Physical activity and structured exercise in patients with type 2 diabetes mellitus and heart failure

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Key points:

- Patients with type 2 diabetes mellitus and heart failure should be encouraged to adopt a physically active lifestyle by reducing sedentary behaviours, increasing incidental daily activity and, where possible, participating in appropriate structured exercise.
- Benefits of exercise include improved cardiorespiratory fitness, physical function and quality of life.
- Many forms of structured exercise exist and exercise prescription should be guided by individual patient preferences and circumstances, in combination with clinical evaluation. Some type of exercise may require medical screening and clearance prior to participation.
- Patients with heart failure should be educated to distinguish severe adverse symptoms during exercise from acceptable levels of breathlessness and fatigue. The latter may represent important physiological responses and should not be reason to discourage patients from engaging in an active lifestyle.

Abstract

Patients with T2DM or HF are encouraged to adopt a physically active lifestyle and participation in structured exercise is endorsed as a safe and effective adjunct to medical therapy in both conditions. This article aims to provide health care professionals with the information required to tailor guidance relating to physical activity and exercise for individuals with T2DM and HF by (1) presenting an overview of current guidelines and (2) providing practical suggestions for their implementation.

'Traditional' forms of exercise training include moderate to vigorous-intensity aerobic exercise and dynamic resistance exercise. Benefits of exercise training include improved cardiorespiratory fitness and physical function, more favourable body composition, lower metabolic risk and enhanced quality of life. Before engaging in structured exercise, medical clearance may be required for certain types of activities and precautions should be taken to minimise risk of hypoglycaemia and left-ventricular overload in patients with T2DM and HF. Importantly, patients with HF should be educated to distinguish severe adverse symptoms during exercise from expected feelings of breathlessness and fatigue. The latter should not be a reason to discourage patients from engaging in as much physical activity and structured exercise as possible.

In order to optimise adherence, exercise prescription should be driven by patient preferences, motivations and individual circumstances. Consideration should also be given to more novel approaches, such as reducing sedentary behaviour and high-intensity interval training.

Preamble

The coexistence of heart failure (HF) and type 2 diabetes mellitus (T2DM) is common and has important implications for clinical management and prognosis (1).

Exercise has been promoted as an effective and safe adjunct to optimal medical treatment in the management of both T2DM and HF (2-5). However, exercise intolerance can trigger acute exacerbation of dyspnea and fatigue (5) which are also common symptoms of worsening HF status. This can lead to confusion for patients and clinicians as to the cause of these symptoms and there is a need for better understanding that feelings of dyspnea and fatigue may, in fact, be evidence of important physiological adaptations (6) and not a reason to discourage patients with HF from engaging in an active lifestyle.

This article discusses the role of physical activity and structured exercise in the management of patients with T2DM and HF, focusing on current recommendations, evidence and clinical implications. Specifically, we aim to provide health care professionals with the information needed to tailor physical activity and exercise advice and prescription to this growing clinical population.

Current recommendations for physical activity

In order to provide a frame of reference, the definitions of physical activity, physical inactivity, sedentary behaviour and exercise are defined in Box 1.

The American College of Sports Medicine (ACSM) provides physical activity recommendations for the general adult population (7). Further guidelines from the American Diabetes Association (ADA) and a consensus group of the Heart Failure Association (HFA) and European Association for Cardiovascular Prevention and Rehabilitation (EACPR), provide specific recommendations for patients with diabetes or HF (New York Health Association class I – III), respectively (4,6).

These guidelines, which are summarised in Table 1, share some common themes. Most prominently, they each fully endorse the use of a personalised, patient-centred approach to promote physical activity within the personal limitations, preferences and circumstances of a given individual. Importantly, whilst increasing light-intensity physical activity and limiting sedentary behaviours should be encouraged in all individuals, certain types or intensities of structured exercise may be contraindicated in some patients. Some of these contraindications may be readily apparent upon clinical review, but others may only be detected during specific pre-participation testing. As such, appropriate screening of patients, particularly those who are previously inactive, is essential prior to engaging in a structured exercise programme. This is particularly important for patients with HF where establishing haemodynamic tolerance to exercise is pivotal. Pre-participation screening procedures are discussed in more detail below (Page 7).

