2021 | Volume 42 | Number 2
A Peer-Reviewed Publication

Diabetes
a dietetic practice group of the
eat right. Academy of Nutrition and Dietetics
Experts in Diabetes Care and Education

ON THE
CUTTING EDGE
Diabetes Dietetic Practice Group

THE EPIDEMIC OF PREDIABETES: THE RDN'S ROLE IN LIFESTYLE COUNSELING AND RISK REDUCTION

Message from the Theme Editor:

Andrea Dunn, RD, LD, CDCES

When I think of prediabetes, I think of the robot from *Lost in Space*, a space-age television series I watched as a child. When the aliens approached, the robot would frequently wave his arms around and shout, "Danger! Danger! Warning! Warning!" As a registered dietitian nutritionist (RDN), I believe prediabetes is a pre-emptive warning to heed the impending danger of developing type 2 diabetes (T2D).

The last time *On the Cutting Edge (OTCE)* wrote on diabetes prevention was in 2012. Back then T2D affected almost 26 million Americans with as many as 79 million people in the United States having prediabetes. Today, we have 34.2 million with T2D and 88 million adults with prediabetes (1). Although we have not been able to halt the epidemic, as RDNs we play a key role in educating our patients to help slow or delay the progression.

The US Preventive Services Task Force (USPSTF) has recently updated their recommendation in screening for prediabetes and T2D. The task force has lowered the starting age for screening from 40 to 35 years old. The USPSTF now recommends adults aged 35 to 70 years who have overweight or obesity (BMI ≥ 25 kg/m^2, or ≥ 23 kg/m^2 for Asian Americans) and have no symptoms of diabetes be screened for prediabetes and T2D. People of ethnic or racial groups that are disproportionately affected by diabetes may even need to be screened at an earlier age. This new screening recommendation will allow earlier detection, diagnosis, and intervention (2).

In the opening article of this *OTCE* edition, Anna Parker, DCN, MS, RD, CDCES, FAND, CCRC, a clinical research dietitian, reviews the Diabetes Prevention Program (DPP) and the Diabetes Prevention Program Outcomes Study (DPPOS). These landmark studies were designed to assess whether lifestyle intervention or metformin could prevent or delay T2D. Dr. Parker highlights the role of Medical Nutrition Therapy (MNT) in the prevention of T2D.

Many of us are aware that prediabetes is more common in certain groups: including older adults, women with polycystic ovarian syndrome (PCOS) and in those with a history of Gestational Diabetes (GDM). Unfortunately, we are also now seeing a substantial rise of

Physical Activity/Exercise for Type 2 Diabetes Prevention

Douglas Glazer, DPE, ATC
Endicott College
Beverly, MA

Jacqueline Ifat Shahar, MEd, RCEP, CDCES
Joslin Diabetes Center
Boston, MA

Introduction

According to the Centers of Disease Control and Prevention, nearly 88 million people have been diagnosed with prediabetes and close to 85% of this population are unaware that they have it (1). There is a 74% risk of progression from prediabetes to type 2 diabetes (T2D) (2). Multiple diabetes complications such as neuropathy, retinopathy, nephropathy; and macrovascular diseases including coronary artery disease, peripheral arterial disease, and stroke have been reported to be associated with prediabetes (3). However, numerous studies have indicated that losing 5-7% of body weight through intensive lifestyle interventions can reduce the risk of developing T2D by 58% (4,5). Therefore, it is important to examine how and to what extent physical activity helps prevent T2D. The purpose of this article is to review the effects of physical activity/ exercise on glucose metabolism, how physical activity/exercise can help manage prediabetes and offer practical recommendations to those with prediabetes.

Metabolic Effects of Exercise

There are two main sources for energy in the body: fat, which is stored in muscle tissue or as free fatty acids from adipose tissue; and glucose, which circulates in the blood, liver or is stored in the liver or muscle tissues in the form of glycogen. While at rest, the body primarily uses free fatty acids as an energy source to meet its needs. Exercise, however, increases the demands of the body, subsequently increasing energy requirements. The substrates that are used for energy are controlled by neuroendocrine responses that are determined by the intensity and length of the exercise. During exercise, the active muscles require glucose to contract. As the body uses more glucose, insulin levels drop, as the hormones epinephrine, glucagon, and cortisol increase simultaneously. As the intensity and duration of exercise increases, these hormones cause increased use of blood glucose and free fatty acids for energy (6).

