Exercise in Diabetes

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Objectives

- understand the impact of sedentary lifestyle and low cardiorespiratory fitness on diabetes
- Identify benefits of aerobic and resistance training
- Understand post activity blood sugar excursions and offer treatment/preventative measures
- Recommend exercise modalities for those with diabetes complications

Introduction

- Significant health problem in US and world wide; worsening
- With T2DM 2/3 of deaths are from CVD, MI, CVA
- Exercise is a cornerstone tx, yet most do not use it
- Sedentary lifestyle is linked with increased morbidity and mortality which is already high with T2DM
- Sedentary + excess calories have lead to an explosion of obesity and T2DM

- Regensteiner, J.G., Reusch, J.E.B., Stewart, K.J. & Veves, A. (Eds). (2009). Contemporary Diabetes, Diabetes and Exercise. New York: Springer.

Introduction of the problem Statistics

- U.S. prevalence: 30.3 million people of all ages, ~23 million diagnosed, ~7 million undiagnosed (9.4% of the population) have T2DM as 2015.
  - Projections estimate 37.7 million (14.5% of adult population) by 2031
- Estimates 2,500 new Dx T2DM each day
- Estimate: 33.9% of adults > 18 y/o (84.1 million) had pre-DM in 2015
  - Estimated 11.6% of people reported being told by their health professional of the Dx of pre-DM
- 7th leading cause of death in the U.S.

- Centers for Disease Control and Prevention. National Diabetes Statistics Report, 2017. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services; 2017. Retrieved from: http://www.diabetes.org/assets/pdfs/basics/cdc-statistics-report-2017.pdf
- Regensteiner, J.G., Reusch, J.E.B., Stewart, K.J. & Veves, A. (Eds). (2009). Contemporary Diabetes, Diabetes and Exercise. New York: Springer.

Introduction Costs

- Total direct and indirect cost of DM $245 billion.
- Ave. cost- $13,700 per person/year. 2.3 times higher than without the diagnosis

- Centers for Disease Control and Prevention. National Diabetes Statistics Report, 2017. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services; 2017. Retrieved from: http://www.diabetes.org/assets/pdfs/basics/cdc-statistics-report-2017.pdf
- Regensteiner, J.G., Reusch, J.E.B., Stewart, K.J. & Veves, A. (Eds). (2009). Contemporary Diabetes, Diabetes and Exercise. New York: Springer.

The Benefits

- Moderate exercise can improve A1c upwards of 20%
- Dx; T2D and metabolic syndrome increase risk of CAD, HTN, hypercoagulation, hyperinsulinemia, central adiposity, atherogenic dyslipidemia. Poor aerobic fitness is associated with many of the same CV risk factors.
- Reduces intra-abdominal adipose leading to improvement of insulin resistance.
- Regular training increases muscle capillary density, oxidative capacity, lipid metabolism, blood vessel compliance, improved lung and immune function, improved cardiac output and insulin signaling proteins, enhanced insulin action—even without weight loss.
  - All of this is lost with detraining

- Unger, J. (2013). *Diabetes Management in Primary Care* (2nd ed). Philadelphia: Wolters Kluwer/Lippincott Williams & WilkinsPhysical
- Activity/Exercise and Diabetes; position statement (2004). American Diabetes Association. *Diabetes Care*, 27, sup. 1
- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.

The Benefits

- Regular exercise is effective in lowering triglyceride rich VLDL
- Regular exercise reduces circulating insulin therefore reducing BP
- Potential for reduced insulin/medication requirements

- Unger, J. (2013). *Diabetes Management in Primary Care* (2nd ed). Philadelphia: Wolters Kluwer/Lippincott Williams & WilkinsPhysical
- Activity/Exercise and Diabetes; position statement (2004). American Diabetes Association. *Diabetes Care*, 27, sup. 1

However…

- Despite known benefits of regular physical activity, many remain physically inactive
- Estimated less than 20% manage to do aerobic exercise more that twice a week, ~60% do no structured exercise at all.
- CDC estimates 40.8% of adults are physically inactive (<10 min/wk)
- 2016: only 21% of children meet the goal of 60 minutes of exercise daily earning a D- on national report card.
- In addition: "The grade for the school indicator dropped from a C- in the 2014 report to a D+ in the 2016 report, noting that less than 50% of high school youth attend a weekly PE class."