Current evidence and mechanisms underlying the effects of physical activity in patients with T2DM and HF

Type 2 diabetes mellitus

Several reviews and meta-analyses have summarised the health benefits of exercise training in T2DM (8,9). In a pooled analysis of 23 randomised controlled trials, 12 to 52 weeks of aerobic, resistance or combined (aerobic plus resistance) exercise training elicits significant reductions in HbA1c compared to non-exercise control participants (mean difference -0.73%,

-0.57% and -0.51%, respectively) (9). Regardless of exercise mode, interventions with a total duration greater than 150 min·wk^{-1} have the greatest effect on HbA1c (-0.89%), but even those below this threshold elicit significant benefits (-0.36%) (9). These results suggest that any form of sustained exercise training is likely to be worthwhile for patients with T2DM.

Aerobic exercise interventions are also repeatedly found to induce clinically significant benefits on cardiorespiratory fitness (mean improvement in peak oxygen uptake [$\dot{V}O_2$ peak] 11.8%), with higher intensity exercise providing additional benefits on both fitness and metabolic control (8,10). Resistance exercise is generally found to improve insulin sensitivity and glucose tolerance, while improving lean body mass and parameters of strength (11,12). Both forms of exercise, and their combination, can also induce several metabolic benefits in skeletal muscle to improve glycolytic and oxidative substrate metabolism, including enhanced capillary density and greater mitochondrial capacity (4,7,11). Chronic adaptions to training also include the lowering of whole-body and ectopic lipid stores, improvements in endothelial function, reduction of systolic and diastolic blood pressure (-6.0 mmHg and -3.6 mmHg, respectively), and promotion of a more favourable circulating lipid profile (4,7,13). Improved physical function and enhanced performance in tasks of daily living, may also mediate improvements in quality of life (QoL) (7).

As little as one bout of exercise transiently improves glycaemic control for up to 72 h, through both insulin-dependent and insulin-independent mechanisms (14,15). However, a dose–response relationship exists whereby exercise of greater intensity, duration or frequency will likely result in greater benefits (16,17). For example, even small amounts of high-intensity exercise, such as those promoted through high-intensity interval training (HIIT), have been shown to improve glucose regulation, in individuals with T2DM (16). In a small study, HIIT was also shown to increase cardiac volumes, stroke volume and ejection fraction, with no effect on myocardial strain (18). Furthermore, this occurred with a corresponding increase in peak early diastolic filling rate measured using MRI (18). Whether such changes result in a lower risk of subsequent heart failure is not known.

It is important to note that while higher intensity exercise elicits a greater range and magnitude of physiological adaptations, any form of increased movement is likely to induce beneficial effects on health. Mounting evidence shows that breaking prolonged sitting time with slow walking or other forms of light-intensity physical activity elicits substantial, acute improvements in postprandial glucose metabolism in individuals with or at high risk of T2DM (19-21). Longer-term benefits have also been demonstrated with supervised interventions employing light-intensity exercise training. Interestingly, when matched for energy expenditure, prolonged continuous light-intensity exercise training was equally effective as continuous moderate- to high-intensity training in lowering HbA1c and increasing whole-body and skeletal muscle oxidative capacity in patients with obesity and T2DM (22).

Heart failure

Despite both falling under the umbrella term of HF, the underlying pathophysiological differences between HFrEF and HFpEF may have important implications for clinical management and the identification of effective exercise therapies. In HFrEF, exercise training is generally associated with central adaptations, such as improved cardiac output and stroke volume (5,23,24). Conversely, in HFpEF, the limited research eludes to improvements in peripheral muscle function, with little evidence of altered cardiovascular structure (25,26).

