Physical activity and exercise in the management of type 2 diabetes: Where to start?

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Abstract

Physical activity is a fundamental therapeutic aid in the management of Type 2 diabetes (T2D). Regular engagement elicits a plethora of adaptations which leads to improvements in clinical outcomes, such as HbA1c, lipids and blood pressure as well as whole body health and physical function benefits. Those with T2D are encouraged to engage in a minimum of 150 minutes/week of moderate-intensity physical activity (or 75 minutes/week of vigorous activity). Current recommendations also suggest that this should be supplemented with two-to-three resistance, flexibility and/or balance training sessions/week. The latter is particularly encouraged for older individuals or those with limited mobility/poor physical function. Those with T2D are also encouraged to break up prolonged bouts of sitting.

However, a large proportion of the general population do not meet current physical activity guidelines, with the figure even lower in those with T2D. Getting started and sustaining a physically active lifestyle is challenging. Therefore, this article aims to provide healthcare professionals with the information required to tailor guidance to individuals with T2D by: presenting an overview of current guidelines, terminology and benefits; discussing the risk of adverse events; precautions when exercising with complications; practical options for getting started and how to tailor advice in primary care.

Where appropriate, individual preferences and motivations should inform decision making regarding exercise modality in order to maximise compliance. That said, the overarching message is that any physical activity is better that none, but more is better especially when combined with a reduction in sitting.

Abbreviated title: Physical activity, exercise and Type 2 diabetes

Key words: Physical activity, exercise, complications, safety, barriers, primary care

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Introduction

Physical activity is at the cornerstone of the lifestyle management of Type 2 diabetes (T2D).[1] Regular physical activity is associated with substantially lower cardiovascular and overall mortality risk.[2, 3] Getting started and sustaining a physically active lifestyle is challenging, particularly for those with established T2D.[4] Data from England shows that in the general population 37% of adults are not meeting current guidelines.[5] For those with long-term conditions[5] and established T2D physical activity is lower.[6, 7] The COVID-19 pandemic has reminded us of the on-going physical inactivity pandemic that should not be ignored.[8] There is evidence of an unprecedented drop in physical activity during lockdown in the general population[9] and those with T2D.[10] We believe that physical activity will be focussed on more than ever due to links between obesity and COVID,[11] motivated by the UK Prime Minister's "war against fat"[12] and will predominantly be looking to solve the negative fall outs from COVID-19.

This paper aims to present accessible information for healthcare professionals on concepts related to physical activity including the physiological benefits, safety considerations and practical options for supporting those wishing to bring regular physical activity into their lives.

Commonly used terms

The movement of the body in space is a simple concept yet the variety of terms related to physical activity have the potential to confuse or alienate those wishing to get active. Physical activity in its most basic definition is any substantial movement produced by skeletal muscles[13] and movements done during daily household chores, occupation and active transport fall under this umbrella. Exercise is a sub-category of physical activity and is typically planned, repetitive and structured, with the purpose of improving or maintaining fitness.[14] Most physical activity that will be recommended to those with T2D will be aerobic

in nature with a view to building cardiorespiratory fitness. This is a measure of the functional capabilities of the heart, lungs and muscles relative to the demands of specific exercise routines and is the ability to carry out daily tasks and routine physical activities without undue fatigue or getting out of breath. At the other end of the movement continuum are sedentary behaviours which any waking behaviours with a low energy expenditure done while in a sitting, reclining or lying posture.[15] In order to aid interpretation, examples of the commonly used terms are presented in Table 1.

