REVIEW

Exercise prescription and the patient with type 2 diabetes: A clinical approach to optimizing patient outcomes

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Abstract

Purpose: To review the current recommendations for physical activity in type 2 diabetes mellitus (T2DM) and propose methods to optimize compliance, reduce the pharmaceutical burden, and improve the general health and well-being of patients with T2DM.
Data sources: PubMed, SportDiscus, Ovid MEDLINE, Psychinfo, Web of Science, LexisNexis, and EBM reviews.
Conclusions: T2DM is a condition in which physical activity has been documented to improve patient outcomes, yet research has noted that healthcare professionals inadequately address this issue, resulting in physical activity being an underutilized therapy.
Implications for practice: An exercise prescription consists of mode (type), frequency, intensity, duration, and progression. Determining the appropriate mode depends upon patient preference and safety issues regarding the state of T2DM or other conditions. Frequency, intensity, and duration are specific to the type of activity and should be tailored to the patient's abilities to safely perform the activity. Finally, the health professional addresses periodic progression in order to maintain the exercise stimulus needed to promote continued health improvements and prevent ''plateauing.'' In this article, on the basis of the current scientific research, we propose recommendations that enable healthcare professionals to advocate for their patients with T2DM by offering safe and effective treatment options.

The current epidemic of type 2 diabetes mellitus (T2DM) is projected to increase to 300 million worldwide by 2025 (Senemmari, 2005). The United States currently has approximately 41 million prediabetics between the ages of 40 and 74 (Senemmari), and significant functional decline will occur in this population if there is progression to diabetes (Gregg et al., 2000). Poor glycemic control and insulin resistance are often present in T2DM, along with the potential for hypertension, hyperlipidemia, and preatherosclerosis (Blair et al., 1996). As a result, these patients are predisposed to coronary heart disease, cerebrovascular accidents, peripheral vascular disease, infections, and microvascular disease (Ivy, Zderic, & Fogt, 1999). Tight glycemic control becomes the goal of any therapeutic regimen to help reduce the onset of these health concerns (Fleury-Milfort, 2008).

T2DM patients report attitudes and knowledge of how to attain better health; however, patients do not necessarily act on the knowledge to create healthier behaviors with regard to nutrition, exercise, and weight management (Green, Bazata, Fox, & Grandy, 2007). About two thirds of T2DM patients do report engaging in physical activity; however, of these active individuals only 40%–43% actually meet the American Diabetes Association (ADA) physical activity guidelines, and this rate is lower than is reported by those without T2DM (Zhao, Ford, Li, & Mokdad, 2008).

Increased healthcare provider involvement in education regarding exercise can be difficult in a busy office setting

(Koch, 2002), yet exercise advice has been shown to increase activity levels and compliance. Older patients have reported that less than 50% of clinicians actively engage in dialog regarding exercise recommendations (Damush, Stewart, Mills, King, & Ritter, 1999). Exercise instruction that is too vague or inappropriate for the patient results in a suboptimal outcome (McDermott & Mernitz, 2006). Emphasizing the beneficial role of exercise for both patients with T2DM and their families may also be beneficial for patients' offspring in reducing the risk of developing T2DM (Ahn et al., 2004). Increasing leisure time activity in the prediabetic population is twice as effective as metformin and standard medical care in reducing the likelihood of developing T2DM, resulting in a 63%–65% risk reduction (Laaksonen et al., 2005). Higher physical activity levels among populations have been determined in both epidemiological (Hu & Manson, 2003) and intervention studies (Hamman et al., 2006; Kriska et al., 2006; Tate, Jeffery, Sherwood, & Wing, 2007) to reduce the inherent risk of developing T2DM and is closely tied to weight management.

Biology of T2DM exercise

Exercise benefits those with T2DM through a number of mechanisms. Regular exercise functions to reduce dyslipidemia and increase insulin sensitivity (Blair et al., 1996; Thomas, Elliott, & Naughton, 2006). By increasing the GLUT-4 receptor concentration on the plasma membrane or sarcolemma, the insulin-resistant state is positively affected through enhanced glucose uptake into cells (Dela, Mikines, Larsen, & Galbo, 1999; Ivy et al., 1999). It is important to note that glycemic control, reductions in visceral adiposity, and decreased plasma triglycerides can be achieved even without systemic weight loss (Thomas et al., 2006).

