Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

Exercise Training for Type 2 Diabetes Mellitus: Impact on Cardiovascular Risk: A Scientific Statement From the American Heart Association

Thomas H. Marwick, Matthew D. Hordern, Todd Miller, Deborah A. Chyun, Alain G. Bertoni, Roger S. Blumenthal, George Philippides, Albert Rocchini and on behalf of the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular Nursing; Council on Nutrition, Physical

Circulation 2009;119;3244-3262; originally published online Jun 8, 2009;
DOI: 10.1161/CIRCULATIONAHA.109.192521
Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 72514
 Print ISSN: 0009-7322. Online ISSN: 1524-4539

AHA Scientific Statement

Exercise Training for Type 2 Diabetes Mellitus

Impact on Cardiovascular Risk

A Scientific Statement From the American Heart Association

Thomas H. Marwick, MD, PhD, Chair; Matthew D. Hordern, PhD; Todd Miller, MD, FAHA; Deborah A. Chyun, RN, PhD, FAHA; Alain G. Bertoni, MD, MPH, FAHA; Roger S. Blumenthal, MD, FAHA; George Philippides, MD; Albert Rocchini, MD, FAHA; on behalf of the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular Nursing; Council on Nutrition, Physical Activity, and Metabolism; and the Interdisciplinary Council on Quality of Care and Outcomes Research

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1. Introduction

The increasing prevalence of overweight and obesity has led to an unprecedented epidemic of type 2 diabetes mellitus (T2DM)[1–4] and is likely to be followed by an epidemic of patients with complications of T2DM.[5] Given the observed increases in the prevalence of T2DM in adults over the past few decades in developed countries,[1,2,6] population-based efforts to reduce the cardiovascular complications of T2DM are as critical as the measures to prevent the problem.[4,7] T2DM is the sixth-leading cause of death,[8] with most deaths attributed to cardiovascular disease (CVD; nearly 70%) and with ischemic heart disease being responsible for nearly 50% of these deaths.[9] The economic cost of T2DM has been estimated to be $172 billion in 2007 in the United States

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on April 1, 2009. A copy of the statement is available at http://www.americanheart.org/presenter.jhtml?identifier=3003999 by selecting either the "topic list" link or the "chronological list" link (No. LS-2091). To purchase additional reprints, call 843-216-2533 or e-mail kelle.ramsay@wolterskluwer.com.

The American Heart Association requests that this document be cited as follows: Marwick TH, Hordern MD, Miller T, Chyun DA, Bertoni AG, Blumenthal RS, Philippides G, Rocchini A; on behalf of the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular Nursing; Council on Nutrition, Physical Activity, and Metabolism; and the Interdisciplinary Council on Quality of Care and Outcomes Research. Exercise training for type 2 diabetes mellitus: impact on cardiovascular risk: a scientific statement from the American Heart Association. *Circulation.* 2009;119:3244–3262.

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(*Circulation*. 2009;119:3244-3262.)

***Circulation* is available at http://circ.ahajournals.org** **DOI: 10.1161/CIRCULATIONAHA.109.192521**

Table 1. Classification of Recommendations and Level of Evidence

	Description
Classification of recommendation	
Class I	Conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, useful, and effective
Class II	Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment
Class IIa	Weight of evidence/opinion is in favor of usefulness/efficacy
Class IIb	Usefulness/efficacy is less well established by evidence/opinion
Class III	Conditions for which there is evidence and/or general agreement that a procedure/ treatment is not useful/effective and in some cases may be harmful
Level of evidence	
Level of evidence A	Data derived from multiple randomized clinical trials or meta-analyses
Level of evidence B	Data derived from a single randomized trial or from nonrandomized studies
Level of evidence C	Consensus opinion of experts

Throughout the document, these are listed as [class (level)]; for example, class I, level of evidence A is listed as [I (A)].

alone[3] (up from $132 billion in 2002)[10] and is likely to be greater when the other indirect costs of its associated complications are included.[11] These complications are due to atherosclerotic vascular disease[4] but also reflect a susceptibility of patients with T2DM to heart failure,[12,13] perhaps mediated by direct effects on the myocardium.[14,15] Pharmaceutical intervention for glycemic control has shown beneficial results for microvascular complications in patients with T2DM; however, whether this therapy has beneficial effects on macrovascular complications and cardiovascular events remains unclear, with recent work suggesting some benefit,[16] although previous studies report conflicting results.[17–20]