T2D-related physical activity recommendations

Regular physical activity and structured exercise is recommended for all individuals with T2D, unless otherwise contraindicated (see safety consideration section below).[2] Those with T2D are encouraged to undertake a minimum of 150 minutes/week of moderate-intensity physical activity[3] in bouts of at least 10 min and spread over ≥three days/week.[2, 16] Vigorous intensity can be substituted in for moderate in those who are already physically active with a minimum of 75 minutes/week suggested.[2, 16] This should be supplemented with two-to-three resistance, flexibility and/or balance training sessions/week. The latter is particularly encouraged for older individuals or those with limited mobility/poor physical function. Indeed, some 29% of 635 adults (median age 66 years) with T2D have impaired physical function with their ability to carry out functional tasks of daily living similar to those without diabetes who are over a decade older.[17] Sarcopenia and frailty risk is greater in individuals with T2D via impaired balance, reduced flexibility, decreased muscle mass and muscle quality compared to healthy age-matched controls.[18-20] This in turn reduces quality of life and the ability to perform activities of daily living.

These recommendations are similar to the UK Chief Medical Officers' guidelines for the general population (18-64 years) and older adults (65 years+).[21] The recently published World Health Organisation (WHO) guidelines state that those with chronic disease (e.g. T2D)

may increase moderate-intensity aerobic activity to >300 minutes (or >150 minutes of vigorous-intensity physical activity per week;[22] for additional health benefits. Sedentary behaviours should also be limited with the American Diabetes Association (ADA) guidelines suggesting that, with prolonged periods of sitting should be interrupted at least every 30 minutes.[2] This specific recommendation may serve as an effective behavioural goal in those wishing to reduce prolonged periods of sedentary behaviour. Conversely, the WHO UK guidelines around sedentary behaviour are more conservative, with no recommendations made regarding sedentary duration and frequency. However, they do suggest that limiting sedentary behaviour and simultaneously increasing MVPA is important.[23] A summary of these guidelines can be found in Table 2.

Benefits of PA in those with established T2D

A summary of the modes of exercise, examples and optimal intensities can be found in Table 1.

Aerobic activities

Regular engagement in moderate-intensity aerobic activity induces a plethora of physiological adaptations including (but not limited to): increased mitochondrial density, improvements in peak oxygen uptake, insulin sensitivity, cardiac output and an increase in oxidative enzymes.[2, 16] In turn, this leads to improvements in clinical outcomes, such as reductions in HbA1c, lipids, blood pressure, and insulin resistance.[24, 25] A dose-response relationship exists, whereby higher intensity activities provide additional cardiorespiratory fitness and metabolic control benefits.[26, 27] As little as a single session (~60 minutes) of moderate intensity exercise can improve glycaemic control for up to 48 hours, through both insulin-dependent and insulin-independent mechanisms.[28] At the other end of the activity spectrum, low-intensity aerobic activities (lasting longer than 60 minutes) have been shown

to enhance insulin action in obese, insulin-resistant adults for at least 24 hours.[29] Taken together, the observed glycaemic benefits may be largely attributed to the cumulative effects of each bout of exercise rather than the response to prolonged exercise training, per se.

Resistance exercise

T2D reflects a powerful physiological model of accelerated biological aging that impacts on whole body health and function.[30] Resistance exercises, or strength training, build muscular strength and are generally found to improve insulin sensitivity and glucose tolerance by upregulating the activity of key proteins in the insulin-signalling cascade, while also improving lean body mass.[24, 31-33] Decreases in muscle mass with aging, inactivity and weight loss also have implications for glucose capacity, as ~80% of the body's glycogen is stored in skeletal muscles.[34] The building and maintenance of lean muscle mass via resistance training is now commonplace in the recommendations.

"Sit less, move more and more often"[35]

Although a higher intensity and duration of activity elicits a greater range and magnitude of physiological adaptations, any form of increased movement has beneficial effects on overall health. The overarching message is that any physical activity is better that none, but more is better especially when combined with a reduction in sitting.[23, 35] Contemporary evidence shows that breaking up prolonged sitting time with light-intensity physical activity (e.g. walking) and simple resistance exercises (i.e. calf raises and squats) elicits acute improvements in postprandial glucose metabolism.[36, 37] The initiation of regular, light-intensity activity also leads to longer-term benefits in obese, T2D individuals. In some instances, they can be as effective as continuous moderate- to high-intensity training (when matched for energy cost) in lowering HbA1c and increasing the body's ability to utilise

oxygen.[38] Similarly, flexibility exercises such as yoga or tai chi induce improvements in balance and gait, thus reducing the falls risk.[2]