Exercise stimulus also results in muscle fiber type conversion. Because most T2DM patients are sedentary, they have a suboptimal ratio of type I (aerobic) to type II (anaerobic) muscle fibers. Muscle fiber type conversion of type IIb to IIa (fast twitch, power fibers) increases muscle insulin receptor number and GLUT-4 concentration (Ivy et al., 1999), thereby enhancing the glucose shuttle mechanism. Various exercise modalities may work through modification of muscle fiber type to optimize insulin sensitivity and improve glucose intolerance (Blair et al., 1996). The muscle fiber hypertrophy and general increase in skeletal muscle mass associated with exercise have also been associated with decreased hemoglobin A1c, possibly related to increased glycogen and glucose within muscle (Eves & Plotnikoff, 2006).

The pancreatic β cells, responsible for insulin production, lose their secretory capacity as T2DM progresses. Enhanced β-cell function appears possible with exercise, if the intervention is initiated when the remaining secretory capacity is moderate and not low (Dela, von Linstow, Mikines, & Galbo, 2004). Therefore, early T2DM identification and therapy initiation by diet, exercise, and/or pharmaceuticals may slow the decline of β-cell function and disease progression.

In T2DM, the beneficial effects of physical activity have been noted with energy expenditures as little as 10 metabolic equivalents (METs)/h/week achieved through moderate intensity activities of between 3 and 6 METs. Because 1 MET equals the caloric consumption of a person at rest (1 MET = 1 kcal/kg body weight/h), a 90-kg adult is estimated to expend ~90 kcal/h at rest. To achieve the 10 METs/week guideline, the 90-kg patient should expend >900 kcal/week through physical activity. Some weekly 10-MET program examples include a daily light to moderate walking routine of 1.3 miles/day or accumulating 7000 steps/day assessed by pedometer 7 days/week, or three 60-min sessions of yoga per week. To optimize beneficial outcomes, including improved glycemic control, lipid profile, and decreased blood pressure, weight, waist circumference, and medical costs, exceeding 20 METs/h/week appears best (Di Loreto et al., 2005). Twenty METs can be met by increasing either the activity's intensity or duration to result in greater weekly caloric expenditure. Also, if weight regulation is a goal, numerous studies have indicated that weight loss and subsequent weight maintenance require greater habitual exercise (60–90 min/day) (Sigal, Kenny, Wasserman, & Castaneda-Sceppa, 2004).

All biochemical and immunological changes associated with T2DM are not completely understood; however, a strong relationship exists between T2DM and a low level of chronic inflammation. Ectopic adipose tissue in the muscle, liver, and pancreas is believed to increase free fatty acids flux in the obese, and intramuscular adipose deposits negatively impact the glucose shuttle into the cell (Pi-Sunyer, 2007). In obese individuals, adipocytes typically hypertrophy with greater lipid storage. The size of the adipose cell correlates with altered endocrine function as hypertrophied adipocytes have increased tumor necrosis factor alpha (TNF-α), interleukin-6 (IL-6), and resistin secretion (Pi-Sunyer).

Adiponectin is insulin sensitizing, antiinflammatory, and antiatherogenic by its direct reciprocal inhibition of TNF-α (Simpson & Fiatarone Singh, 2008). Adiponectin secretion is decreased in hypertrophied adipocytes (Pi-Sunyer, 2007). Its action on TNF-α equates to an indirect effect on c-reactive protein (CRP) and IL-6 (Simpson & Fiatarone Singh). Also, endothelial adhesion molecule expression is reduced, and there is decreased cytokine production from macrophages resulting in a countering state of antiinflammation (Simpson & Fiatarone Singh). Moderate intensity exercise increases adiponectin (Brooks et al., 2007) and is followed by the anticipated decline in CRP (Brooks et al.; Kadoglou et al., 2007). Moderate intensity exercise also decreases resistin (Kadoglou et al.), IL-6 (Kadoglou et al.), IL-18 (Kadoglou et al.), and other inflammatory markers such as mannose binding lecithin (Ostergard et al., 2006), and potentially osteoprotegerin (Ostergard et al.).

Exercise appears to counter the effects of insulin resistance, obesity, and T2DM, with some improvements occurring quickly upon initiating an exercise program. After only 4 weeks of training, adhesion molecules (ICAM-1, VCAM-1, and E-selectin) associated with endothelial dysfunction and atherosclerosis normalize (Tonjes et al., 2007).

