders et al., 2010). Therefore, a single bout of low-intensity work may actually be more effective at lowering the prevalence of hyperglycemia throughout the subsequent 24-h period than high-intensity work. Others have confirmed that when matched for energy cost, prolonged continuous low- to moderate-intensity endurance-type exercise and moderate- to high-intensity training done 3 days a week are equally effective in lowering HbA1c and increasing whole body and skeletal muscle oxidative capacity in obese individuals with type 2 diabetes (Hansen et al., 2009).

Engaging in low-intensity activities likely bestows other positive effects, including preventing some of the potential decline in cognition commonly found in older individuals with type 2 diabetes (Colberg et al., 2008). Even simple, low-intensity balance training done for 6 weeks by older participants with type 2 diabetes substantially lowers their falls risk (Morrison et al., 2010, 2012), which may promote further participation in all levels of physical activity by removing their fear of falling (Borer, 2005; Zijlstra et al., 2007).

SHOULD EXERCISE BE DAILY OR LESS FREQUENT?

Although the common belief is that doing daily exercise is better, but that may not be necessary. A graded dose–response relationship appears to exist between the aerobic exercise training dose (a product of exercise intensity, duration, and frequency) and improvements in insulin sensitivity. Exercise intensity has been shown to be significantly related to improvements in insulin action, while frequency may not be, at least in 55 healthy adults undergoing 16 weeks of supervised endurance training (three to five sessions lasting 45 min/week, with three sessions supervised; Dube et al., 2012). Others have shown that engaging in structured exercise training of more than 150 min/week results in greater glycemic benefits, thus the total exercise dose may be important (Umpierre et al., 2011). Engaging in 170 min of exercise per week has been shown to improve insulin sensitivity more substantially than 115 min, regardless of exercise intensity and volume, suggesting that total exercise duration should thus be considered when designing training programs to improve insulin action (Houmard et al., 2004).

Aerobic exercise is recommended at least 3 days/week with no more than two consecutive days between bouts of activity

due to the short-lived nature of improvements in insulin action (King et al., 1995; Boulé et al., 2005). Most exercise interventions in adults with type 2 diabetes have used a frequency of three times per week (Boulé et al., 2001; Snowling and Hopkins, 2006; Thomas et al., 2006; Sigal et al., 2007), but current guidelines for adults generally recommend five sessions of moderate activity (Haskell et al., 2007; Nelson et al., 2007; Physical Activity Guidelines Advisory Committee, 2008). However, in a recent study, when adults with type 2 diabetes either did no exercise or engaged in 60 min of moderate cycling exercise distributed either as a single session performed every other day or as 30 min of exercise performed daily and their blood glucose was monitored continuously for 48 h, their prevalence of hyperglycemia was reduced from 32% of that period following no exercise to 24% over 48 h following daily cycling or following cycling done every other day (van Dijk et al., 2012b). Thus, it appears that as long as total caloric expenditure during exercise is matched, daily exercise can be done every other day instead and have the same beneficial glycemic results.

IS RESISTANCE TRAINING NECESSARY?

In older individuals who are overweight or obese, the loss of muscle mass combined with fat weight gain can result in sarcopenic obesity and decreased mobility (Baumgartner, 2000; Baumgartner et al., 2004). Resistance training has been shown to improve musculoskeletal health, enhance the ability to perform activities of daily living, and lower the risk of injury (including from accidental falls) and descent into frailty (Willey and Singh, 2003; Haskell et al., 2007; Nelson et al., 2007; Garber et al., 2011). In fact, properly designed resistance programs may improve cardiovascular function, glucose tolerance, strength, and body composition, allowing older adults to remain more independent and self-sufficient as they age (Bemben et al., 2000; Castaneda et al., 2002; Dunstan et al., 2002; Cornelissen and Fagard, 2005; Daly et al., 2005; Cohen et al., 2008; American College of Sports Medicine, 2009; Church et al., 2010).