- Riddell, M.C., Gallen, I.W., Smart, C.E., Taplin, C. E., Adolfsson, P., Lumb, A.N., Kowalski, A…Laffel, L.M. (2017). Exercise management in type 1 diabetes: a consensus statement. *The Lancet*. (5). 377-390
- Dempsy, P.C., Larsen, R.N., Sethi, P., Sacre, J. W., Straznicky, N.E., Cohen, N.D…Dunstan, D.W. (2016). Benefits for Type 2 Diabetes of Interrupting Prolonged Sitting With Brief Bouts of Light Walking or Simple Resistance Activities. Diabets Care (39). 964-972.
- Office of Disease Prevention and Health Promotion (2016). 2016 United States Report Card on Physical Activity for Children and Youth. Retrieved from: https://health.gov/news/blog-bayw/2016/11/2016-united-states-report-card-on-physical-activity-for-children-and-youth-released/

Introduction

- Creation and implementation of safe and effective exercise plans for those living with diabetes is essential for improving health, wellbeing and reducing cardiovascular complications

Definitions

- Physical activity: all movement that increases energy.
  - Specific role in prevention of diabetes complications not clear
- Exercise: Planned, structured physical activity designed to improve physical fitness.
  - Shown to improve blood sugar control, reduce CV risk factors, improve well being

- Riddell et al. (2018). Exercise management in type 1 diabetes: a consensus statement. The Lancet. (5). 377-390.
- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.
- Standards of Medical Care in Diabetes; 2018. American Diabetes Association. Diabetes Care (41). Supplement 1.

Definitions

- Aerobic exercise: involves repeated and continuous movement of large muscle groups. Energy system is aerobic
- Resistance (strength) training: exercise that involves the use of weights, machines, body weight, elastic bands. Energy system is anaerobic
- High intensity interval training (HIIT): alternate between periods of vigorous or high intensity exercise with periods of low to moderate exercise. Energy system is both aerobic and anaerobic

- Riddell et al. (2018). Exercise management in type 1 diabetes: a consensus statement. The Lancet. (5). 377-390.
- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.

Definitions

- RPE. Report of perceived exertion. Scales like the one below is often used

TABLE 3-17. Borg 6-20 Relative Perceived Exertion Scale

Rate of Perceived Exertion (RPE)	Verbal Description of RPE
6–7	Very, very light
8–9	Very light
10–12	Fairly light
13–14	Somewhat hard
15–16	Hard
17–18	Very hard
19–20	Very, very hard

- MPHR. Maximum predicted heart rate. Calcuated 220-age, then multiplied by percentage to get heart rate at that percent. Ie: 220-50 = 170 x 0.85 =145.
- MET. Metabolic equivalent. Measure of relative work. 1 MET is the body at rest.
- Closed kinetic chain. Activities performed with a hand or foot fixed in space
- Table copied from: Unger, J. (2013). *Diabetes Management in Primary Care* (2nd ed). Philadelphia: Wolters Kluver/Lippincott Williams & Wilkins. P. 97

low cardiorespiratory fitness

- Low cardiorespiratory fitness is a critical prognostic factor for CVD in T2DM
- Described in METs (Metabolic equivalents)
- Low CRF (4 or less METS has greatest all cause mortality rates when adjusting for age, sex, smoking, SBP, FPG
  - Every 1 MET increase translates to 13%-15% decreased Risk for all cause mortality