A wealth of evidence supports the potential for exercise training to elicit meaningful benefits in patients with HF without adverse effects on LV remodelling (2,6,27-30). In this patient group, regular aerobic exercise elicits significant improvements in exercise capacity and QoL, with meta-analyses reporting 13% and 12% improvements in $\dot{V}O_2$ peak and 6-minute walking distance, respectively, and a 9.7 point improvement in the Minnesota Living with Heart Failure Questionnaire (30-32). These benefits may be mediated by both central and peripheral adaptations (2,6,27-31)**.** Furthermore, a recent Cochrane review (including 4740 patients with HF from 33 exercise training studies), reported a reduction in overall (25%) and HF-specific hospitalisation (39%) with exercise, compared to standard clinical care (30). This review also reported lower all-cause mortality with exercise training when patients were followed up for more than 1 year, but this did not reach statistical significance (P = 0.09) (30,32). Interestingly, patients with HF and T2DM have lower functional capacity, an increased rate of hospitalization and a reduced response to aerobic exercise training compared to patients with HF alone (33).

Evidence surrounding the effects of dynamic resistance exercise in patients with HF is limited. However, when appropriately prescribed, resistance exercise appears to be safe and effective and, in combination with aerobic exercise, improves skeletal muscle strength and function (28,34,35). These peripheral benefits may have particular importance for individuals with HF (with or without T2DM) as these patients are often hindered by skeletal muscle weakness (28), and muscular strength and cross sectional area (particularly of the lower body) are independent predictors of exercise tolerance, clinical prognosis and long term survival (36). Greater upper body strength may also lead to greater performance in tasks of daily living, which may in turn improve QoL (28)**.** Combined aerobic and resistance training has also been shown to improve exercise capacity and elicit anti-inflammatory effects

(28,35,37). Moreover, improvements in submaximal exercise capacity may be greater than those with aerobic training alone (35).

HIIT has also been shown to yield improvements in exercise capacity and QoL for patients with HF with no apparent deleterious effects to LV remodelling (29,38,39). Furthermore, although the evidence to date is limited, one study reports that improvements in cardiorespiratory fitness with HIIT may be greater than those seen with continuous aerobic training (46% vs 14% increase in $\dot{V}O_2$ peak, respectively) (38).

Practical implications for employing different modes of exercise in patients with T2DM and HF

Pre-participation screening

Whilst the risk of cardiovascular events (sudden cardiac death and acute myocardial infarction) are transiently increased during vigorous-intensity exercise, the overall absolute and relative risks remain low and the benefits of an active lifestyle far outweigh the modest increase in risk of these adverse events (40-42). Previously inactive individuals and patients with T2DM are, however, at a higher relative risk of such events and should therefore receive medical clearance from a healthcare professional prior to engaging in structured exercise. The ACSM provide guidelines for pre-participation screening (40), but stress that these should be considered in conjunction with the clinical assessment of each given individual to identify their specific risk, requirements and limitations. Importantly, screening should be appropriate for the intensity of activity prescribed and categorising exercise intensity is discussed in more detail below. Medical evaluation may include symptom-limited exercise testing, at the discretion of the healthcare professional, whist cardiovascular disease (CVD) risk should also be considered (40). Stratifying individuals purely on the number of CVD risk factors present should be avoided, however, as this approach may result in unnecessary barriers to participation (40). Notably, the ADA suggest that necessitating medical clearance for all individuals with T2DM may be excessive. Clinical assessment beyond ongoing diabetes management may be reserved for individuals wishing to engage in activities above the demands of brisk walking or tasks of daily living, or when adverse symptoms are experienced at these lower intensities (4).