Exercise, which is often viewed in relation to glycemic control, has important effects on the development of cardiovascular complications in T2DM. For the purpose of this statement, exercise is defined as planned and structured activity that is aimed at improving cardiovascular health and metabolic control. The goals of this scientific statement are to document the mechanisms whereby exercise is important in T2DM management, analyze the existing evidence regarding exercise interventions, and provide practical guidelines about preparation for exercise training programs and safety issues, as well as specific exercise training guidelines that can be used to initiate an exercise program. The recommendations are based on data available from previous investigations; unfortunately, only a few large-scale, randomized, controlled trials are available, and more are needed to confirm this position. The recommendations provided have been classified according to Table 1. Throughout this statement, the classifications and levels of evidence are shown in abbreviated form as class (level of evidence) (eg, [I(A)] for Class I, Level of Evidence A).

2. Beneficial Effects of Exercise in T2DM

The overall beneficial effects of exercise in T2DM are well documented with regard to glucose control and multiple CVD risk factors. Table 2 outlines the exercise prescription and general effect of randomized, controlled trials that have assessed the effect of exercise training on glycemic control and other CVD risk factors in patients with T2DM.[21–45] Searches of PubMed for exercise training intervention studies using the terms *exercise* and *diabetes* were performed. Criteria for the inclusion of studies in Table 2 were as follows: (1) The study was written in English; (2) it was published in August 2008 or earlier; (3) it included patients with T2DM only; (4) the study design included a nonexercise control group that did not receive intensive dietary therapy; (5) details of the randomized, controlled design were included; and (6) changes in glycemic control were assessed. Studies that included a separate or combined dietary component to the intervention were included; however, focus was placed on the exercise prescription of these studies. Improvements in glycemic control included improvements in hemoglobin (Hb) A_{1c}, blood glucose, insulin sensitivity, and glucose area under the curve during an oral glucose tolerance test, among others. Table 3 similarly outlines the exercise prescription and effects of randomized, controlled trials that have assessed the effect of exercise training on endothelial function and vascular structure and distensibility in patients with T2DM.[46–48] Searches for these studies were identical to those performed for glycemic control, except that studies were selected that included vascular structure and function as outcome measures. Changes in vascular function included changes in endothelial function (eg, flow-mediated dilation), carotid artery intima-media thickness, and arterial distensibility. Tables 2 and 3 also report changes in body composition, body mass index, and $\dot{V}O_{2max}$ when data are available. Briefly, exercise has favorable metabolic effects (glycemic control, weight loss), effects on other risk factors (lipids, hypertension), and direct vascular effects. However, despite a number of studies suggesting favorable effects on metabolic control and CVD risk factors, the net effect of these on clinical outcomes in T2DM is yet to be defined.

Glycemic Control

The effects of exercise on metabolic control have been an important focus of exercise prescription.[49] Previous studies have reported that exercise leads to improvements in metabolic control, measured by HbA_{1c}, blood glucose, or insulin sensitivity (Table 2) [I (A)]. Generally, studies that failed to elicit this benefit have utilized interventions of low intensity[21,22] or low volume[41] or have reported poor adherence to the intervention.[42] Importantly, the definitive study on this to date, a randomized, controlled trial in 251 T2DM patients, reported improvements ranging from −0.38 to −0.97 percentage points in HbA_{1c} from exercise training that ranged

Table 2. Randomized, Controlled Exercise Training Intervention Studies in Patients With T2DM and Their Effect on Metabolic Control