Physical activity	MET
Light intensity activities	**< 3**
sleeping	0.9
watching television	1.0
writing, desk work, typing	1.8
walking, 1.7 mph (2.7 km/h), level ground, strolling, very slow	2.3
walking, 2.5 mph (4 km/h)	2.9
Moderate intensity activities	**3 to 6**
bicycling, stationary, 50 watts, very light effort	3.0
walking 3.0 mph (4.8 km/h)	3.3
calisthenics, home exercise, light or moderate effort, general	3.5
walking 3.4 mph (5.5 km/h)	3.6
bicycling, <10 mph (16 km/h), leisure, to work or for pleasure	4.0
bicycling, stationary, 100 watts, light effort	5.5
Vigorous intensity activities	**> 6**
jogging, general	7.0
calisthenics (e.g. pushups, situps, pullups,jumping jacks), heavy, vigorous effort	8.0
running,jogging, in place	8.0
rope jumping	10.0

- Rousch, J.E.B., Regensteiner, J.G., Stewart, K. & Yeves, A. (2018). Diabetes and Exercise. From Pathophysiology to Clinical Implementation (2nd ed.). Switzerland: Springer International.

low cardiorespiratory fitness

- Habitual aerobic physical activity is associated with a significant decrease in cardiovascular and all cause mortality
- T2DM associated with reduced exercise capacity, lower maximal oxygen consumption (VO2 max)
- Low fitness men: 2.2 fold greater mortality compared to moderately or highly fit
- Mortality rates in men with T2DM without physical activity is 1.8 times greater than those who were regularly physically active.

- Unger, J. (2013). *Diabetes Management in Primary Care* (2nd ed). Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins
- Riddell, M.C., Gallen, I.W., Smart, C.E., Taplin, C. E., Adolfsson, P., Lumb, A.N., Kowalski, A....Laffel, L.M. (2017). Exercise management in type 1 diabetes: a consensus statement. *The Lancet*. (5). 377-390

Sedentary behavior

- Sedentary behavior: low energy expenditure during waking hours is ubiquitious
  - Defined as any waking, sitting or reclining behavior with low energy expenditure (less than 1.5 MET).
- Higher amounts, increased morbidity and mortality, poorer glycemic control, worse metabolic risk
- Technology
- Transportation
- Sociocultural

- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.

Acute exercise response

- Whole body oxygen consumption may increase 20-fold
- To meet these needs: increased use of muscle glycogen, triglycerides, FFAs
- Increased counter regulatory hormone release increases hepatic glucose output

Neuroendocrine response to exercise

- Aerobic:
  - Insulin secretion decreases
  - Glucagon increases to facilitate hepatic release of glucose to match uptake by working muscles
  - Exercise can increase glucose uptake by muscles by up to 50 times -independent of insulin
  - Extended exercise relies on muscle glycogen and lipid oxidation
  - Higher intensity exercise relies on glycogen and glucose
  - Muscular glucose uptake decreases immediately after aerobic exercise
- Anaerobic.
  - Reliance on phosphogens, glycogen, lactate as energy sources

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Current Recommendations

- Adults
  - 150 minutes / week moderate to vigorous intensity aerobic activity, Or…
  - 75 minutes / week of vigorous intensity or interval training
  - 2-3 sessions of resistance training
- Children
  - 60 minutes per day of moderate to vigorous intensity at least 3 days per week

- Standards of Medical Care in Diabetes; 2018. American Diabetes Association. Diabetes Care (41). Supplement 1.

Current Recommendations

- Aerobic activity should ideally last at least 10 minutes. Goal of 30 minutes/day
- Not allowing more than 2 days between sessions to improve insulin sensitivity
- Time/intensity should progress

- Standards of Medical Care in Diabetes; 2018. American Diabetes Association. Diabetes Care (41). Supplement 1.

Specific populations Youth

- Youth
  - Both T1D, T2D
  - 60 minutes + per day moderate or vigorous intensity aerobic activity
  - Vigorous muscle and bone strengthening activities 2-3 days per week
  - Reduce sedentary time ie: screen time with brief light physical activity every 30 minutes

- Standards of Medical Care in Diabetes; 2018. American Diabetes Association. Diabetes Care (41). Supplement 1.