Exercise prescription

Ideally, each patient's exercise capacity should be determined (or at least predicted using validated methods) prior to engaging in an exercise programme, allowing the prescription of exercise intensity in relative terms (Table 2). Where possible, light-intensity physical activity, moderate-to vigorous-intensity aerobic exercise and HIIT may be prescribed at an intensity relative to cardiorespiratory fitness (%$\dot{V}O_2$ peak) or maximal heart rate (%HR max). However, given the practical limitations within primary care (namely time and cost), physical activity or exercise can also be prescribed according to the absolute energy demands of the activity, which may be presented as 'metabolic equivalents of task' (METs). The 'Compendium of Physical Activities' (43) details the intensity (in METs) of numerous different activities, ranging from very light to maximal. Practical examples are outlined in Table 2. Moreover, rating of perceived exertion (RPE) (44), assessed using a scale that ranges from 6 (no exertion at all) to 20 (maximal exertion), is an easily implemented measure to monitor subjective perceptions of exercise intensity. RPE may also be used in a prescriptive capacity when asking patients to self-select the intensity of a given exercise (e.g. "please walk at a speed with an RPE of 9"). Despite its simplicity, however, it is important that patients are familiarised with RPE to ensure its effective use.

Resistance exercise can also be prescribed relative to a 1-repetition maximum (1-RM), which 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.

For longer exercise programmes, exercise capacity should be re-assessed at appropriate intervals to ensure progression. Assessments of exercise capacity and subsequent exercise prescription should be done in conjunction with a clinical assessment of the patient and their individual stability/limitations.

Practical considerations (mode of exercise)

Table 3 presents a summary of example exercise training regimens for patients with T2DM and HF, specifically light-intensity physical activity, moderate-to vigorous-intensity aerobic exercise, HIIT and dynamic resistance exercise.

Given the relative equivalency of metabolic benefits across aerobic and resistance exercise modalities for patients with T2DM (45) (and to an extent HF), choice of exercise should be primarily driven by patient preferences, motivations and circumstances. The presence of other comorbidities may also be an important factor. For example, some form of resistance training in combination with aerobic exercise may be strongly encouraged in patients with sarcopenia, given their higher risk of falling and other peripheral limitations. Patient age should also be considered as this may have important implications on the precise nature of physical activity performed. Whilst T2DM is prevalent in younger adults (18 – 40 years)

(46,47), and these individuals may display some extent of cardiovascular dysfunction, older individuals constitute a high proportion of patients with T2DM and/or HF (48,49).

Moderate- to vigorous-intensity aerobic exercise

Continuous moderate to vigorous-intensity aerobic exercise remains the most prevalent form of exercise training, due to its well-demonstrated efficacy and safety (27,50-53). Typically, it is performed on a stationary cycle ergometer or motorised treadmill and is characterised by steady-state moderate- to vigorous-intensity exercise (50-80% $\dot{V}O_2$ peak), with the ultimate aim of enabling individuals to perform prolonged training sessions (45-60 min duration). The improvement in exercise capacity after continuous aerobic exercise training is primarily determined by the total energy expenditure of training, which results from the intensity, duration and frequency of exercise. Session duration should be progressed according to patient tolerance, with a minimum target of 30 min per session, at least three times per week (54,55). However, patients with recent haemodynamic instability, lower exercise capacity or greater fatigue should start with shorter exercise bouts (i.e. 10 min), which can be repeated several times a day (28).

Light-intensity physical activity

In previously inactive patients with T2DM and HF, ensuring safety during exercise is paramount. The implementation of lower-intensity exercise, at least during the early stages of exercise training, may lower the risk of adverse events and reduce the reliance on risk stratification and monitoring. Light-intensity physical activity may also be more acceptable to a broader population, including older adults or those with physical limitations. Light-intensity activity corresponds to approximately 40% VO_2 peak (RPE 9-11) and individuals should aim for a minimum of 30 min per session, at least three times per week.

For patients with severe HF, or those that are severely deconditioned, gradual mobilisation ('calisthenic exercises') may be warranted as a prerequisite to more formal exercise (6). Practically, this consists of a range of simple muscular movements for the purpose of physical conditioning, performed without weights or equipment and intended to increase body strength and flexibility. For these individuals, it is recommended to start even lower and progress even slower (i.e. low-intensity exercises for 5–10 min twice a week). If well tolerated, session duration and frequency may be gradually increased towards the guidelines outlined above (6).