Skeletal muscles use significant amounts of glucose. About 80% of glucose uptake occurs in skeletal muscles among healthy people, while in people with prediabetes and T2D, only about 50% of glucose uptake occurs in skeletal muscles (7,8). This decreases oxidative capacity and does not allow appropriate metabolism of glucose and lipids, thereby increasing glucose circulating in the blood stream which can contribute to the development of T2D. Aerobic and resistance training promote the effectiveness of insulin in part by either maintaining or increasing muscle mass and increasing insulin sensitivity (6). An increase in type 1 muscle fibers, also known as slow twitch, muscle fibers can lead to greater increase in glucose uptake (9).

Muscle contraction increases glucose uptake by muscle fibers (7). The increased glucose uptake in the muscle is due to the recruitment of glucose transporter protein 4 (GLUT 4) in the cell membrane. The protein carrier, GLUT 4, helps increase glucose uptake into the active muscles. Exercise leads to the activation of glucose transport by GLUT 4. As the frequency and duration of exercise increases, the number of GLUT 4 that are available to move more glucose to the active muscle increase. This is an adaptation of exercise training mediated through an insulin-independent pathway. An important aspect of this improved insulin sensitivity is that it occurs regardless of any effects of weight loss or reduction in adipose tissue (6,7). Exercise training is the most potent stimulus to increase skeletal muscle GLUT4 expression, an effect that may partly contribute to improved insulin action and glucose disposal and enhanced muscle glycogen storage following exercise training in health and disease (10). During the recovery period, more glucose enters the muscle cells due to the increased insulin sensitivity. This can last between 12 to 48 hours after the exercise has been completed and is connected to restoring muscle glycogen (11).

Benefits of Physical Activity/Exercise for Diabetes Prevention

Physical activity is defined as activity that involves large muscle groups with increased respiration and heart rate while expanding energy (12,13).

Exercise refers to structured planned physical activity that focuses on achieving specific goals such as improving endurance and increasing strength and flexibility as well as balance. Physical activity provides physical and mental benefits such as improvement in the cardiovascular system, increase in muscle strength, increased bone mineral density, and improved blood pressure, blood glucose and lipid profiles. In addition, physical activity reduces stress and anxiety, helps with sleep, and reduces risk of chronic disease. Despite the great benefits of physical activity, most Americans (77%) do not perform sustained physical activity and only 10% of American adults exercise at an intensity that increases cardiovascular fitness (12).

Physical activity and reducing a sedentary lifestyle are essential in managing prediabetes. Incorporating short bouts of activity throughout the day can promote energy expenditure, reduce post-prandial hyperglycemia, improve blood glucose control long-term, and reduce the risk for T2D, some cancers and all-cause mortality (14-17). Chung et al. reported that non-exercise activity thermogenesis (NEAT) can assist in increasing energy expenditure (18). Several researchers reported that briefly interrupting (≤ 5 min) prolonged sitting with standing or light walking every 30 minutes improves glucose control in sedentary people with overweight or obesity and with impaired glucose control (19-21). Increasing standing and light physical activity that are easy to incorporate as part of daily activities are appealing can promote metabolic benefits (20). Therefore, using standing desks or treadmill desks could be useful to break up extended periods of inactivity. In those with T2D, other activities such as yoga or tai chi training may improve glucose control (22,23).

Benefits of Resistance Training

There are physiological changes occurring as a person ages including sarcopenia that affect insulin utilization. Sarcopenia refers to the loss of muscle mass associated with aging. Skeletal muscle mass starts decreasing around the mid-40s with the process accelerating after age 60 ranging from 3-8% every decade (24).

Aerobic exercise for some people can be challenging due to a variety of reasons, making resistance training a valuable alternative. Resistance training can provide many benefits, including decrease in fat mass, blood pressure, and hemoglobin A1C; as well as increases in bone mineral density, lean muscle mass cardiovascular endurance, daily energy expenditure, glycemic control, insulin sensitivity and quality of life (24).

The increase in muscle mass (both type I and II muscle fibers) from resistance training is especially important for those with prediabetes since it contributes to increased insulin sensitivity. Resistance training increases GLUT4 protein content and the upregulation of insulin receptors (25,26). These benefits were demonstrated in the Health Professional Follow-up Study, in which adult subjects who performed resistance training for more than 150 min per week had a 34% reduction in risk of T2D. In subjects who had obesity and performed resistance training for at least 150 minutes per week or more, the risk reduction in developing T2D increased to 60% (27). Furthermore, Umpierre et al. conducted a meta-analysis and found that A1C levels in those with T2D decreased by 0.67% as a result of a 12-week resistance training program compared to sedentary controls (28).