Individualizing patient exercise and training styles

Promoting daily activity of any kind is a key component. Lifestyle modification can be individualized by examining the patient's existing daily routine and exploring different approaches to increase physical activity, specifically as it impacts obesity (Whittemore, Bak, Melkus, & Grey, 2003). One approach may be to more actively incorporate daily life activities, such as climbing the stairs over taking the elevator or parking further from an entrance to increase total walking distance (McDermott & Mernitz, 2006). Others may prefer structured exercise periods, such as a morning walk or gym class. The weekly physical activity energy expenditure goal for patients with T2DM or pre-T2DM should be a net expenditure of at least 1000 kcal/week above daily living requirements (Albright et al., 2000), in which exercise can come in any combination of leisure type activity, aerobic, flexibility, or resistance exercise modalities (Albright et al.; McDermott & Mernitz; Nelson et al., 2007; Sigal, Kenny, Wasserman, Castaneda-Sceppa, & White, 2006). In addition to increasing activity level, lifestyle modification may address the need for improved sleep habits as sleep loss has been associated with insulin resistance and T2DM (Spiegel, Knutson, Leproult, Tasali, & Van Cauter, 2005). Table S1 shows the definitions of terms commonly used in publications addressing exercise and physical activity. Table S2 outlines specific recommendations for each type of exercise in the management of T2DM.

Physical activity reduces both morbidity and mortality in all populations. Self-management interventions, including proper exercise recommendations, can improve metabolic control (Conn et al., 2007) and reduce other negative risk factors, even following a previously sedentary life (McDermott & Mernitz, 2006). When caring for patients with T2DM, and health issues such as peripheral circulatory and neuropathy problems, the emphasis is on encouraging appropriate exercise interventions that can be performed comfortably by that patient (Conn et al.).

Aerobic training

Aerobic exercise involves repetitive movements that increase heart rate for an extended duration of time with a concomitant increase in core body temperature (McDermott & Mernitz, 2006). Activities generally included under this classification include walking, running, cycling, swimming, aerobics, and aqua fitness classes. Walking may be the most convenient low-impact mode of exercise, but other forms of nonweight bearing activities may need to be considered because of the progression of diabetic symptoms (Albright et al., 2000). For most patients with T2DM, the benefits of walking are substantial with little to no harm to the patient (Hu & Manson, 2003). Heart rate monitors and pedometers/step counters offer inexpensive objective tools to assess activity levels and progress, stimulate patient/clinician dialog, and have been demonstrated to increase patient compliance (Stovitz, Van Wormer, Center, & Bremer, 2005).

Resistance training

Resistance training exercises use muscles to generate a force to move or resist weight (Baechle & Earle, 1995; McDermott & Mernitz, 2006). Resistance training prescriptions reported in the literature are usually based on the objective results of a 1-repetition maximum (1RM) test (see Table S1). The 1RM process allows for exercise prescriptions to be customized to the health state and the individual. For most health states, the training protocol prescribed would vary the difficulty by incorporating ''heavy workloads'' of 85%–95% 1RM and ''low to moderate workloads'' of 50%–50% 1RM (Baechle & Earle). However, clinical outcomes often demand individualized protocols. For example, large systolic blood pressure increases during a 1RM test have the potential to result in ocular damage in patients with T2DM (Albright et al., 2000). As a result, a reduced work load has been incorporated in many T2DM protocols with 75% 1RM as the cut off for heavy workloads and 50%–74% 1RM as low to moderate workloads (Sigal et al., 2004).

Given the impracticality of conducting 1RM tests in the clinical setting and the limited availability of clinical exercise physiologists, the authors suggest the Borg rating and perceived exertion (RPE) scale (Table 1), an easy to use, readily available and effective guide to help patients monitor all their exercise programs (Centers for Disease Control and Prevention [CDC],

Table 1 Borg RPE scale

Borg scale	Comments
6	No exertion at all
7	Extremely light (7.5)
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Note. CDC (2007).

2007). The RPE scale is also applicable for patients taking medications that alter heart response to exercise, and encouraging patients to maintain a workload in the 11–15 range can reduce concerns of breathholding, extreme strain, or muscle failure. In order to support the application of physical activity in the medical setting, the American College of Sports Medicine and the American Medical Association have collaboratively launched an educational website with materials and toolkits (http://www.exerciseismedicine.org).

Resistance training can be performed in a class setting, with a certified personal trainer, or solitary, providing the patient is comfortable with proper technique. Practitioners and patients must research their own area's fitness programs making sure that exercise professionals understand the implications of exercise on the patient with T2DM. Amputees or individuals without the ability to walk can perform resistance training from a chair or wheelchair (Bowker & Pfeifer, 2008). Weight machines, dumbbells, barbells, tubing, balance balls, resistance bands, and strap-on limb-weights (especially helpful for those with arthritis or grip strength problems) are devices typically used to perform repetitions (Baechle & Earle, 1995). If the patient chooses not to purchase such equipment, household objects (such as soup cans) can be substituted for resistance.