All individuals should also be encouraged to increase their total daily incidental (non-exercise) physical activity to gain additional health benefits (4,56-58). This includes various activities that are conducted in both occupational and leisure time such as light walking, gardening and housework. Increasing unstructured physical activity increases daily energy expenditure, whilst also reducing total daily sitting time. Increasing unstructured physical activity should be encouraged as part of a whole-day approach, or at least initially as a stepping stone for individuals who are sedentary/deconditioned and unable/reluctant to participate in more formal exercise.

High-intensity interval training

Low adherence to exercise training programs remains a major concern in clinical care. New and refined strategies are thus warranted to further improve the effectiveness of exercise training in patients with HF and T2DM. One such strategy is HIIT, which is typically divided into two main categories: sprint and aerobic types (38,59). Sprint protocols are characterised by very short bursts (10-30 s) of maximal activity and are thus particularly physically demanding. As a result, evidence in clinical populations is limited. Aerobic HIIT protocols are more practical alternatives for patients with T2DM and/or HF and, whilst several protocols exist, low-volume HIIT (LV-HIIT) and aerobic interval training (AIT) are the most widely studied. LV-HIIT consists of 10 x 1-min intervals performed at near-maximal aerobic capacity (80-95% $\dot{V}O_2$ peak), which are alternated with 1-min periods of low-intensity active recovery. AIT is characterized by 4 x 4-min bouts at 85-95% of maximal heart rate (HR max), interspersed by 3-min recovery intervals at 50-75% HR max (38,59). Given the high-intensity nature of HIIT, caution regarding its use in patients with HF is understandable. However, as highlighted in Table 3, a personalised approach whereby interval intensity and duration begin low, before progressing according to patient tolerance, should be implemented.

Resistance exercise

Whilst improving endurance capacity in patients with HF and T2DM is important, aerobic exercise training alone does not address the multi-domain deficits present in this population. Typically, these patients may also be at risk of sarcopenia, impaired balance and reduced flexibility (60), all of which may limit functional capacity and QoL. Initiating exercise training of any kind without addressing these deficits may also increase risk of injury and aggravate outcomes. As such, the inclusion of resistance training is now accepted practice when designing an exercise programme for patients with HF (34). Training should be initiated with a low weight and number of repetitions and emphasis should be placed on the quality of exercise technique. Intensity may then be progressed as tolerated. Chosen exercises should include both upper and lower body muscle groups, with a focus on functional improvements relevant to tasks of daily living rather than skeletal muscle hypertrophy (increasing muscle mass) *per se*.

Contraindications/adverse events

Type 2 diabetes mellitus

For the large majority of people with T2DM, exercise is a valuable therapeutic aid to optimise health that can be undertaken at their convenience. Depending on specific circumstances such as the characteristics of exercise, the timing in relation to meals, the patient's habitual glycaemic control and the suitability/effectiveness of any precautions undertaken, the risk of hypo- or hyperglycaemia may be increased both during and after exercise, particular in patients on insulin therapy (4). However, implementing appropriate precautions (including changes to insulin regimens, carbohydrate intake and the timing of activity), along with regular monitoring of blood glucose before, during and after exercise should effectively minimise risk (4). These precautions should be discussed with patients prior to initiating exercise training.

Other temporary contraindications include acute systemic infections, severe exacerbations of inflammatory joint disease or musculoskeletal injury, severe hypertension or unstable HF. Physical activity undertaken with peripheral neuropathy necessitates proper foot care to detect, or ideally prevent, problems early to avoid ulceration and increased risk of amputation (4). Such individuals may still participate in moderate weight-bearing exercise and moderate-intensity walking is unlikely to increase the risk of foot ulcer development or reulceration (61). Similarly, the presence of autonomic neuropathy may complicate an active lifestyle, so patients should obtain physician approval and discuss symptom-limited exercise testing before commencing exercise (4).