Specific populations
Eyes

- Retinopathy
- Proliferative DR or severe non-proliferative DR
  - At risk for vitreous hemorrhage or retinal detachment
  - Avoid activities that dramatically elevate BP, jumping, jarring, head down, breath holding activities. Avoid vigorous activities.
  - Consider ophthalmologist input before recommending exercise regimen
  - Low intensity exercises: walking, tai chi. Some yoga poses.

- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care (39)*. 2065-2079.

Specific populations
Eyes

- Mild to moderate non proliferative DR
  - Mild: all activities ok. Annual exam is essential
  - Moderate: avoid dramatic rises in BP. Ie: powerlifting.
- Cataracts
  - May need to avoid activities that require high level visual acuity ie: outdoor bicycling, ball sports, undulating terrain
  - May need supervision for safety
  - Treadmill, elliptical, swimming, resistance training

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Specific populations
Neurological

- DPN
  - Distal symmetric polyneuropathy is most common
  - Small nerve
    - Component of IGT and metabolic syndrome
    - Pain without objective findings
    - Higher risk for foot ulceration
  - Large nerve
    - Numbness, ataxia, incoordination
    - Higher risk for fall and fracture (charcot foot)
  - Proper foot wear. Assess kinesthetic and proprioceptive sense.
  - Consider non-weight bearing activities, brisk walk, tai chi, elliptical, stationary bike

- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care (39)*. 2065-2079.
- Swaim, D.P., Brawner, C.A., Chamblliss, H.O., Nagelkirk, P. R., Bayles, M. P., Swan, A. M. (Eds). (2014). ACSMs Resource Manual for Guidelines for Exercise Testing and Prescription. 7th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins.

Specific populations Neurological

- DAN
- Decreased cardiac response, postural hypotension, impaired thermoregulation, impaired vision, greater susceptibility to hypoglycemia which may be harder to treat duto GP.
- Higher risk for SCD, silent MI
- Cardiac evaluation prior to exercise is recommended
- Avoid activities with rapid postural or directional change, exercising in the heat
- Low to Moderate intensity activities using perceived exertion scale (Borg).

- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.
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Specific populations Altered feet

- Deformity
  - Appropriate foot wear is a must. Examine feet daily. Avoid increased plantar pressures if charcot changes
  - Focus on non-weight bearing. Circuit, resistance, upper body aerobic, aquatics
- Ulcers/amputations
  - Avoid weight bearing If untreated ulcers
  - Avoid jogging/pounding type activities.
  - Moderate walking ok. Closed kinetic chain exercises.

- Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.

Specific populations Cardiovascular

- Stable CAD
  - Higher intensity exercise enhances coronary perfusion
  - No limitations. Consider cardiac clearance prior to initiation
- MI
  - Review signs/symptoms of coronary insufficiency.
  - Consider cardiac rehab after event. Start with low intensity, progress. No restriction on aerobic/resistance
- CHF
  - Avoid activities that accelerate HR
  - Low - moderate intensity
  - Beta blockers/diuretics

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Specific populations vascular

- CVA
  - DM increases risk of ischemic CVA
  - Review signs, symptoms of CVA
  - Post CVA, supervised cardiac rehab. May need alterations if deficits.
  - Both aerobic and resistance ok. Start low, go slow
- PAD
  - Claudication symptoms
  - Low-moderate walking, arm ergometer, resistance/circuit

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Specific populations Renal

- Microalbuminuria
  - No limitations. Avoid heavy physical activity the day prior to checking labs
- Overt Nephropathy
  - Both aerobic and anaerobic exercise improve physical function and QOL with CKD
  - Avoid breath holding and high intensity exercise to prevent large increases in BP
  - Begin low intensity
- ESRD
- Low intensity
- Monitor electrolytes

Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.