Benefits of Aerobic Training

Aerobic training improves cardiorespiratory fitness which in turn improves insulin sensitivity. An appropriate intensity for people with metabolic diseases such as prediabetes would be moderate intensity, 50% to 68% of maximal oxygen uptake (6), which is equivalent to 12 to 14 (somewhat hard) on the Borg Rating of Perceived Exertion (RPE) scale. The RPE scale ranges from 6 perceiving 'no exertion at all' to 20 perceiving a 'maximal exertion' of effort (29). For greater increases in insulin sensitivity, a duration of 30-60 minutes per exercise session appears to be more beneficial than shorter durations. Furthermore, high-intensity interval training (HIIT), which occurs in short bursts (15-240 seconds) of high intensity (17 or higher on the RPE scale) appear to have even greater effects on insulin, but this type of training may not be feasible for all. Researchers suggest that combining numerous bouts of high intensity long duration aerobic training will result in the greatest insulin-sensitizing effects (6). RezkAllah et al. conducted a single-blinded, randomized controlled study comparing low volume HIIT (LVHIIT) to high volume HIIT (HVHIIT) on a treadmill (30). Participants were randomized to either HVHIIT or LVHIIT. Participants in the HVHIIT group exercised for a total of 40 minutes including bouts of 4 minutes at 90% of maximal heart rate and 3 minutes recovery at 70% of maximal heart rate; this was repeated 4 times. LVHIIT consisted of participants exercising for a total of 25 minutes including 1 minute at 90% of maximal heart rate and 1 minute recovery repeated 10 times. Sessions were performed 3 days per week for 12 weeks. It was found that HVHIIT was more beneficial in improving fasting blood glucose (FBG) and hemoglobin A1C in people with prediabetes in comparison to

LVHIIT (30). Another benefit of aerobic training is a decrease in fat tissue mass especially visceral fat, which also helps with insulin sensitivity. Furthermore, it has been found that aerobic training can improve pancreatic beta-cell function in people with prediabetes and those with T2D (6).

Practical Recommendations for Physical Activity

The latest physical activity guidelines for adults from the U.S. Department of Health and Human Services, Physical Activity Guidelines for Americans, 2nd edition, were updated in 2018 and focused on reducing sedentary lifestyle to minimize the risk of comorbidities and featured the message that some activity is better than no activity (17). It is recommended that American adults engage in at least 150 minutes per week of moderate intensity aerobic activity with a minimum of 10 minute bouts accumulated throughout the day, or 75 minutes of combined moderate to vigorous activity, using the individual's perceived exertion. This should occur on three or more days per week with no more than two consecutive days without any physical activity. Aerobic activity should include using large muscle groups, including activities such as walking, cycling, hiking, dancing, swimming or using cardiovascular machines such as an elliptical or rower, etc. To receive additional health benefits it is recommended to engage in 300 minutes of moderate to vigorous activity including HIIT (31).

Resistance training should be incorporated into the physical activity program to manage sarcopenia, preserve muscle mass and increase muscle strength (17). These exercises should focus on functional movements to improve activities of daily living and quality of life. Types of exercise include using resistance machines, free weights and resistance bands, as well as body weight. Initial training intensity should be moderate, which involves 10-15 repetitions to near fatigue per set. Eight to ten different exercises in a full range of motion, focusing on various parts of the body should be completed in 1-3 sets. Once the targeted number of repetitions can be consistently reached or even exceeded, then one should progress to increase the resistance or weight/load on the muscle and decrease to 6-10 repetitions near fatigue. Further progressions include increasing the sets as well as training frequency. Resistance training should be performed 2-3 times per week on non-consecutive days to improve muscular endurance and strength (17).

Exercise programs should also include flexibility exercises to improve range of motion at the joints, and balance training to develop proprioception cells and reduce the risk of falls (13,17). Stretches can be static and dynamic. Static stretches need to be held to the point of mild discomfort or tension for 10-30 seconds and repeated 1-2 times. Stretching and balance exercises should be performed at least 2-3 days per week (17). Alternative activities that are beneficial to increase flexibility, balance and strength include tai chi and yoga (22,23). Exercise sessions should begin with a warm-up to prepare the body for activity and end with a cool down (18).