<u>Heart failure</u>

Caution is vital when patients with HF (with or without diabetes) wish to undertake resistance exercise, to avoid pressure and/or volume overload of the left ventricle (62). It is therefore recommended that short-duration exercise is performed to provide a sufficient peripheral muscular stimulus, but with sufficient rest intervals to avoid high cardiovascular stress. Ultimately, the intensity and duration of exercise prescribed should reflect the clinical stability of the patient and the size of the working muscle mass. The aim of resistance training in this population should not be to significantly increase muscle strength or size but instead to maintain a more normal skeletal muscle mass and reverse or delay adverse functional changes. As such, heavy weights should be avoided. For example, individuals with low cardiovascular reserve may benefit from the use of small hand weights (e.g. 0.5, 1 or 3 kg). Furthermore, the guidelines outlined in this article are focussed at patients in NYHA class I-III. At present, evidence of the safety and efficacy for resistance exercise in NYHA class IV patients is extremely limited, but patients should be encouraged to maintain functional strength, range of movement and balance through participation in modified programmes (6). Absolute contraindications to exercise for patients with HF, regardless of activity type, include unstable angina, uncontrolled HF or arrhythmias, uncontrolled hypertension or diabetes and acute systemic illness or fever, as well as severe and symptomatic valvular heart disease (6).

Importantly, patients should be educated to recognise the adverse signs and symptoms associated with exercise and to report these promptly to their primary healthcare professional. This is vital because caution of unexpected adverse events should be intricately balanced with education of acceptable and expected levels of fatigue and exertion. Patients should be reassured that feelings of breathlessness associated with the initiation of exercise may be a product of signalling between the periphery and central haemodynamic performance and not necessarily an unhelpful exacerbation of symptoms (63). Those with HF and T2DM should also monitor and self-manage their blood glucose levels before, during (if deemed necessary) and after exercise in order to reduce the risk of hypoglycaemia.

Conclusion

Collectively, the evidence suggests that exercise training yields both central and peripheral adaptations for patients with T2DM and HF, which are clinically translated into anti-remodelling effects, increased exercise capacity and reduced morbidity. Furthermore, patients actively involved in any kind of exercise training may benefit from improved prognosis, QoL and anatomic function. However there is extremely limited data in patients with HFpEF and further studies are needed.

Exercise is clearly an effective but neglected treatment for many chronic conditions, including T2DM and HF. However, as is the case with surgical and pharmacological treatments, exercise is not a single entity and must be tailored to the specific conditions of the individual. This is important, as preliminary data suggest that the clinical benefit of exercise may be reduced (but, importantly, not abolished) in patients with T2DM and HF. Therefore, the agreed exercise strategy for a given individual should be based on clinical evaluation and personal preference, to increase long-term adherence and the magnitude of benefits elicited. Individuals may also benefit from regular follow-up with a multidisciplinary team in order to prevent re-hospitalisation.

Although there are few absolute contraindications to exercise in patients with chronic conditions, it is important that patients receive a thorough assessment before undertaking exercise, which should be done in consultation with a multidisciplinary team of healthcare professionals. 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, as tolerated, towards desired targets. Sedentary individuals may benefit most from a stepped approach whereby they first aim to reduce sitting time through increasing standing, light ambulation or simple resistance exercises (19-21). If tolerated, light ambulation may then progress to purposeful exercise.

Finally, guidelines promote minimum targets but patients should be encouraged to engage in as much physical activity and structured exercise as possible. Conversely, in patients where 150 $min.wk^{-1}$ of moderate exercise may not be achievable, any activity is likely to be of benefit and should therefore be encouraged.

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Box 1 Definitions of key terms used throughout this article

Physical activity – a range of waking behaviours that share the common feature of increasing energy expenditure. Energy expenditure for a given activity is determined by the intensity, duration and frequency of muscular movement (64).

Physical inactivity – the failure to achieve the minimum activity recommendations for health (64,65).

Sedentary behaviour – Sedentary behaviour refers to any waking behaviour characterized by an energy expenditure ≤1.5 METs, while in a sitting, reclining or lying posture (66).

Exercise – a form of physical activity that is planned, structured and repetitive with the aim of improving or maintaining fitness (67).