Specific populations Orthopedic

- Joint and structural disorders
  - Flexibility training is very helpful. Stretching during or after activity improves flexibility
  - Strengthen muscles around the joints
- Arthritis
  - Low-moderate intensity ok
  - Non-weight bearing activities, closed kinetic chain to reduce pounding
  - Tai chi, yoga
  - Avoid rapid directional changes, contact sports

Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.

Specific populations T1DM

- In adults with T1, both retinopathy and microalbuminuria are less common in those who are physically active
- Tend to have less DKA
- Glycemic response can be influenced by location of insulin delivery, amount of insulin circulating at time of exercise, composition of last meal/snack intensity of planned activity
- The risk of hypoglycemia is elevated for at least 24 hours after exercise.
- Greatest risk is nocturnal hypoglycemia after exercise in the afternoon.

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Bg response varies depending on activity

- Aerobic: risk hypoglycemia immediately after to multiple hours after an exercise session
- Mixed: can have hyper or hypoglycemia depending on the type and duration of exercise session.
- Anaerobic: can have mild to marked hyperglycemia depending on type of activity and pre-exercise blood sugar

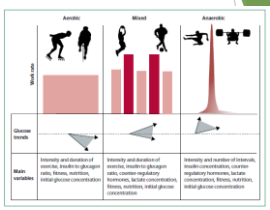

Figure 1: Variability in blood glucose responses to different forms of exercise in people with type 1 diabetes
High individual variability exists in the blood glucose responses to different form of exercise, as denoted by the arrows and grey shading. In general, aerobic exercise decreases glycaemia, anaerobic exercise increases glycaemia, and mixed activities are associated with glucose stability. Individual responses are dependent on various additional factors, including the duration and intensity of the activity, initial blood glucose concentrations, individual fitness, concentrations of insulin, glucagon, and other counter-regulatory hormones in the circulation, and the nutritional status of the individual.

Figure copied from:

Riddell, M.C., Gallen, I.W., Smart, C.E., Taplin, C. E., Adolfsson, P., Lumb, A.N., Kowalski, A....Laffel, L.M. (2017). Exercise management in type 1 diabetes: a consensus statement. *The Lancet*. (5). 377-390

Safety: T1DM

- Contraindications:
  - Elevated Ketones
    - illness, omitted insulin, prolonged exercise session, low CHO diet
  - Recent Hypoglycemia
    - <50 or needing assistance. Contraindicated to exercise within 24 hours

Panel 1: Blood glucose concentrations before exercise commencement and recommended glucose management strategies

The carbohydrate intakes shown here aim to stabilise glycaemia at the start of exercise. Blood glucose at the start of exercise must also be viewed within a wider context. Factors to consider include directional trends in glucose and insulin concentrations, patient safety, and individual patient preferences based on experience. Carbohydrate intake will need to be higher if circulating insulin concentrations are high at the onset of exercise.

Starting glycaemia below target (<5 mmol/L; <90 mg/dL)
- Ingest 10–20 g of glucose before starting exercise.
- Delay exercise until blood glucose is more than 5 mmol/L (>90 mg/dL) and monitor closely for hypoglycaemia.

Starting glycaemia near target (5–6·9 mmol/L; 90–124 mg/dL)
- Ingest 10 g of glucose before starting aerobic exercise.
- Anaerobic exercise and high intensity interval training sessions can be started.

Starting glycaemia at target levels (7–10 mmol/L; 126–180 mg/dL)
- Aerobic exercise can be started.
- Anaerobic exercise and high intensity interval training sessions can be started, but glucose concentrations could rise.

Starting glycaemia slightly above target (10·1–15·0 mmol/L; 182–270 mg/dL)
- Aerobic exercise can be started.
- Anaerobic exercise can be started, but glucose concentrations could rise.