Flexibility training

Flexibility facilitates movements through an improved range of motion (ROM) and the potential for injury prevention (McDermott & Mernitz, 2006). Decreased hamstring flexibility and atrophied or imbalanced hip musculature may contribute to lower back pain (McDermott & Mernitz), and decreased hip, knee, and ankle joint ROM each increase the risk of falls and contributes to age-related gait changes (Gehlsen & Whaley, 1990; Judge, Davis, & Ounpuu, 1996).

Some examples of activities that enhance flexibility include: dynamic stretching, static stretching, yoga, and tai chi. Dynamic stretching involves flexibility during sport-specific movements, without the bouncing associated with ballistic stretching (Baechle & Earle, 1995). Static stretching is slow and constant with the end position held for a duration of time (Baechle & Earle). Both dynamic and static stretching can be done as an activity alone or as part of the warm-up or cool-down portion of either aerobic or resistance training protocols (Baechle & Earle).

Yoga

Yoga is an ancient form of low-impact exercise, stretching, and breathing (Manyam, 2004; Nayak & Shankar, 2004) with its origins in India. Asanas are body postures held for 5–20 breaths, and pranayamas are controlled abdominal and diaphragmatic breathing (Jayasinghe, 2004), which are both used to form breathing exercise sequences. Research on yoga practice has examined a variety of conditions related to T2DM including hypertension (Chaudhary, Bhatnagar, Bhatnagar, & Chaudhary, 1988; Damodaran et al., 2002; Jayasinghe; Khalsa, 2004; Latha & Kaliappan, 1991; Murugesan, Govindarajulu, & Bera, 2000; Tenghe, 1990), heart disease (Jayasinghe; Khalsa; Manchanda, Narang, & Reddy, 2000; Tenghe), and hyperlipidemia (McDermott, 1999). Yoga may also reduce the anxiety associated with having a chronic condition (Gupta, Khera, Vempati, Sharma, & Bijlani, 2006).

Specific to T2DM, yoga studies demonstrate improved glycemic profiles (Agte & Tarwadi, 2004; Jain & Talukdar, 1995; Jain, Uppal, Bhatnagar, & Talukdar, 1993; Khare & Jain, 1999; Malhotra et al., 2002a; Malhotra, Singh, Tandon, & Sharma, 2005; Monro, Power, Coumar, Nagarathna, & Dandona, 1992; Singh et al., 2001; Singh, Malhotra, Singh, Madhu, & Tandon, 2004), lipid profiles (Agte & Tarwadi, 2004; Jain & Talukdar, 1995), decreased oxidative stress (Agte & Tarwadi, 2004; Singh et al.), decreased body mass (Khare & Jain), blood pressure lowering (Singh et al., 2004), heart rate lowering (Singh et al.), pulmonary function tests (Malhotra et al., 2002a), and nerve conduction (Malhotra, et al., 2002b). However, the interventions to date often combined diet plus yoga, involved small sample sizes, and some results have not been consistently duplicated.

Musculoskeletal injuries can occur with any form of exercise, but yoga does appear safe under the supervision of a qualified instructor (Chaudhary et al., 1988; Earley

& Shannon, 2006; Innes, Bourguignon, & Taylor, 2005; Kerr et al., 2002) or as long as postures are performed appropriately. Yoga research specifically examining its effectiveness for T2DM is limited; however, yoga is generally considered a safe mode of physical activity and can be modified for patients and sedentary adults. Also, a primary goal when working with a sedentary population is to encourage any movement. Therefore, yoga may be recommended, even if it has not been conclusively proved to be the most optimal exercise form for T2DM.

Tai chi

Tai chi is an ancient low-impact, moderate intensity activity focusing on tranquility and meditation (Lan, Lai, & Chen, 2002). Worldwide it is the most known and widely practiced form of low-impact martial arts (Lan et al., 2002). Based upon coordinated diaphragmatic and abdominal breathing techniques (Danusantoso & Heijnen, 2001; Lan et al.) and graceful movements (Lan et al.), the Chinese population has accepted it as a viable therapy for chronic disease management (Siu, Chan, Poon, Chui, & Chan, 2007). Clinical applications of tai chi have been researched in coronary artery disease (Lan et al.), hypertension (Lan et al.; Taylor-Piliae, Haskell, & Froelicher, 2006a), T2DM (Orr, Tsang, Lam, Comino, & Singh, 2006; Tsang, Orr, Lam, Comino, & Singh, 2007), fall prevention (Chen, Chen, & Huang, 2006; Lan et al.), arthritis (Chen, Hsu, Chen, & Tseng, 2007; Hartman et al., 2000), low back pain (Chen et al., 2007), fibromyalgia (Taggart, Arslanian, Bae, & Singh, 2003), and neurological diseases such as Parkinson's disease (Kluding & McGinnis, 2006; Lan et al.).