First Author of Study	Year	Patients	Exercise Prescription					Effect
			Frequency	Intensity	Duration	Period	Type	
Wing[21]	1988	25 T2DM	3 d/wk	3 mph	60 min/d	81/2 mo	Aerobic	• No improvement in glycemic control • No improvement in BMI
		30 T2DM	4 d/wk	3 mph	60 min/d	141/2 mo	Aerobic	• No improvement in glycemic control • Greater reduction in medication • Reduction in BMI
Khan[22]	1995	39 Sedentary T2DM	5 d/wk	40%–60% $\dot{V}o_{2max}$	50 min/d	15 wk	Aerobic	• No improvement in glycemic control • Reduction in body fat • Increase in $\dot{V}o_{2max}$
Agurs-Collins[23]	1997	64 Black T2DM	3 d/wk	Unspecified	30 min/d	6 mo	Aerobic	• Improvement in glycemic control • Reduction in body weight • Maintained BP
Dunstan[24]	1997	55 Sedentary T2DM	3 d/wk	55%–65% $\dot{V}o_{2max}$	45 min/d	8 wk	Aerobic	• Prevented a deterioration in glycemic control • Reduction in body weight • Increase in $\dot{V}o_{2max}$
Honkola[25]	1997	38 Sedentary T2DM	2 d/wk	12–15 RM	Unspecified	5 mo	Resistance	• Improvement in glycemic control • Improvement in blood lipid profile
Mourier[26]	1997	24 T2DM	3 d/wk	75% $\dot{V}o_{2max}$	45 min/d	8 wk	Aerobic & interval	• Increase in insulin sensitivity
				50%–58% $\dot{V}o_{2max}$				• Increase in $\dot{V}o_{2max}$ • Decrease in abdominal fat
Dunstan[27]	1998	21 T2DM	3 d/wk	50%–55% 1RM	60 min/d	8 wk	Circuit resistance	• Improvement in glycemic control • Reduction in BMI
Tessier[28]	2000	39 Elderly T2DM	3 d/wk	60%–79% HR_{max}	60 min/d	16 wk	Aerobic & resistance	• Improvement in glycemic control • Increase in exercise capacity
Castaneda[29]	2002	62 T2DM	3 d/wk	60%–80% 1RM	45 min/d	16 wk	Resistance	• Improvement in glycemic control • Increase muscle glycogen stores • Reduction in T2DM medications • No reduction in body weight • No reduction in whole-body fat mass • Reduction in trunk fat mass
Dunstan[30]	2002	36 Sedentary older T2DM	3 d/wk	75%–85% 1RM	45 min/d	6 mo	Resistance	• Improvement in glycemic control • Increase in muscular strength • Increase in lean mass
Maiorana[31]	2002	16 T2DM	3 d/wk	70%–80% HR_{max} (aerobic)	60 min/d	8 wk	Aerobic & resistance	• Improvement in glycemic control
				55%–65% 1RM				• Reduction in body fat and waist-to-hip ratio • Increase in exercise capacity
Tsujiuchi[32]	2002	26 T2DM	Unspecified	Unspecified	120 min/d	4 mo	Thai Chi	• Improvement in glycemic control
Baldi[33]	2003	18 T2DM	3 d/wk	12 RM	Unspecified	10 wk	Resistance	• Improvement in blood glucose and insulin • Increase in fat free mass • Prevent increase in fat mass • Increase in muscular strength
Cuff[34]	2003	28 Obese T2DM women	3 d/wk	60%–75% HRR, 12 RM	75 min/d	16 wk	Aerobic & resistance	• Increase in insulin sensitivity • Reduction in body weight, abdominal obesity • Increase in $\dot{V}o_{2max}$
			3 d/wk	60%–75% HRR	75 min/d	16 wk	Aerobic	• Reduction in body weight, abdominal obesity • Increase in $\dot{V}o_{2max}$

(*Continued*)

Table 2. Continued

First Author of Study	Year	Patients	Exercise Prescription					Effect
			Frequency	Intensity	Duration	Period	Type	
Di Loreto[35]	2003	340 T2DM	Unspecified	>10 MET.h/wk		2 y		• Improvement in glycemic control • Reduction in BMI
Dunstan[36]	2005	36 Sedentary older T2DM	3 d/wk	75%–85% 1RM	45 min/d	6 mo (1st Period)	Resistance	• Improvement in glycemic control • Increase in muscular strength • Increase in lean mass
			3 d/wk	75%–85% 1RM	45 min/d	6 mo (2nd Period)	Resistance	• Failure to maintain improvement in glycemic control • Maintained strength gains
Kadoglou[37]	2007	95 T2DM	4 d/wk	50%–80% $\dot{V}o_{2max}$	45–60 min/d	8 mo	Aerobic	• Improvement in glycemic control • Increased $\dot{V}o_{2max}$
Kadoglou[38]	2007	60 Overweight T2DM	4 d/wk	50%–75% $\dot{V}o_{2max}$	45–60 min/d	6 mo	Aerobic	• Improvement in glycemic control • Reduction in insulin resistance • Improvement in antiinflammatory markers • Improvement in blood lipid profile • Increase in $\dot{V}o_{2max}$ • No change in body composition
Pi-Sunyer[39]	2007	5145 T2DM	Weekly to monthly	Moderate	175 min/wk	12 mo	Aerobic	• Improvement in glycemic control • Decrease in BP • Improvement in blood lipid profile
Sigal[40]	2007	251 T2DM	3 d/wk	75% HR_{max}	45 min/d	6 mo	Aerobic	• Improvement in glycemic control • Reduction in BMI, waist circumference, fat mass • Increase in muscle mass • Improvement in glycemic control
			3 d/wk	7–9 RM	45 min/d	6 mo	Resistance	• Reduction in subcutaneous fat • Increase in muscle mass
			3 d/wk	75% HR_{max}, 7–9 RM	90 min/d	6 mo	Aerobic & resistance	• Greater improvement in glycemic control
Brun[41]	2008	25 T2DM	2 d/wk	Ventilatory threshold	30–45 min/d	12 mo	Aerobic	• Increase in insulin sensitivity • No change in body composition • Maintained $\dot{V}o_{2max}$
Krousel-Wood[42]	2008	76 Sedentary T2DM	5 d/wk	3–6 METS	30 min/d	3 mo	Aerobic & resistance	• No improvement in glycemic control • Trend towards improvement in BMI and quality of life
Nojima[43]	2008	134 T2DM	3 d/wk	50% $\dot{V}o_{2max}$	30 min/d	12 mo	Aerobic	• Improvement in glycemic control • Reduction in oxidative stress • Improvement in body composition • Reduction in BP
Tsang[44]	2008	38 T2DM	2 d/wk	Light	60 min/d	16 wk	Thai Chi	• No improvement in glycemic control • No effect on body composition
Winnick[45]	2008	13 T2DM women	7 d/wk	60%–70% $\dot{V}o_{2max}$	50–60 min/d	7 d	Aerobic	• Improvement in whole-body insulin sensitivity but not hepatic insulin sensitivity