Starting glycaemia above target (>15 mmol/L; >270 mg/dL)
- If the hyperglycaemia is unexplained (not associated with a recent meal), check blood ketones. If blood ketones are modestly elevated (up to 1·4 mmol/L), exercise should be restricted to a light intensity for only a brief duration (<30 min) and a small corrective insulin dose might be needed before starting exercise. If blood ketones are elevated (>1·5 mmol/L), exercise is contraindicated and glucose management should be initiated rapidly as per the advice of the health care professional team.
- Mild to moderate aerobic exercise can be started if blood ketones are low (<0·6 mmol/L) or the urine ketone dipstick is less than 2+ (or <4·0 mmol/L). Blood glucose concentrations should be monitored during exercise to help detect whether glucose concentrations increase further. Intense exercise should be initiated only with caution as it could promote further hyperglycaemia.

Post exercise hypoglycemia prevention

- Reduction of pre-exercise bolus by 30%-50% 90 minutes prior to aerobic activity
  - Requires planning
- Consume 30-60g high glycemic index during or immediately post activity
- 75% bolus reduction + low glycemic snack just prior to activity
- Reduction of basal dose may ameliorate the 4-12 hour post exercise hypo risk, but increase hyperglycemia during the day otherwise
  - If predictable, can use shorter half life basal insulins: Detemir, NPH
  - Won't work with degludec

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	Endurance exercise performance in athletes with and without diabetes	Hypoglycaemia prevention under low insulin conditions	Hyperglycaemia prevention under high insulin conditions
Meal (low fat, low glycaemic index) consumed before exercise	A minimum of 1 g carbohydrate per kg bodyweight according to exercise intensity and type	A minimum of 1 g carbohydrate per kg bodyweight according to exercise intensity and type	A minimum of 1 g carbohydrate per kg bodyweight according to exercise intensity and type
Meal or snack consumed immediately before exercise (high glycaemic index)	No carbohydrate required for performance	If blood glucose concentration is less than 5 mmol/l, (<90 mg/dl), ingest 10–20 g carbohydrate	If blood glucose concentration is less than 5 mmol/l, (<90 mg/dl), ingest 20–30 g carbohydrate
Meal consumed after exercise	1·0–1·2 g carbohydrate per kg bodyweight	Follow sports nutrition guidelines to maximise recovery with appropriate insulin adjustment for glycaemic management	Follow sports nutrition guidelines to maximise recovery with appropriate insulin adjustment for glycaemic management
Exercise (up to 30 min duration)	No carbohydrate required for performance	If blood glucose concentration is less than 5 mmol/l, (<90 mg/dl), ingest 10–20 g carbohydrate	Might require 15–30 g carbohydrate to prevent or treat hyperglycaemia
Exercise (30–60 min duration)	Small amounts of carbohydrate (10–15 g/h) could enhance performance	Low to moderate intensity exercise (aerobic): small amounts of carbohydrate (10–15 g/h) depending on exercise intensity and blood glucose concentration measured during the activity High intensity exercise (anaerobic): no carbohydrate required during exercise unless blood glucose concentration measured during the activity is less than 5 mmol/l, (<90 mg/dl), if so, ingest 10–20 g carbohydrate; replace carbohydrate needs after exercise	Might require up to 15–30 g carbohydrate every 30 min to prevent hypoglycaemia
Exercise (60–150 min duration)	30–60 g carbohydrate per h	30–60 g carbohydrate per h to prevent hypoglycaemia and enhance performance	Up to 75 g carbohydrate per h to prevent hyperglycaemia and enhance performance*
Exercise (>150 min duration), mixture of carbohydrate sources	60–90 g carbohydrate per h spread across the activity (e.g. 20–30 g carbohydrate every 20 min) Use carbohydrate sources that use different gut transporters (eg, glucose and fructose)	Follow sports nutrition guidelines (60–90 g/h) with appropriate insulin adjustment for glycaemic management	Follow sports nutrition guidelines (60–90 g/h) with appropriate insulin adjustment for glycaemic management

These guidelines are based on published studies,[4–6] and on our own expert opinion. *Carbohydrate consumption at a high rate might cause gastric upset in some individuals and might contribute to hyperglycaemia during and after the activity. To increase the rate of carbohydrate absorption during exercise, and maintain hydration status, sports beverages containing glucose and fructose might be preferable.