Resistance training has additional metabolic benefits. It can improve glycemic control, likely even more so than aerobic training (Ishii et al., 1998; Poehlman et al., 2000; Castaneda et al., 2002; Vincent et al., 2002; Ibanez et al., 2005; Snowling and Hopkins, 2006). Despite the fact that intense resistance exercise can acutely raise blood glucose levels ensuing from an exaggerated counter regulatory hormonal response (Kreisman et al., 2003), regular resistance work improves overall glycemic control and insulin sensitivity by increasing levels of muscle GLUT4, insulin receptors, protein kinase B, glycogen synthase, and glycogen synthase total activity following acute training (Holten et al., 2004). In older men with new-onset diabetes, 16 weeks of twice-weekly progressive resistance training resulted in a 46% increase in insulin sensitivity, 7% reduction in fasting blood glucose, and loss of visceral fat, all while consuming a 15.5% average higher calorie intake (Ibanez et al., 2005). In fact, when combined with moderate weight loss, resistance training was more effective for improving overall glycemic control than moderate weight loss alone and prevented muscle mass loss (Dunstan et al., 2002).

Much of the observed enhancement in insulin action with resistance exercise may be related to greater muscle mass, which

can result from a variety of different training intensities (Bemben et al., 2000; Castaneda et al., 2002; Willey and Singh, 2003). Engaging in 16 weeks of progressive resistance training not only reduces HbA1c levels significantly in adults with type 2 diabetes, but also increases muscle glycogen stores and allows 72% of participants to reduce prescribed medication doses (Castaneda et al., 2002). Acute resistance exercise sessions with either light or moderate intensities are effective for controlling blood glucose levels (Moreira et al., 2011); however, home-based progressive resistance training following supervised training is less effective for maintaining glycemic control than gymnasium-based work. Improvements in muscle strength and mass can be similar, but reduced adherence and exercise training volume and intensity may impede its glycemic impact (Dunstan et al., 2005).

WHAT ABOUT COMBINED AEROBIC AND RESISTANCE TRAINING?

Finally, in almost all studies undertaken to date that have compared combined training with either aerobic or resistance training alone, the total duration of exercise and caloric expenditure have been greater during combined training (Cuff et al., 2003; Sigal et al., 2007; Marcus et al., 2008), and both types of training have been undertaken together on the same days. However, a recent study examined the effects of an equal caloric expenditure among combined and separate aerobic and resistance training groups (Church et al., 2010). In that study, adults with type 2 diabetes did resistance training alone 3 days a week, aerobic exercise (expending 12 kcal/kg/week), or combined aerobic and resistance training. Surprisingly, only those doing combined training

(with twice-weekly resistance work) improved their HbA1c levels significantly.

In a recent meta-analysis, aerobic, resistance, and combined exercise training were found to be associated with HbA1c reductions of 0.67% following 12 or more weeks of training (Umpierre et al., 2011). Structured exercise exceeding 150 min/week, however, was associated with greater glycemic benefit (0.89% lower HbA1c) than 150 min or less (0.36% reduction), although any type of training caused greater declines in glycemic levels than physical activity advice alone. Unfortunately, no studies have yet investigated whether daily, but alternating, training would be more effective, and the blood glucose impact of various isocaloric combinations of training programs remains to be fully studied.

CONCLUSION

Since simply avoiding sedentary behavior appears to have a large impact on glycemic management, individuals with type 2 diabetes should be encouraged to minimally engage in frequent daily movement to better manage their diabetes and body weight. While daily movement is not as effective as most structured exercise programs in increasing fitness levels, it is important for expending extra calories, breaking up sitting time, and building a fitness base in sedentary individuals. Once increased daily movement is implemented, individuals will likely feel more confident, ready, and able to participate in structured forms of physical activity, including both aerobic and resistance training of varying intensities, which can greatly enhance their health and diabetes management.

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