BMI indicates body mass index; $\dot{V}o_{2max}$, maximal cardiorespiratory fitness; BP, blood pressure; RM, repetition maximum; 1RM, 1 repetition maximum; HR_{max}, maximum heart rate; HRR, heart rate reserve; and MET, metabolic equivalents.

from ≈135 to 270 minutes of exercise per week for 6 months.[40] Quantification of effects across trials reveals that the overall beneficial effect of exercise on HbA_{1c} levels is modest (average HbA_{1c} reduction −0.8%, 90% confidence interval [CI] −1.3% to −0.2%)[50]; however, even these small improvements have been reported to be clinically significant in terms of the effects on an aggregate composite of macrovascular, microvascular, and nonvascular end points, similar to what is produced from an intensive pharmaceutical intervention.[17]

In addition, previous research has reported improved insulin sensitivity/resistance and reductions in hyperglycemia-related medications as a result of exercise training.[34,51] These changes typically have been reported in obese subjects with T2DM,[39,52–55] which suggests that there is a good relationship between loss of body fat and improved glycemic control.[56] However, improvement in glycemic control may be independent of fat loss.[51] Moreover, patients with greater metabolic disturbances have shown the greatest improvement in

Table 3. Randomized, Controlled Exercise Training Intervention Studies in Patients With T2DM and the Effect on Vascular Structure and Function

			Exercise Prescription					
First Author of Study	Year	Patients	Frequency	Intensity	Duration	Period	Type	Effect
Maiorana[46]	2001	16 T2DM	3 d/wk	70%–80% HR_{max} (aerobic), 55%–65% 1RM	60 min/d	8 wk	Aerobic and resistance	• Improvement in endothelial function • Improvement in glycemic control • Increase in $\dot{V}o_{2max}$
Kim[47]	2006	58 T2DM			150 min/wk	6 mo	Aerobic	• Attenuated progression of carotid intima-media thickness • Improvement in glycemic control, BP, body mass
Middlebrooke[48]	2006	59 T2DM	3 d/wk	70%–80% HR_{max}	30 min/d	6 mo		• No improvement in microvascular function • No improvement in glycemic control, $\dot{V}o_{2max}$, or CVD risk factors

glycemic control.[57] Other potential mechanisms for better glucose control include improvement in insulin sensitivity[58,59] and effects on glucose transporters (eg, GLUT4).[60–64] Muscle contractions can elicit movement of glucose transporters (GLUT4) to the plasma membrane independently of insulin,[65–67] and it is further speculated that muscle hypertrophy[30,40,51,68] and blood flow[69] are also contributing mechanisms.