Multiple barriers to engaging in physical activity have been identified among people with T2D in different countries, including: a lack of time; competing priorities/work and family commitments; medical issues and extreme weather; not being in a good shape; limited ability to exercise due to heart disease and joint and muscle pain; not having access to exercise facilities; lack of motivation; difficulty using apps for exercise; and a lack of understanding about the need to exercise (32,33). To help overcome these barriers and to minimize the risks of injuries or other adverse events, the following suggestions are recommended:

- People should choose the types of physical activities that they enjoy and are appropriate for their current fitness level, medical conditions and health goals.
- Sedentary people should start with short, light bouts of activity at a low intensity. It is best for physical activity to gradually progress in intensity, duration and/or frequency as tolerated (17).
- Establishing a support system by exercising with friends and family can help as well. Working on time-management skills and setting realistic individualized goals can increase an individual's self-efficacy which can help overcome barriers and fears to exercise (34).
- Increasing one's knowledge about the benefits of exercise, as well as, increasing their exercise skills can also help build confidence and increase their motivation to exercise.
- To help overcome barriers, prediabetes requires ongoing management by an interprofessional healthcare team and effective self-management to achieve better glucose control.

Summary

Physical activity and exercise offer numerous benefits for people with prediabetes and can help to delay or prevent development of T2DM. These benefits include improved insulin sensitivity and glucose control, reduction in visceral body fat, increase in muscle mass, and an increase in glucose transport into the muscle. Therefore, a lifestyle intervention program including physical activity and exercise are extremely important for people with prediabetes.

> An ideal exercise program may include 5 days of aerobic exercise, 2-3 days of resistance and 2-3 days of flexibility and balance exercises. It can also be beneficial to add short bouts of activity for non-exercise activity thermogenesis to break up long periods of sitting or inactivity. Following the exercise guidelines provided in this article can help minimize the risk for developing T2D. It is important for people with prediabetes to consult with a healthcare professional or exercise specialist before starting a new exercise routine, and to help maximize the benefits of exercise and to help manage any complications or issues that may arise.