Safety considerations

Although exercise is a valuable therapeutic aid to optimise health, it may carry additional risk of cardiac events or hypo/hyper glycaemia.[2] Although the risk of cardiovascular events is transiently increased during vigorous-intensity exercise, the overall absolute and relative risks still remain low.[39] Therefore, the benefits of regular activity outweigh the risks, which are arguably even lower when engaging in light- or moderate-intensity activity, the likely prescription for previously sedentary and/or inactive individuals.

ADA guidelines suggest that mandatory medical clearance for all individuals with T2D may be unnecessary.[2] Indeed, initiating any screening protocol beyond usual T2D care does not necessarily reduce the risk of exercise-induced adverse events in asymptomatic individuals.[40] However, clinical assessment beyond ongoing T2D management may be warranted for individuals wishing to engage in activities above the demands of brisk walking (who were previously sedentary and/or inactive), when adverse symptoms are experienced at lower intensities,[2] or in those who meet certain high risk criteria. For example, poor cardiorespiratory fitness, diabetic retinopathy, and aged >60 years represent good predictors for the likelihood of a cardiac event, particularly when considered in combination with traditional cardiac risk factors.[41-43] The clinical evaluation may include symptom-limited exercise testing in the first instance or more sensitive diagnostic tests should silent myocardial ischemia be suspected.[44] Importantly, screening should be appropriate for the intensity of activity prescribed, with the latter often reserved for vigorous-intensities.

By initiating certain safety precautions under the guidance of a healthcare professional along with regular monitoring of blood glucose before, during and after exercise, the risk of hypo- or hyperglycaemia should also reduce. This may be particularly pertinent for those

individuals taking insulin and/or insulin secretagogues.[45] Considerations include; changes to/potential interactions with medication regimens, timing and the macronutrient composition of food (in particular carbohydrate intake). Engagement in moderate-to-vigorous activities (in particular high intensity interval training) will involve switching from a predominantly catabolic state to an anabolic state, which may cause glucose levels to remain elevated after exercise due to glycogen repletion.[34, 46] Similarly, the risk of nocturnal hypoglycaemia following exercise may be reduced by lowering basal insulin doses, consuming bedtime snacks, and/or use of continuous glucose monitoring.[2]

Given the potential risks, where possible, healthcare professionals should monitor the individual response to exercise and be prepared to make necessary adjustments to medications or exercise prescriptions accordingly. It should also be ensured that previously inactive individuals start by performing short sessions of low-intensity exercise before the duration and intensity of exercise are increased progressively, towards desired targets.[47] Sedentary and/or inactive individuals may benefit most from a graded approach whereby the first aim is to reduce sitting time through increasing standing, light ambulation or simple resistance exercises (e.g. calf raises). Light ambulation (i.e. slow walking) may then progress to continuous bouts of exercise.

Activity or exercise in the presence of complications

When considering physical activity or exercise interventions, special and serious considerations are required for those with T2D complications[1] with the ADA making a series of recommendations on how to manage exercise in specific situations.[2]

Diabetic retinopathy

In the case of mild non-proliferative retinopathy no alterations are required, although individuals should be encouraged to have yearly scans to monitor progression. However, in moderate to severe non-proliferative/unstable proliferative retinopathy, activities that dramatically increase blood pressure (such as powerlifting) or any activities involving jumping, jarring or breath holding should be avoided.[2] No exercise should be undertaken during a vitreous haemorrhage.[2]

Diabetic nephropathy

Exercise is generally safe in all stages of kidney disease, when appropriate to the patient's condition. For example, in those with end-stage or dialysis dependent renal disease, exercise should be limited to low intensity and regular monitoring of renal function is essential.[48] Individuals should not undertake exercise within the three months following initiation of haemodialysis.[49] In those individuals with microalbuminuria, exercise acutely increases protein excretion (so falsely elevated readings are possible if urine protein tests are performed within 24-hour of exercise cessation).[45]