Body Composition

Exercise improves and maintains cardiorespiratory fitness, muscular strength, endurance, and body composition (Table 2) [I (A)]. Again, quantification of effects across trials shows modest reductions in body mass (average −5.1%, 90% CI −7.6% to −2.5%) and body fat (average −15%, 90% CI −26% to −2%).[50] Moreover, improvements in body composition may not be a precondition for the beneficial effect of endurance training, most likely because this reduces visceral fat.[26] Indeed, loss in body fat alone, achieved through liposuction, fails to improve T2DM and other risk parameters, which emphasizes mediation of the benefits of weight loss through the metabolic effects of exercise,[70] because liposuction would not alter visceral adiposity. Because weight loss is related to energy expenditure, aerobic exercise training has greater potential to yield results than resistance training, although studies have reported beneficial effects on weight loss and body composition from both modes of training.[30,33,40] However, although there are studies that have reported these benefits as a result of exercise training, not all of the studies have shown improvements in body composition. This may be due to the different methods used to assess body composition (eg, body mass index, weight, or fat mass), different training regimens (ie, aerobic versus resistance), and potentially the inclusion or lack of a dietary component to accompany the intervention.

Risk Factors

Exercise has a favorable effect on cardiovascular risk factors. In particular, it has specific beneficial effects on the reduction of hypertension, hyperlipidemia, and obesity and the improvement in blood lipid profile,[71,72] even when combined with a rigorous calorie-restricted diet in obese patients with T2DM [II (A)].[39] Many trials have shown the reduction in systolic (average −5.6 mm Hg, 90% CI −9.3 to −1.8 mm Hg) and diastolic (average −5.5 mm Hg, 90% CI −9.9 to −1.1 mm Hg) blood pressure to be in the range associated with prognostic benefit.[73] Modest reductions in triglycerides (average −26.6 mg/dL [−0.3 mmol/L], 90% CI −124.0 to 70.9 mg/dL) and small increases in high-density lipoprotein (average 5.0 mg/dL [0.13 mmol/L], 90% CI 2.7 to 7.7 mg/dL)[72] are less clearly associated with prognostic benefit.

Vascular Effects

The effects of exercise training on abnormal vascular structure and function (including endothelial dysfunction and vascular distensibility) associated with T2DM are yet to be fully understood. Table 3 summarizes recent human studies, some of which show beneficial effects. Furthermore, another study, without a nonexercise control group, showed no effect on endothelial function in T2DM patients with severe chronic heart failure, in whom the intervention lasted for only 4 weeks.[74] However, in this same investigation, the authors reported improvements in exercise capacity, left ventricular ejection fraction, and left ventricular stroke volume over the training period.

Myocardial Function

To date, the effect of exercise training on myocardial function generally has been limited to animal models of T2DM. Most of these involve 5 days per week of exercise over an 8- to 10-week period and involve treadmill training at 20 to 30 m/min. These studies have uniformly shown that exercise training restores myocardial structure and performance, with increasing resistance to ischemia and favorable metabolic effects.[75–84] A recent study showed that weight loss in patients enrolled in an exercise program may have a beneficial effect on myocardial function, but the relative roles of exercise and weight loss require further definition.[85]

Development of CVD

Inactivity is associated with reduced survival in T2DM, irrespective of weight level[86] and other risk factors.[87] The inverse association of moderate-intensity physical activity with the development of coronary atherosclerosis, as evidenced by coronary calcification, has been demonstrated in patients without

Table 4. Features in Favor of and Against Screening for CAD in Patients With T2DM Before Exercise Training

	For	Against
Detection of some patients with severe (left main and/or 3-vessel) CAD	Patients with silent CAD may include those with prognostically important CAD who are candidates for revascularization therapy	No published data demonstrating that screening for CAD in asymptomatic diabetic patients results in improved outcomes in this population and 1 randomized trial demonstrating no effect on clinical outcomes (DIAD)[96]
Identification of more minor CAD	Recognition of CAD could lead to more intensive treatment of risk factors	Existing recommendations in T2DM already recommend more aggressive treatment of hypertension and lipids simply on the basis of T2DM status and do not require the demonstration of CAD[97,98]
Identification of low risk	Available stress imaging modalities can risk-stratify symptomatic and asymptomatic patients with T2DM	Identification of a truly low-risk subset with T2DM is difficult.[99] Annual rates of cardiovascular death and MI or total mortality with normal or low-risk images are 2% to 6% in retrospective studies.[100–102]
Use in exercise prescription	Identification of patients with myocardial ischemia may be of value in instructing these patients to keep their target heart rate below their ischemic threshold	
Cost-effectiveness		80% of the 18 million diabetic patients in the United States do not have established CAD,[103] which leads to many negative test results

MI indicates myocardial infarction; DIAD, Detection of Ischemia in Asymptomatic Diabetics.

T2DM.[88] The combined effects of exercise on metabolism, risk factors, and vascular function have been proposed to be beneficial in T2DM,[89] but it is unclear to what extent this can be expected to reduce the prevalence of atherosclerotic CVD.