Table 1: Carbohydrate requirements for endurance (aerobic) exercise performance and hypoglycaemia prevention

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Post exercise hypoglycemia prevention

- Pumps
  - Reduce basal rate 60-90 min before exercise, not suspending

	Exercise duration	
	30 min	60 min
Mild aerobic exercise (~25% VO_2max)	~25%	~50%
Moderate aerobic exercise (~50% VO_2max)	~50%	~75%
Heavy aerobic exercise (70–75% VO_2max)	~75%	NA
Intense aerobic or anaerobic exercise (>80% VO_2max)	No reduction recommended	NA

Our recommendations are based on published studies.[4,16,17,19] NA=not assessed, since exercise intensity is typically too high to be sustained for 60 min for most individuals. VO_2max=maximal oxygen consumption.

Table 3: Suggested reduction in bolus insulin dose before exercise, based on intensity of exercise, for exercise started within 90 min of consumption of the meal

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Exercise Rx

- Motivating anyone to engage in or increase exercise is a challenge
- Many see exercise as a punishment or burden
- To change perception: 4 principles
  - Individualize benefits. Health, social, psych, other
  - Identify barriers . Make recommendations fit into person's life
  - Express positive outcomes of exercise, not negative consequences of not exercising
  - Reinforce behavior and effort often. No "failures"

- Unger, J. (2013). *Diabetes Management in Primary Care* (2nd ed). Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins.

Exercise Rx

- Set goals: person centered. Specific. Measurable. Realistic. Behavior not outcome
- Identify preferences: short or long duration. High/low intensity. Group/individual. Home/facility. Indoor/outdoor etc.
- Modest levels of activity can be effective.
- Target Bg.

Unger, J. (2013). *Diabetes Management in Primary Care* (2nd ed). Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins.

FITT Principle

- Frequency:
  - Resistance: 2-3 days per week on non-consecutive days
- Intensity
  - Moderate. - 50% of 1-RM to start, 75%-80% to optimize gains in strength and insulin action leading to lower A1c
  - Home based: adequate for maintenance. Structured/gym based better for improving glucose control
- Time
  - Ideally should be done to near fatigue per set. Minimum of 1 set to near fatigue
  - Goal 3 sets of 8-12 reps at 75% of 1-RM
- Type
  - Should reflect individual goals, preferences, skill, co-morbidities
  - Use all major muscle groups; back, legs, hips, chest, shoulders, arms, abd.

- Swain, D.P., Brawner, C.A., Chambliss, H.O., Nagelkirk, P. R., Bayles, M. P., Swan, A. M. (Eds). (2014). ACSMs Resource Manual for Guidelines for Exercise Testing and Prescription. 7th ed. Philadelphia. Wolters Kluwer/Lippincott Williams & Wilkins.

Recommended FITT program for resistance training in DM

Variable	T1DM and T2DM
Type of exercise	All major muscle groups Upper body: 4-5 exercises Lower body: 4-5 exercises
Frequency	2-3d/wk resistance
Intensity	60-80% of 1-RM -start with lower intensity RPE: 11-15 (6-20 scale)
Time	8-12 reps/exercise 1-3 sets/exercise

- Swain, D.P., Brawner, C.A., Chambliss, H.O., Nagelkirk, P. R., Bayles, M. P., Swan, A. M. (Eds). (2014). ACSMs Resource Manual for Guidelines for Exercise Testing and Prescription. 7th ed. Philadelphia. Wolters Kluwer/Lippincott Williams & Wilkins.