Tai chi costs little (Lan et al., 2002; Taylor-Piliae et al., 2006a), and squat stance adaptations can be made to individualize the workload for the patient (Lan et al.). Higher squat postures are more suitable for deconditioned patients, whereas lower squat postures offer a greater workload and stimulus for healthier or younger participants (Lan et al.). Complex routines that present difficulties for elderly individuals with dementia can be simplified if necessary (Chen et al., 2006). Tai chi expends between 1.5 and 4.6 METs at approximately 50% maximal oxygen consumption (VO2 max) (Taylor-Piliae & Froelicher, 2004; Taylor-Piliae, Haskell, Stotts, & Froelicher, 2006b), a level of activity equivalent to brisk walking 4–6 km/h (~2.5–3.75 miles/h) (Hartman et al., 2000; Johnson, Tudor-Locke, McCargar, & Bell, 2005).

In T2DM, tai chi was found to improve glycemic profile (Orr et al., 2006; Shen et al., 2007; Yeh et al., 2007), increase maximum gait speed (Orr et al.; Tsang et al., 2007), and positively modify immune system function (Yeh et al.) with no side effects reported (Orr et al.; Shen et al.; Tsang et al.; Yeh et al.). Therefore, tai chi is considered a safe activity and should be recommended as an activity option, even though T2DM research is limited. To date tai chi may not be scientifically proved to be the optimal exercise mode for T2DM, but it offers a safe way for patients to engage in some physical activity.

Alternative exercise types including mind-body activities

Ayurveda, qigong, and wai tan kung, which may include prominent or subtle flexibility training components, have all been used to assist in a variety of health conditions. Ayurveda is an Indian protocol using herbals, transcendental meditation, diet, yogic postures, and exercise (Elder, 2004; Elder, Aickin, Bauer, Cairns, & Vuckovic, 2006). Limited research has promoted ayurveda for improving glycemic and lipid profiles in T2DM patients (Elder et al., 2006). Qigong is a Chinese practice of 7000–8000 exercises focused on slow breathing and relaxation (Chu, 2004), which may regulate immune function, metabolic rate, and cell death (Li, Li, Garcia, Johnson, & Feng, 2005). Wai tan kung is a martial art form similar to tai chi, but involves harmonic vibration, fluttering, and trembling (Lu & Kuo, 2006).

Lifestyle modifications

Lifestyle modification refers to working within the patient's current daily routine and determining methods to improve activity in all ways possible (McDermott & Mernitz, 2006). Examples are not limited to taking the stairs instead of the elevator or parking farther away from a store entrance (McDermott & Mernitz). Pedometers provide an inexpensive objective and useful tool in assisting patients to assess current status and progress toward daily step counts, such as the 10,000 steps a day recommendation for weight maintenance and general health (Hill, 2005; Johnson et al., 2006; Swartz et al., 2003; Tudor-Locke et al., 2002a; Tudor-Locke, Myers, Bell, Harris, & Wilson Rodger, 2002b). Online web support for 10,000 step programs is readily available such as at Kaiser Permanente (http://kp.10k-steps.com/default.aspx). American woman take on average 5200 steps/day and men about 7200; both short of the 10,000 step goal. And adults with T2DM are known to report lower activity levels than nondiabetic adults (Tudor-Locke et al., 2005). To date, a number of studies have demonstrated the effectiveness of first objectively assessing current habitual steps and second prescribing defined step count objectives (Stovitz et al., 2005).

Topics to address lifestyle changes include the following: reductions in sedentary behaviors (less television time); increasing moderate activity levels (minimum of 30 min activity ≥5 days/week); gradual progression (periodically increase duration, intensity, or mode), a variety of activity modes (cross-training to target cardiovascular, strength, and flexibility); and taking strides to prevent injuries (incorporate rest and listen to your body) (Nelson et al., 2007).