597 **Table 1. Physical activity guidelines for the general adult population and patients with T2DM and/or HF**

	ACSM Guidelines for the General Adult Population (7)	**ADA Guidelines for Adults with T2DM (4)**	**HFA and EACPR Guidelines for Adults with HF (NYHA class I to III) (6)**
Continuous moderate-intensity exercise	30 – 60 min performed on 5 or more days of the week, in bouts of at least 10 min and with a minimum target of 150 $min \cdot wk^{-1}$. Bouts less than 10 min may still have benefits for severely deconditioned individuals.	A minimum of 150 $min \cdot wk^{-1}$, performed in bouts of at least 10 min spread over 3 or more days of the week.	20 – 60 min, performed on 3 – 5 days per week.
Vigorous-intensity exercise *(including vigorous-intensity continuous exercise as well as high-intensity interval training; HIIT)*	May replace some or all moderate-intensity aerobic exercise, although a combination of moderate- and vigorous-intensity exercise is strongly recommended for most adults. Using vigorous-intensity exercise alone, 20 – 60 min should be performed on 3 or more days of the week, in bouts of at least 10 min and with a minimum target of 75 $min \cdot wk^{-1}$.	May replace some or all moderate-intensity aerobic exercise (in younger or more active individuals), provided at least 75 $min \cdot wk^{-1}$ is performed.	When patient capabilities allow, HIIT may replace sessions of continuous moderate-intensity aerobic exercise.
Light-intensity physical activity *(including occupational and leisure-time tasks of daily living as well as low-intensity structured exercise)*	Should be strongly recommended for severely deconditioned individuals. A minimum of 7000 steps per day should be encouraged for all adults.	Increasing active tasks of daily living (dog-walking, gardening, housework etc.) should be recommended to all patients. May also be used as the initial focus of exercise interventions in previously inactive individuals, before progressing to more intense structured exercise.	Increasing activity in tasks of daily living should be encouraged in all patients. Severely deconditioned patients may benefit from gradual mobilization though ‘calisthenic exercises’ or 5 – 10 min of low-intensity exercise twice weekly before progressing, as tolerated, to moderate-intensity aerobic exercise.

Resistance exercise	2 – 3 sessions per week, training major muscle groups. Training the same muscle group on consecutive days should be avoided. The number of ‘sets’, repetitions and weight may be manipulated to promote greater improvements in muscular strength or endurance. Older adults and individuals previously unfamiliar with resistance exercise may see benefits in strength, power and endurance with a lower number of sets, repetitions and weight.	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. Weight can be adjusted according to patient preference but ‘near-fatigue’ should be reached within 6 – 15 repetitions.	May be considered as an addition to moderate- to vigorous-intensity aerobic training. May be particularly considered for older patients to attenuate muscle wasting. However, care should be taken to avoid excessive pressure load by using lower weight, shorter contraction duration and longer rest periods.
Flexibility training	2 – 3 sessions per week focussing on major muscle-tendon groups. May be most effective when performed after light- to moderate-intensity aerobic activity. Static stretches should be repeated 2 – 4 times (10 – 30 s each time) for a total of approximately 60 s per exercise. Holding stretches for longer (30 – 60 s) may elicit greater benefits in older individuals.	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. Yoga or tai chi may be encouraged in interested individuals.	No specific guidelines are provided. However, patients may benefit from ‘calisthenic exercises’ (see *Light-intensity physical activity)*.
Sedentary behaviour	Reduce sedentary behaviours, particularly avoiding prolonged periods of sitting, in all adults, irrespective of exercise habits.	All patients should reduce daily sedentary behaviour. In particular, prolonged sitting should be interrupted at least every 30 min with bouts of light activity.	No specific guidelines are provided.