Peripheral neuropathy

This debilitating complication of T2D causes alterations in sensation, balance, and walking ability, increasing the risk of for foot ulceration and falls.[50] This may be a barrier to initiating or maintaining an active lifestyle, but exercise can be used to prevent or manage peripheral neuropathy.[51] Understandably, those who suffer from severe foot pain, numbness, or other foot complaints may remain hesitant about engaging in physical activity/exercise. Although previous guidelines have advised against weight-bearing physical activity to reduce the risk of ulceration, moderate walking does not appear to increase this risk.[52] However, those with active ulcers, amputations or foot deformities should avoid any weight-bearing exercises

(particularly if their gait has altered) and opt for swimming, cycling or arm exercises.[2] Indeed, arm ergometry ('arm crank' machine) is proposed as a non-weight bearing activity to allow those with diabetic foot ulceration to meet aerobic physical activity guidelines (and yield the aforementioned benefits) at home via a commercially available lightweight table-top arm ergometer.[53] Other temporary but significant contraindications should also be noted.[54]

Overall, when prescribing, encouraging or monitoring aerobic and resistance activities, it is necessary to consider the T2D stage, the presence of comorbidities and other lifestyle behaviours. For example, an analysis of 233,110 UK Biobank participants showed a clustering of unhealthy behaviours in those with T2D with and without complications[7] so it is likely that multiple health-related behaviours can be intervened on. Similarly, although the combination of weight loss and improved glycaemic control associated with novel dietary interventions (e.g. meal replacement plans[55]) and newer pharmacological therapies yield promising results on markers of cardiometabolic health, it is also important to understand the impact of these therapies on other health indicators i.e. physical function and body composition. Physical activity has the potential to maximise the health benefits. For example, diet or medication induced weight loss results in the loss of lean mass so an adjunct of physical activity may attenuate this loss.[56] When aerobic and resistance activities are combined, they provide a powerful stimulus that improves muscle quality, muscle strength, increases muscle mass and enhances cardiorespiratory fitness and function.[57] This combination may be particularly pertinent in those with sarcopenia/frailty/poor physical function, given their higher risk of falling and the limited ability of the exercising muscle to extract and utilise oxygen.[20, 58] The subsequent improvements in physical function and enhanced performance in tasks of daily living, may also mediate improvements in quality of life.[59]

The role of healthcare professionals

Guidelines alone are unlikely to increase population levels of physical activity.[60] Advice from a healthcare professional, mass media campaigns (see the Sport England "We are Undefeatable"[61] social media campaign aiming to inspire, assure and support those with long-term conditions to build physical activity into their lives) and changes to the environment such as increased walkability and bikeability and improved community design[62] can all work synchronously. That said, contacts with healthcare professional are thought to be a cost-effective and viable approach to physical activity promotion.[63] While 73% of 1013 GPs in England said they would discuss and recommend physical activity to T2D patients, ~50% of them had not completed or received any training in physical activity advising themselves.[64] Communication methods and channels to reach healthcare professionals with physical activity promotion opportunities are not clear.[60] The ambition to consistently embed effective physical activity counselling into routine undergraduate, postgraduate and continuing professional development clinical training and ultimately everyday clinical practice in England may be a good step.[63]

Getting started: Primary care brief advice

NICE recommends brief advice is being offered to T2D patients in primary care through:[65]

- Establishing patient needs (screening);
- Tailoring advice to patient motivations and goals, current level of activity and ability, circumstances, preferences and barriers and health status;
- Signposting to good information and local opportunities;
- Recording advice and goals and follow-up with reinforcement.