Recommended FITT program for aerobic training in diabetes

Variable	T1DM/T2DM
Frequency	3-7 days/week (3 days of vigorous or 5 days of moderate)
Intensity	Modertate-vigorous (40% - 85% of MPHR). RPE 12-16 (6-20 scale)
Time	30-60 min/session. Accumulate 150 minutes per week

- Type: walk, jog, row, swim, aquatics, seated row, team sports.

Swain, D.P., Brawner, C.A., Chambliss, H.O., Nagelkirk, P. R., Bayles, M. P., Swan, A. M. (Eds). (2014). ACSMs Resource Manual for Guidelines for Exercise Testing and Prescription. 7th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins.

High intensity interval training (HIIT)

- Alternating bouts of high and low intensity exercise
  - Work:rest ratio vary 1:1-1:4 depending on fitness
- Improvements in cardiovascular adaptations (VO2max—cardiorespiratory fitness), endothelial function, improved BP, insulin signaling, contraction coupling when compared with moderate intensity aerobic.
- Increased fat loss
- Heightens the post exercise oxygen consumption
- Time efficient
- Increase adrenaline, growth hormone—could lead to hyperglycemia
- Caution w/ CV disease
- Effective in older adults especially when coupled with moderate weight loss;
  - Study: 6 months 1.2 % +/- 1% reduction in A1c

Dunstan, D.W., Daly, R.M., Owen, N., Jolley, D., DeCourten, M., Shaw, J. & Zimmet, P. (2002). High-Intensity Resistance Training Improves Glycemic Control in Older Patients With Type 2 Diabetes. *Diabetes Care*, 25 (10). 1729-1736.

Schoenfeld, B., Dawes, J. (2009). High-Intensity Interval Training: Applications for General Fitness Training. *Strength and Conditioning Journal*, 31 (6). P 44-46.

Bodyweight Training

- Chosen method in history—Greeks, Romans, Egyptians, U.S. Military
- Move against always present gravity and ground reaction forces
- Functional; work is done in 3 dimensions
- Examples: calisthenics, yoga
- Closed and open chain exercises
- Strengthen multiple muscle groups at once
- Portable, versatile, no cost other than time

Harrison, J.S. (2010). Bodyweight Training. A Return to Basics. Strength and Conditioning Journal. 32 (2). P 52-55.

Bodyweight Training

- Examples
- Closed kinetic chain: Squats (chair), pushups (wall), lying hip raises, lunges (side), planks (side), bicycle crunch, double leg lifts, crunches, mountain climbers, wall sit, calf raise
- Open kinetic chain: Burpee, squat jumps, jumping jacks, tuck jumps, butt kickers

Brief physical activity

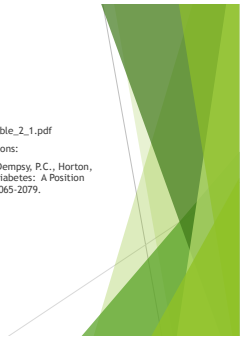
- Interrupting prolonged sitting with brief (3 minutes) bouts of physical activity attenuate post prandial glucose
- Study: overweight/obese men and women. 3 minutes every 30 minutes walk or 3 minutes simples resistance (half squats, calf raises, knee raises, gluteal contractions)
  - reduced post prandial glucose by 37%-39%, insulin by 36%-37%, C peptide 27%-30%
  - Comparable to 3x15 minute walking on same measures

Dempsy, P.C., Larsen, R.N., Sethi, P., Sacre, J. W.,Straznicky, N.E., Cohen, N.D....Dunstan, D.W. (2016). Benefits for Type 2 Diabetes of Interrupting Prolonged Sitting With Brief Bouts of Light Walking or Simple Resistance Activities. *Diabetes Care* (39). 964-972.

Helpful references

- Physical activity table: https://www.cdc.gov/nccdphp/dnpa/physical/pdf/pa_intensity_table_2_1.pdf
- Useful table of physical activity considerations for specific populations:

Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsy, P.C., Horton, E.S., Castorino, K. & Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care* (39). 2065-2079.



Questions?