Current recommendations

Weight maintenance is evidence of a cumulative balancing of energy intake and output. Exercise and nutrition should be used in combination to help achieve a balance and promote overall health. Patients are often aware that T2DM is associated with obesity, yet many do not realize the body's sensitivity to even small changes in weight and abdominal fat in particular, nor the benefits derived from decreasing body mass (Alberti, Zimmet, & Shaw, 2006). Daily physical activity to maximize caloric expenditure, maintain muscle mass, and optimize weight control appears to optimize outcomes for the obese diabetic patients(Albright et al., 2000). According to the Albright recommendations, a minimum cumulative caloric debt of 1000 kcal/week (e.g., ∼10 miles walking) is suggested for all T2DM. Through an exercise prescription including frequency, intensity, duration, mode, and progression, safety and health outcome objectives are more likely to be met. An emphasis on periodization is indicated as periodization (see Table S1) involves varying levels of exercise frequency, intensity, duration, and altering exercise modes in order to reduce overuse injuries and maintain motivation (Baechle & Earle, 1995).

Frequency

Regular physical activity is of primary importance in the exercise prescription for T2DM. The acute effects of a single bout of exercise on blood glucose are maintained for less than 72 h. Therefore, it is imperative to increase exercise frequency to greater than 3 days/week to optimize its benefits (Albright et al., 2000), with the goal being 5 days or more days per week (Praet & van Loon, 2007). Patients requiring insulin treatment can lower the amount of insulin required per day if daily physical activity is standardized (Albright et al.).

Intensity

For the majority of T2DM patients, low to moderate intensity (40%–70% VO2 max) is recommended. Use of the Borg RPE scale (Table 1) correlates closely with VO2 max and is an easy, patient-friendly tool recommended for all ages and health status (CDC, 2007). The RPE scale is particularly helpful for patients taking medications that interfere with heart rate, such as beta-blockers. A general guide is 10 × Borg scale rate equals the approximate heart beats per minute (bpm) (i.e., a patient rating an activity as a moderate intensity activity with a Borg scale of 12 will give the equation: $10 \times 12 = 120$ bpm).

Lower intensity exercises may result in positive metabolic changes; however, the stimulus may be insufficient to improve cardiorespiratory endurance (Albright et al., 2000). Because adherence in this population is generally enhanced at lower intensity levels, the clinician's endorsement of any activity at any level is indicated. The progression phase of exercise prescription involves a guided challenge to incorporate longer duration, and then increasing intensity levels in an intermittent fashion (as long as the individual has no contraindication to this protocol). An example of intermittent speed is repeatedly altering 30 s fast walk speed with 1 min moderate speed throughout one exercise session. In absence of contraindications, maximal exercise testing and exercise stress tests should remain a consideration in all patients to assess maximal heart rate. Testing does allow for program safety at higher intensities, but the costs may be prohibitive (Sigal et al., 2004).

Duration

Recommendations for an exact duration of activity are affected by the activity type and intensity level. As a general guideline, duration should be increased gradually as intensity is increased. The duration can be continuous or intermittent, with total cumulative activity being most important (Albright et al., 2000). Rest breaks for hydration are particularly important and should be built into activities. As a general guideline, most research has advised striving for at least 30 min of activity when performing a low to moderate intensity activity (Albright et al.) (∼50% VO2 max or RPE between ∼9 and 14) (CDC, 2007).

Mode

Combinations of aerobic, resistance, flexibility, and lifestyle activity modes can be tailored to the patient's preference and prescribed with success (McDermott & Mernitz, 2006). Aerobic exercise such as walking 20–30 min may initially be challenging and uncomfortable for the sedentary individual, but it is comforting for patient to know that deconditioned adults benefit the most from initiating any aerobic program and that benefits are quickly seen (Eves & Plotnikoff, 2006).

Lifestyle interventions targeting patients at high risk for developing T2DM have been proved to be highly efficacious in preventing the onset of T2DM (Hamman et al., 2006; Kriska et al., 2006; Laaksonen et al., 2005; Lindstrom et al., 2006; Tate et al., 2007). In fact, these diet/exercise interventions were twice as effective as standard medical care in preventing T2DM incidence. Patients experiencing the marked sarcopenia that accompanies sedentary lifestyle, disease, and aging should also focus on muscle building activities, such as progressive resistance training (Praet & van Loon, 2007). Combination aerobic/resistance training protocols appear to be the superior exercise intervention in improving health outcomes (Snowling & Hopkins, 2006).