Table 2. Categories of exercise intensity for use when prescribing light-intensity physical activity, moderate- to vigorous aerobic exercise training or HIIT

Exercise Intensity	% $\dot{V}O_2$ peak	% HR max	RPE *	% 1-RM	METs	Example activities (METs) (43)
Light	37 to 40	57 to 63	9 to 11	30 to 49	2.0 to 2.9	Standing (2.0)
Moderate	46 to 63	64 to 76	12 to 13	50 to 69	3.0 to 5.9	Walking the dog (3.0) Walking for exercise (4.3) Mowing the lawn (5.5)
Vigorous	64 to 90	77 to 95	14 to 17	70 to 84	6.0 to 8.7	Jogging (7.0) Cycling (8.0)
Near-maximal to supra-maximal	91 or above	96 or above	18 or above	85 or above	8.8 or above	Stair climbing, fast pace (8.8)

*** RPE is measured on a scale of 6 (no exertion at all) to 20 (maximal exertion). Instructions are provided and participant should be familiarised with these before exercise.**

METs – metabolic equivalent of task
% $\dot{V}O_2$ peak – percentage of peak oxygen consumption
% HR max – percentage maximal heart rate
RPE - Rating of perceived exertion (44)
% 1-RM - percentage of 1-repetition maximum

Adapted from (7).

Table 3. Example exercise regimens in patients with T2DM and HF

Training modality	Start	Progression - duration and frequency of training is increased according to symptoms and clinical status	Optimal intensity	Frequency	Outcomes of interest (number of ticks reflects strength of the effect)				
					VO_2 peak	Physical function	HbA1c	Exercise (in)tolerance	Muscle strength/ mass
Light-intensity physical activity	<u>Calisthenic exercises</u> *Intensity*: RPE <11 *Duration*: 5–10 minutes	Increase frequency and duration gradually, whilst also incorporating non-exercise physical activities *Duration*: 30 minutes	*Intensity*: 40-50% *V*O_2 peak (RPE ~11) *Duration*: 30-45 minutes	2-5 sessions per week	✓	✓✓	✓	✓	✓
Continuous aerobic exercise training	*Intensity*: 40-50% *V*O_2 peak *Duration*: 10-15 minutes	Increase intensity gradually towards 50-70% *V*O_2 peak *Duration*: 30 minutes	*Intensity*: 50-70% *V*O_2 peak (RPE 13-15) *Duration*: 45-60 minutes	3-5 sessions per week	✓✓	✓✓	✓✓	✓✓	-
High-intensity interval training (HIIT) (Aerobic interval training; AIT)	*Intensity*: 50-60% of HR max during 1-2 x 3-4 minute bouts. Patients should remain 'active' during recovery periods (3-min each) but at a low intensity (50-70% of HR max) *Duration*: 5-15 minutes (including recovery periods). Start low and go slow. The very deconditioned may require longer recovery periods between high-intensity bouts	*Intensity*: Gradually increase interval number and duration up to 4 x 4 minutes, whilst simultaneously decreasing the recovery period (if required) towards 3 minutes. Subsequently, increase intensity of exercise intervals towards 85-95% HR max *Duration*: 15-30 minutes	*Intensity*: 4 x 4-minute intervals at 85-95% HR max (RPE 15-16 during intervals) *Duration*: 30-40 minutes	3 sessions per week	✓✓	✓✓	✓✓	✓✓	-

Resistance training*	*Intensity*: <30% 1-RM focussing on use of the correct technique. *Circuits:* 1-3 per session, containing a range of upper and lower body exercises. *Repetitions*: 5-10 per exercise per circuit	*Intensity*: (RPE: 12-13) *Circuits: 1 per session* *Repetitions*: 15-25 per exercise per circuit	*Intensity*: 40-60% 1-RM (RPE 13-15) *Circuits: 1 per session* *Repetitions*: 8-15 per exercise per circuit	2-3 sessions per week	✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓

*** Sustained maximal isometric exercise (i.e. weight lifting) is contraindicated, because of the excessive rise in blood pressure and the lowering of the stroke volume**

1-RM - the highest weight that a person can lift once with correct form, throughout a complete range of motion
VO_2 peak – peak oxygen consumption
HR max – maximal heart rate
RPE - Rating of perceived exertion (44)

Adapted from (6)