3. Cardiac Risks of Exercise Training in T2DM

Generic Cardiac Risks of Training

The risk of a major cardiac event during exercise is small,[90] and even in heart failure patients, who are recognized as being at high risk, no deaths have been reported during exercise in the course of an exercise training study (>80 000 patient-hours).[91] The overall balance of benefit of exercise substantially exceeds its risk in unselected subjects,[92] although this balance has not been defined in patients with T2DM. The major concern relates to whether exercise may be either limited or hazardous because of occult coronary artery disease. Whether exercise limitation due to undiagnosed left ventricular dysfunction may be improved by exercise training remains undefined.

Screening for Coronary Artery Disease

The office attendance of a patient with T2DM for advice regarding exercise is an opportunity for lifestyle modification and general health screening. These patients should undergo a thorough history and physical examination before pursuing an exercise program. Patients with symptoms suggestive of coronary artery disease (CAD) should be evaluated appropriately, irrespective of T2DM status.[93,94]

The investigation of asymptomatic patients for CAD is a vexing topic. The use of screening before an exercise program might be justifiable on 2 grounds but remains unproven. First, the identification of occult CAD might identify patients who are at risk from exercise, but the risks of exercise are minimal. Second, CAD is more prevalent, cardiovascular event rates are higher, and myocardial ischemia is more often silent in patients with rather than those without T2DM.[95] Patients with advanced CAD may derive prognostic benefit from coronary revascularization, but this is unproven in subjects with T2DM, in whom revascularization targets may be suboptimal. Several arguments have been proposed in favor of and against such a program (Table 4).[96–103] Perhaps the least favorable aspect is that screening for CAD represents an additional barrier to exercise in an overweight and deconditioned group among whom barriers to exercise need to be reduced.

Prior Studies of CAD Screening

A number of studies with standard exercise (treadmill or cycle ergometry) testing, nuclear or echocardiographic stress imaging, and, more recently, computed tomography for detection of coronary artery calcification (CAC) have given a range of results for screening for CAD in asymptomatic T2DM patients. Many of these studies had methodological limitations, including small numbers of patients, enrollment of highly selected patients, retrospective design, or poorly described or outdated stress testing techniques (eg, planar thallium imaging). Many studies have been performed with pharmacological stress, which is less potent than exercise stress and may provide less prognostic information than obtained with exercise testing. However, the biggest problem is a probabilistic one: The limited return of studies in low-risk patients is well exemplified by the Milan Study on Atherosclerosis and Diabetes (MiSAD), which identified only 3 fatal myocardial infarctions and 20 nonfatal myocardial infarctions in a follow-up study of a subset of 735 of these patients over 5 years.[104]

The published studies of stress imaging that involved 500 or more asymptomatic patients with T2DM but without known CAD are summarized in Table 5.[96,102,105–107] Two retrospectively designed studies, which included patients with abnormal resting electrocardiograms (ECGs), reported abnormal stress single-photon emission computed tomography images in 39%[105] and 58%[102] of patients, respectively, and suggested that this test was useful for risk stratification. In contrast, in the prospectively designed Detection of Ischemia in Asymptomatic Diabetics (DIAD) study, which excluded patients with abnormal resting

Table 5. Results of Stress SPECT and Stress Echocardiographic Screening for CAD in Patients With T2DM

First Author	Year	Design	Patients	Age, y	Men, %	Diabetes Duration, y	Abnormal ECG Excluded	Type of Stress	Results
MiSAD Group[107]	1997	Prospective asymptomatic	925	54±6	64	7.4±6.0	Yes (if echocardiographic confirmation)	Exercise ECG followed by exercise planar Tl-201 if equivocal or positive	Exercise test abnormal 12% (112/925); exercise Tl-201 abnormal in 53% (59/112)
Zellweger[105]	2004	Retrospective symptomatic/ asymptomatic	826	65±12	57	. . .	No	Exercise SPECT 54%; adenosine SPECT 46%	Abnormal 39%
Rajagopalan[102]	2005	Retrospective asymptomatic	1427	60±14	70	10 (Median)	No (ECG Q wave 9%, ST-T abnormality 34%)	Exercise SPECT 52%; SPECT 48%	Abnormal 58%; high-risk 18%
Wackers (DIAD)[96]	2004	Prospective asymptomatic	522	61±7	53	8.1±7.1	Yes	Low-level exercise adenosine SPECT	Abnormal 22%; 16% abnormal SPECT
Scognamiglio[106]	2006	Prospective asymptomatic	1899	52±7	67	9±6	Yes	Dipyridamole myocardial contrast echocardiogram	Abnormal 59%

SPECT indicates single-photon emission computed tomography; MiSAD, Milan Study on Atherosclerosis and Diabetes; and T1-201, thallium 201.