Action planning (goal setting) is typically done as part of T2D self-management education[66] and is one key behaviour change technique used in interventions that see a HbA1c reduction

>0.3 %.[67] Any action plans previously developed could be shared with the patient's own healthcare professional.[66] Asking patients whether they made any physical activity or exercise changes or goals during the COVID-19 lockdown could open the conversation about beginning and sustaining activity behaviour change. Perhaps it was a short daily walk outdoors or living room-based activities led by online trainers. Many free websites, phone apps and online resources are available to support goal setting and action planning. Self-monitoring of activity goals can be done using an inexpensive pedometer or capitalising on the fact that patient's likely already own a smartphone with an in-built movement sensor and app and the trends for wearable technology (for a review see[68]) make self-monitoring cheaper, easier and even fashionable.

As physical activity and exercise counselling should be tailored to meet the needs of individuals[2] identifying the myriad of real and perceived barriers faced when engaging in physical activity is crucial.[69] Some of these may be physical (e.g. joint pain), psychological (e.g. lack of comfort being active in public) but others larger and systemic (e.g. lack of time due to working two jobs and not feeling safe being out in own neighbourhood due to crime) and beyond the capabilities of primary care. The availability of local appropriate and tailored activity opportunities is just one way to overcome some barriers. Collaborative locally developed and driven programmes such as 'Walking Cricket' (a culturally appealing activity for men with or at risk of T2D) or 'Healthy Goals' (an education programme for South Asian women)[70] have sought to overcome the barriers reported in BME groups in the UK.[71] These programmes seek to address individual level barriers by including social support[72] and providing instruction[67] as evidence for better clinical outcomes and behaviour change exists when these are featured.

The COVID-19 pandemic has shone a spotlight on our nation's health. Physical activity will predominantly be looking to solve the negative fall outs from COVID-19 including social

isolation, mental health difficulties and obesity while capitalising on the beneficial effects of the outdoors, social support and community-driven solutions.

Conclusions

Healthcare professionals must individualise their approach when advising and supporting physical activity engagement in those with T2D with or without complications. After considering the existence of comorbidities and complications, where possible, individual preferences and motivations should primarily inform decision making regarding modality (aerobic and resistance). Although recommending a single mode of activity (e.g. aerobic) is unlikely to address the multi-domain deficits often present in those with T2D, the healthcare professional should also be pragmatic regarding realistic targets, particularly if the individual is sedentary/inactive. An approach combining both aerobic and resistance activity yields the greatest benefit, but in truth, the kind of activity is far less important than the decision of whether to be active at all.

While guidelines promote minimum targets, patients should be encouraged to know that more physical activity is better. Conversely, in patients where 150 minutes/week of moderate exercise seems daunting they should be encouraged that any increase in movement and reduction in time spent sedentary is of benefit. The provision of, and sign-posting to, appropriate local opportunities as well as changes to the environment in which people live will together influence whether the brief advice offered in primary care has an impact on a patient's physical activity.

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Table 1. A summary of the different modes of activity, examples and their desirable intensity. Adapted from Garber et al., 2011[73]

		Sedentary behaviours	Light intensity	Moderate intensity	Vigorous intensity	Resistance activities	Flexibility/balance activities
Intensity (ranging from initial introduction to optimal intensity)	% VO2 peak	-	37 - 40	46 - 63	64-90	-	-
	% HR max	-	57 - 63	64 - 76	77 - 95	-	-
	Borg RPE	6 - 8	9 - 11	12 - 13	14 - 17	9 - 15	9 - 13
	Metabolic equivalents (MET)	≤1.5	>1.5 - 2.9	3.0 - 5.9	≥6.0	2.0-≥6.0	2.0-4.0
	1-RM	-	30 - 49	50 - 69	≥70	40 - 60	20 - 50
	Definition	Any waking behaviour characterized by an low energy expenditure ≤1.5 METs, while in a sitting, reclining or lying posture (47)	Activities that require standing up and moving around, either in the home, workplace or community. Can also include activities of daily living.	This level of activity can be defined by the 'talk test': being able to talk but not sing indicates moderate intensity activity. Conversely, having difficulty talking without pausing is a sign of vigorous activity.	An activity that requires a large amount of effort and causes rapid breathing and substantial increases in heart rate. This category also includes high intensity interval exercise – a very vigorous intensity activity performed in short bouts interspersed with breaks.	Any activity that makes your muscles work harder than usual. The activities involve using your body weight or working against a resistance.	Flexibility and balance exercises are activities that improve the ability of a joint to maintain the movement necessary for carrying out daily tasks and physical activity.
	Examples	* Sitting or lying while watching TV * Sitting at a desk or computer	* Standing * Light housework * "Pottering"	* Brisk walking * Water aerobics * Heavier housework	* Running, sprinting * Fast cycling * Swimming	* Lifting weights * Squats * Lifting/carrying children or groceries	* Yoga * Pilates * Heel to toe walking * One leg stand