Seasonal changes and weather conditions are also a consideration in exercise prescription and can influence the exercise mode the patient is capable of safely performing or chooses to engage in (Dasgupta et al., 2007). For example, patients in a cold environment are less likely to meet the activity requirements if they lack access to an indoor fitness facility or shopping mall. By engaging in patient-centered dialog, the clinician can discuss the patient's preferred exercise mode and concerns and then make recommendations.

Progression

Progression is the strategy of periodically advancing the exercise loads so as to continue to experience beneficial health improvements and not plateau (Baechle & Earle, 1995). In T2DM, the progression rate is dependent upon age, functional capacity, medical and clinical status, and patient preferences (Albright et al., 2000). Progression recommendations usually identify increases in frequency and duration prior to altering intensity, and this strategy is generally thought to be the safer method (Albright et al.). This may involve longer increments of exercise or increased distance between breaks if performing intermittent exercise, keeping in mind that breaks are necessary for hydration and injury prevention.

From the healthcare professional perspective, progression may involve altering the patient's current pharmacologic intervention, recognizing that therapeutic interventions comprised of lifestyle/medication combinations are superior to pharmaceuticals alone (Tang & Reed, 2001; Wagner et al., 2006). Routine checks need to be made to make sure that treatment is aligned with the patient's current health state and insure that hypoglycemic, hyperglycemic, hypertensive, or hypotensive episodes are prevented. Patients treated with insulin will require patient education and monitoring (Albright et al., 2000) to safely assess progression.

Special considerations in T2DM disease progression

Healthcare professionals should evaluate all T2DM patients prior to initiating an exercise program (Table S2). Potential health conditions not necessarily related to T2DM that may contraindicate specific exercises include bleeding or detached retina, symptomatic hernia, severe ongoing undiagnosed weight loss, fever, chest pain, any unidentified pain, joint swelling, acute deep venous thrombosis, severe shortness of breath, infections accompanied by fever, an irregular heartbeat, and non-healing open sores (Ferrari, 2007). Specific T2DM conditions that should be considered before exercise prescription include ability to weight bear, peripheral vascular disease, retinopathy, microalbuminuria/nephropathy, and autonomic neuropathy (Albright et al., 2000; Bowker & Pfeifer, 2008; Sigal et al., 2004, 2006).

Weight bearing/nonweight bearing

Neuropathic foot ulceration results from the combination of abnormal plantar pressures, limited joint mobility, and gait changes (Giacomozzi et al., 2002; van Deursen, 2004; Viswanathan, Snehalatha, Sivagami, Seena, & Ramachandran, 2003; Wu & Armstrong, 2006). Reducing the central and medial forefoot plantar pressures through proper footwear and orthoses should be prescribed for both treatment and prevention purposes when clinically indicated (Armstrong, Lavery, Wu, & Boulton, 2005; Guldemond et al., 2007; Saltzman et al., 2004). Patients with active ulcers or who are at high risk can consider partial or nonweight bearing exercises (Kanade, van Deursen, Harding, & Price, 2006) such as limiting yoga postures to those least weight bearing.

Patient and caretaker education, including instruction on proper foot examination (Albright et al., 2000) and wound care, may also assist with the design of safe activity protocols (Bowker & Pfeifer, 2008). A written footwear prescription to consult a specialist with extensive training in the field of the diabetic foot is recommended (Bowker & Pfeifer). If active ulcers are an issue, activities such as yoga may be considered because aquatic exercise increases the risk of pseudomonas bacterial infections (often isolated from wounds soaked in water) (Bowker & Pfeifer).

Peripheral vascular disease with or without presence of claudication

Peripheral artery disease (PAD) can limit walking pace and distance, but not induce muscle ischemic symptoms that would be expected with other comorbidities, such as chronic obstructive pulmonary disease or arthritis. As a result, PAD patients are asymptomatic regarding intermittent claudication or rest pain (Aronow, 2007). PAD treatment involves smoking cessation, blood pressure reduction, tight glycemic control, control of dyslipidemia, antiplatelet therapy, angiotensin-converting enzyme inhibitor, beta-blocker, statin, foot care, exercise rehabilitation, and cilostazol for patients experiencing intermittent claudication (Aronow). Cilostazol prescription can increase walking distance, as long as there is no heart or renal failure diagnosis, predisposition for bleeding, or concurrent CYP3A4 or CYP2C19 inhibitor use (Aronow).