ECGs,[96] the yield of abnormal studies was only 22% (16% with perfusion abnormalities and 6% with stress ECG or ventricular function abnormalities). Myocardial contrast echocardiography was abnormal in 60% of patients in a large, prospectively designed echocardiographic study[106] that excluded patients with abnormal resting ECGs; 65% of these had significant anatomic CAD (stenoses >50%) at angiography.

The limited number of studies that have examined the value of computed tomography for detection of CAC in asymptomatic T2DM patients have shown that a majority of the population had at least some CAC (Table 6).[108–111] The percentages of patients with Agatston CAC scores >100 were 31% to 53%, and CAC scores >400 were found in 12% to 27%. In a prospectively designed study that used a sequential imaging strategy of computed tomography in all patients followed by stress single-photon emission computed tomography in those with CAC >100 (27% of the population), Anand et al[111] reported that 39% had mild to moderate perfusion abnormalities. Race clearly has an effect on the prevalence of subclinical abnormalities in CAC. In a Multiethnic Study of Atherosclerosis substudy of 204 white, 387 black, 311 Hispanic, and 126 Chinese individuals with T2DM in which the overall prevalence of CAC was 62%, the highest prevalence of measurable CAC was in whites (78%), followed by Chinese (68%), Hispanics (58%), and blacks (54%). High scores (CAC >400, 17% of the total) followed a similar pattern of prevalence, with 24%, 20%, 15%, and 14% of white, Chinese, Hispanic, and black participants, respectively, having high scores.[112] In 2 studies that collected follow-up data,[110,111] the CAC score was associated with patient outcome; however, a smaller study (n=269) reported that CAC scores were not predictive of outcome in T2DM.[113]

Guidelines/Position Statements

The results of the above studies do not clarify in a definitive manner which asymptomatic diabetic patients should be screened for CAD. Publications by both the American College of Cardiology (ACC)/American Heart Association (AHA)[93,94] and the American Diabetes Association (ADA)[114,115] address the screening of asymptomatic diabetic patients for CAD in general, as well as before pursuing an exercise program. In

Table 6. Results of Electron Beam Computed Tomography Screening for CAD in Patients With T2DM

First Author	Year	Design	Patients	Age, y	Men, %	Diabetes Duration, y	Abnormal ECG Excluded	Type of Examination	Results
Hoff[108]	2003	Retrospective	1075	55±9	69	. . .	No	EBCT	CAC >0: M 90%, W 75%; ≥75th percentile: M 39%, W 40%
Elkeles (PREDICT)[109]	2004	Prospective	495	63±7	68	8 (Median)	No	EBCT	CAC >0: 94%; >100: 53%; >400: 27%
Raggi[110]	2004	Retrospective	903	57±10	57	. . .	No	EBCT	CAC >0: 70%; >100: 40%; >400: 20%
Anand[111]	2006	Prospective	510	53±8	61	8±6	Yes	EBCT followed by exercise plus dipyridamole SPECT if CAC >100	CAC <10: 54%; >100: 31%; >400: 12%. Abnormal SPECT in 39% with CAC >100; 60% if CAC >400

PREDICT indicates Prospective Evaluation of Diabetic Ischemic Heart Disease by Computed Tomography; EBCT, electron beam computed tomography; M, men; and W, women.

Table 7. Guidelines for Stress Testing Before Exercise Training in Asymptomatic Individuals With T2DM [IIb (C)]

Stress Testing Not Necessary (All Criteria Should Be Present)	Stress Testing Recommended (if ≥1 Criteria Present)
No clinical history of CAD	History of CAD; no stress test within past 2 years
Asymptomatic	Symptoms of chest discomfort or dyspnea
No evidence of PAD or CVD	Clinical or laboratory evidence of PAD or cerebrovascular disease
ECG normal	ECG evidence of infarction or ischemia
Light to moderate exercise program	Vigorous exercise program

PAD indicates peripheral arterial disease.

the general setting, the ACC/AHA guidelines classify the screening of asymptomatic persons with multiple risk factors (including patients with T2DM) as a class IIb indication (usefulness/efficacy not well established by evidence/opinion). Recommendations from the ADA are more aggressive and state that stress testing is indicated in the presence of prevalent cerebral or peripheral arterial disease, abnormal ECG (ST-T abnormalities, ischemia, or infarction), and ≥2 risk factors. In the specific setting of assessment before an exercise program is begun, both the ACC/AHA and the ADA recommend that an exercise stress test be performed (ACC/AHA guidelines as a class IIa indication, weight of evidence/opinion is in favor of usefulness/efficacy) before a vigorous exercise program is started.