% VO2 peak: Peak oxygen consumption
% HR max: Percentage of maximal heart rate
RPE: Rating of perceived exertion (48)
METs: Metabolic equivalent of task. One MET is defined as the energy used when at rest. Therefore, an activity with a MET value of 3 means exerting three times the energy than you would if you were sitting still.
1-RM: 1-repetition maximum is the heaviest weight that can be successfully lifted once through the complete range of motion and using the correct technique. 1-RM should be determined for each exercise that is contained within a resistance training programme.

Table 2. Summary of physical activity recommendations for those with T2D and the general population

	American Diabetes Association guidelines (T2D) [2]	**World Health Organisation guidelines (those living with chronic conditions)** [22]	**United Kingdom - Chief Medical Officers' guidelines** [21]
Sedentary behaviour	All patients should reduce their daily levels of sedentary behaviour. In particular, prolonged sitting should be interrupted at least every 30 minute with either light or moderate activity.	Limit the amount of time spent being sedentary. In parallel, all adults should also aim for the recommended levels of moderate- to vigorous-intensity physical activity	Adults should aim to minimise the amount of time spent being sedentary,
Light intensity exercise	Increasing active tasks of daily living should be recommended to all. This intensity of exercise may also be used as the initial focus or as an introduction to exercise in previously inactive individuals.	No specific recommendations, although it is promulgated as a viable form of activity to break up sedentary behaviour.	No specific recommendations, although it can be used to break up prolonged periods of inactivity/sedentary behaviour.
Moderate intensity exercise	A minimum of 150 minutes per week, not allowing more than 2 days to elapse between exercise sessions.	At least 150–300 minutes per week. Potential to increase moderate-intensity aerobic physical a3ctivity to >300 minutes per week	Each week, adults should accumulate at least 150 minutes of moderate intensity activity
Vigorous intensity exercise	Potential to be used as an alternative to moderate-intensity aerobic exercise provided a minimum of 75 minutes per week is undertaken.	At least 75–150 minutes OR an equivalent combination of moderate and vigorous-intensity exercise	75 minutes of vigorous intensity activity; or even shorter durations of very vigorous intensity activity OR a combination of moderate, vigorous and

			very vigorous intensity activity.
Resistance exercise	2 – 3 sessions per week performed on non-consecutive days, with 8 – 10 exercises per session. 1 – 3 sets of each exercise should be performed, reaching 'near-fatigue' by the end of each set.	Muscle-strengthening activities at moderate or greater intensity (involving all major muscle groups) on 2 or more days a week	Adults should do activities to develop or maintain strength in the major muscle groups. Muscle strengthening activities should be done at least two days a week, but any strengthening activity is better than none.
Flexibility	2 – 3 sessions per week focussing on major muscle-tendon groups. Strongly recommended for patients aged 50 years or more, or those with peripheral neuropathy.	Older adults should undertake multicomponent physical activity with a specific focus on ≥3 days a week. Functional balance and strength training should be performed at a moderate intensity (as a minimum) in order to enhance physical function.	Older adults (>65) Older adults should maintain or improve their physical function by undertaking activities aimed at improving or maintaining muscle strength, balance and flexibility on at least two days a week.