PAD exercise rehabilitation guidelines include beginning with a 6-month protocol consisting of intermittent walking for 30–45 min/per session, ≥3 times/week, with monthly reassessment for progression and periodization. The pain threshold becomes a guideline as walking intensity is brought to near-maximal pain with allotted rest periods (Aronow, 2007). Because PAD patients are generally at high risk for cardiovascular events, an exercise stress test is recommended (McDermott & Mernitz, 2006). For patients unable to walk or who report rest pain or claudication, low- or nonweight bearing exercises such as swimming, aquacize, stationary cycling, or yoga are recommended (Albright et al., 2000). Again, aquatic conditions are contraindicated in patients with active ulcerations, and patient education on proper foot examination is recommended (Albright et al.).

Retinopathy

Diabetic retinopathy and macular edema have not been proved to be altered by various modalities of exercise including resistance and aerobic exercise (Sigal et al., 2006). In a well supervised environment in which systolic blood pressure does not exceed 20–30 mmHg above baseline or activities do not involve head-down or arms overhead positions or excessive jarring, a low-intensity aerobic exercise program can be performed (Albright et al., 2000). However, with proliferative or severe nonproliferative diabetic retinopathy, vigorous exercise may progress vitreous hemorrhage or retinal detachment (Sigal et al.). To limit blood pressure increases, resistance training protocols can incorporate breathing techniques and keep intensity levels low. Yoga and tai chi offer the benefit of lower increases in blood pressure and postural options. When the patient has more advanced disease, consultation with an ophthalmologist can provide individualized recommendations.

Microalbuminuria and nephropathy

Nephropathy is worsened by increased systolic blood pressure; therefore, activities that result in systolic blood pressures ≥180–200 mmHg such as Valsalva maneuver and high-intensity resistance or aerobic exercise should be avoided (Albright et al., 2000). At later stage renal disease, patients should not exceed 50% VO2 max (Albright et al.), and a medical approval is required prior to initiating an exercise program. In this case, an exercise stress test to determine appropriate intensity limits is helpful (Albright et al.; Sigal et al., 2006). Resistance training is not contraindicated; however, the intensity performed should limit excessive blood pressure elevations, although no studies to date demonstrate that high-intensity exercise causes rapid renal function deterioration (Sigal et al.). Yoga, tai chi, aerobic, and resistance training can be safely performed at low- to moderate-level intensity.

Autonomic neuropathy

Because cardiac responsiveness to increased demand is impaired in autonomic neuropathy, achieving 60%–90% of the maximum heart rate may be not appropriate (Albright et al., 2000; Sigal et al., 2006). Identifying autonomic neuropathy prior to initiating an exercise program will aid in determining the appropriate exercise mode, plus allow patients to safely exercise at an optimal intensity level. Using the Borg RPE scale may be useful in patients with autonomic neuropathy (Table 1). Severe autonomic neuropathy patients may be best suited for emphasizing functional activities of daily living, yoga, or tai chi. To decrease the risk of dehydration, appropriate rest and water breaks should be build into the protocol.

Summary

Patients place their trust in their clinicians to prescribe optimally effective treatment options. To achieve this, healthcare professionals must help disseminate and validate information regarding lifestyle interventions to patients, their families, and the community at large (c.f., letters to the editor) by consistently emphasizing the importance and effectiveness of physical activity as a treatment component for improved health outcomes (Nelson et al., 2007). As seen with diet, vague recommendations for exercise (eat less, move more) prove subjective and ineffective. Through a dedicated effort by healthcare professionals to discuss patient-centered diet and exercise specifics (Praet & van Loon, 2007), provide referrals for specialized care to insure safe and effective self-management, and promote ongoing support systems, more patients with T2DM will be guided toward the current ADA physical activity recommendations (Zhao et al., 2008) and optimized patient care.

Physical readiness is only one aspect of patient program compliance. Patients can be cleared for the most appropriate exercises by having healthcare providers perform a physical examination (Praet & van Loon, 2007), and high dropout rates can be avoided by patient education that offers strategies to reduce injuries and increase motivation (Praet et al., 2008). The patient's willingness to increase physical activity can be enhanced through patient education and counseling regarding the benefits, risk, problem-solving skills, and specifics of a therapeutic exercise prescription. In the big picture, the patient needs to hear that (a) any movement is good movement, (b) it is never too late to start, and (c) the most deconditioned individuals respond with the most rapid improvements. Positive dialog with noncompliant patients should be reinitiated at each medical visit, just as is done with smoking cessation.

Supporting Information

Additional supporting information may be found in the online version of this article:

Table S1 Definitions of common terms in exercise.

Table S2 Exercise recommendations for patients with T2DM.

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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