References

1. U.S. Department of Health and Human Services. Prediabetes - Your Chance to Prevent Type 2 Diabetes. Available at https://www.cdc.gov/diabetes/basics/prediabetes.html. Accessed July 21, 2021
2. Ligthart S, van Herpt TTW, Leening MJG, et al. Lifetime risk of developing impaired glucose metabolism and eventual progression from prediabetes to type 2 diabetes: a prospective cohort study. *Lancet Diabetes Endocrinol*. 2016;4(1):44-51. doi: 10.1016/S2213-8587(15)00362-9
3. Bansal N. Prediabetes diagnosis and treatment: A review. *World J Diabetes*. 2015;6(2):296-303. doi: 10.4239/wjd.v6.i2.296
4. Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346(6): 393–403.
5. Tuomilehto J, Lindström J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344(18):1343–1350.
6. Burr JF, Rowan CP, Jamnik VK, Riddell MC. The Role of Physical Activity in Type 2 Diabetes Prevention: Physiological and Practical Perspectives. *Phys Sportsmed*. 2010;38(1):72-82. https://doi.org/10.3810/psm.2010.04.1764
7. Holten MK, Zacho M, Gaster M, Juel C, Wojtaszewski JFP, Dela F. Strength training increase insulin-mediated glucose uptake, GLUT 4 content, and insulin signaling in skeletal muscle in patients with type 2 diabetes. *Diabetes*. 2004;53(2):294-305.
8. DeFronzo RA, Gunnarson R, Björkman O, Olsson M, Wahren J. Effects of insulin on peripheral and splanchnic glucose metabolism in noninsulin-dependent (type II) diabetes mellitus. *J Clin Invest*. 1985;76(1):149-155.
9. Corcoran MP, Lamon-Fava S, Fielding RA. Skeletal muscle lipid deposition and insulin resistance: effect of dietary fatty acids and exercise. *Am J Clin Nutr*. 2007;85(3):662-677.
10. Richter EA, Hargreaves M. Exercise, GLUT 4, and skeletal muscle glucose uptake. *Physiol Rev*. 2013;93(3):993-1017.
11. Magkos F, Tsekouras Y, Kavouras SA, Mittendorfer B, Sidossis LS. Improved insulin sensitivity after a single bout of exercise is curvilinear related to exercise energy expenditure. *Clin Sci (Lond)*. 2008; 114(1):59-64.
12. Chui K, Tudini F, Yen SC. Exercise. In Edelman CL, Kudzma EC, eds. *Health Promotion Throughout the Life Span*. St. Louis, MO: Elsevier; 2018: 272-307.
13. Elmagd MA. Benefits, need and importance of daily exercise. *International Journal of Physical Education, Sports and Health*. 2016;3(5):22-27.
14. Levine JA, McCrady SK, Lanningham-Foster LM, Kane PH, Foster RC, Manohar CU. The role of free-living daily walking in human weight gain and obesity. *Diabetes*. 2008;57(3):548–554.
15. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. *Science*. 2005;307(5709):584–586.
16. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science*. 1999;283(5399):212–214.
17. U.S. Department of Health and Human Services. Physical Activity Guidelines for Americans, 2nd edition. Washington, DC: U.S. Department of Health and Human Services; 2018.
18. Chung N, Park MY, Kim J, et al. Non-exercise activity thermogenesis (NEAT): a component of total daily energy expenditure. *Journal of Exercise Nutrition Biochemistry*. 2018;22(2):23–30. doi: 10.20463/jenb.2018.0013
19. Buckley JP, Mellor DD, Morris M, Joseph F. Standing-based office work shows encouraging signs of attenuating post-prandial glycaemic excursion. *Occup Environ Med*. 2014;71(2):109–111.
20. Henson J, Davies MJ, Bodicoat DH, et al. Breaking up prolonged sitting with standing or walking attenuates the postprandial metabolic response in postmenopausal women: a randomized acute study. *Diabetes Care*. 2016;39(1): 130-138.
21. Thorp AA, Kingwell BA, Sethi P, Hammond L, Owen N, Dunstan DW. Alternating bouts of sitting and standing attenuate postprandial glucose responses. *Med Sci Sports Exerc*. 2014;46(11):2053-2061.
22. Innes KE, Selfe TK. Yoga for adults with type 2 diabetes: a systematic review of controlled trials. *J Diabetes Res*. 2016; 2016:6979370.
23. Ahn S, Song R. Effects of tai chi exercise on glucose control, neuropathy scores, balance, and quality of life in patients with type 2 diabetes and neuropathy. *J Altern Complement Med*. 2012;18(12):1172–1178.
24. Codella R, Ialacqua M, Terruzzi I, Luzi L. May the force be with you: why resistance training is essential for subjects with type 2 diabetes mellitus without complications. *Endocrine*. 2018;62(1):14-25. doi: 10.1007/s12020-018-1603-7
25. Tabata I, Suzuki Y, Fukunaga T, Yokozeki T, Akima H, Funato K. Resistance training affects GLUT-4 content in skeletal muscle of humans after 19 days of head-down bed rest. *J Appl Physiol*. 1999;86(3):909–914.
26. Cauza E, Hanusch-Enserer U, Strasser B, et al. The relative benefits of endurance and strength training on the metabolic factors and muscle function of people with type 2 diabetes mellitus. *Arch Phys Med Rehabil*. 2005;86(8):1527–1533.
27. Grøntved A, Rimm EB, Willett WC, Andersen LB, Hu FB. A prospective study of weight training and risk of type 2 diabetes mellitus in men. *Arch Intern Med*. 2012;172(17): 1306-1312.
28. Umpierre D, Ribeiro PAB, Kramer CK, et al. Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: a systematic review and meta-analysis. *JAMA*. 2011;305(17):1790-1799. doi: 10.1001/jama.2011.576
29. Centers for Disease Control and Prevention. Physical Activity – Perceived Exertion. COVID-19: How to Be Physically Active While Social Distancing. Available at https://www.cdc.gov/physicalactivity/basics/measuring/exertion.htm. Accessed July 21, 2021
30. RezkAllah SS, Takla MK. Effects of different dosages of interval training on glycemic control in people with prediabetes: A randomized controlled trial. *Diabetes Spectrum*. 2019;32(2):125-131.
31. Jelleyman C, Yates T, O'Donovan G, et al. The effects of high-intensity interval training on glucose regulation and insulin resistance: a meta-analysis. *Obes Rev*. 2015;16(11):942-961. doi: 10.1111/obr.12317
32. Adeniyi AF, Anjana RM, Weber MB. Global account of barriers and facilitators of physical activity among patients with diabetes mellitus: a narrative review of the literature. *Current Diabetes Rev*. 2016;12(4) 440-448.
33. Lidegaard LP, Schwennesen N, Willaing I, Faerch, K. Barriers to and motivators for physical activity among people with type 2 diabetes: patients' perspective. *Diabetic Med*. 2016;33(12):1677-1685. DOI: 10.1111/dme.13167
34. American Diabetes Association. Overcoming Barriers and Get Moving. Available at https://www.diabetes.org/healthy-living/fitness/overcoming-barriers. Accessed July 21, 2021.