The published data do not indicate precisely which asymptomatic patients with T2DM should undergo screening. Clearly, more data, preferably generated from randomized trials, are needed, but because it is unlikely that such data will become available for several years, the following recommendations (Table 7) are based on published expert opinion. For patients with T2DM who wish to pursue an exercise program based on low to moderate exercise intensity, a stress test should not be necessary in the absence of high-risk clinical or ECG features. A stress test may be recommended before a patient with known (symptomatic or previously diagnosed) CAD begins an exercise program if there is a change in clinical status or no recent (<2 years) stress test. In the patient with T2DM but no history of CAD, a stress test might be recommended if there are symptoms (chest pain or exertional dyspnea), if there is a suspicion of CAD, with clinical findings indicative of peripheral arterial or cerebrovascular disease, with ECG findings indicative of infarction or ischemia, or if the patient is planning to pursue a vigorous exercise program.

The type of stress test should be an exercise test (usually on the treadmill) whenever possible, because the results can be used to refine the exercise prescription. Patients with an uninterpretable resting ECG (left bundle-branch block, ventricular pacing, preexcitation, or major ST-T abnormalities) should undergo stress imaging,[93,94] and those who are incapable of leg exercise should undergo pharmacological stress imaging; these individuals are at particularly high risk. Although patients with ischemia at a low workload should generally be referred for coronary angiography, those with ischemia at a high workload in whom no additional testing is planned can be provided with an exercise prescription. The exercise heart rate should be maintained at least 10 bpm below the ischemic threshold.

4. Noncardiac Risks of Exercise Training in T2DM

Hypoglycemia

Hypoglycemia occurs less commonly in insulin-treated T2DM than in type 1 diabetes mellitus, although >70% of subjects report an episode of hypoglycemia, with an incidence of 0.28 episodes per patient per year.[116] Severe hypoglycemia is closely related to the frequency of low blood glucose readings (eg, <3.5 mmol/L), which is somewhat associated with the acute blood glucose–lowering effect of exercise.[117] Patients who are most at risk include those with low and variable glucose measurements, longer T2DM duration, lower body mass index, and impaired awareness of hypoglycemia. Although concern is often focused on insulin-treated patients with T2DM, the risk of hypoglycemia is also present with insulin secretagogues, including sulfonylureas (eg, glyburide, glipizide) and meglitinides (eg, repaglinide, nateglinide).

The self-monitoring of blood glucose is the most effective means of anticipating and avoiding hypoglycemic episodes during exercise.[118] Prevention of hypoglycemia in subjects taking insulin may be based on increased carbohydrate intake, insulin dosage reduction, or both. Adequate replacement of carbohydrate has been proposed as the most effective strategy for most forms of exercise, although the risk with prolonged exercise (>60 minutes) is reduced with a 20% to 30% reduction of insulin dosage. A program for prevention of hypoglycemia with physical activity of different intensity and duration recently has been proposed for use in type 1 diabetes mellitus.[119] Recent work in young subjects with insulin-treated, complication-free type 1 diabetes mellitus has shown that a brief maximal sprint after moderate-intensity exercise can oppose a further fall in blood glucose levels,[120] but the efficacy and feasibility of this have not been studied in older subjects. Guidance on this matter is limited in T2DM. In the Look AHEAD (Action for Health in Diabetes) trial (a multicenter, randomized trial of lifestyle intervention designed to achieve and maintain weight loss over the long term), treatment at entry into a lifestyle program (including increased physical activity and hypocaloric diet) is altered in accordance with how well the subjects had their diabetes controlled before they entered the program.[121] Patients with very tight control, defined by ≥3 blood glucose measurements <80 mg/dL, and those with frequent (>2/week) symptomatic hypoglycemic episodes have their dosages of hypoglycemic medications cut by 50% to 100%, according to the physician's judgment. Those with modest control have 25% to 50% reductions in medications, whereas subjects with usual blood glucose readings >100 mg/dL have no or very limited change in medications.

Peripheral Arterial Disease and Foot Care

Limb vessel disease in T2DM may involve conduit vessels, small vessels, or both. Although benefits of training have

Table 8. Summary of Exercise Prescription for Patients With T2DM

Mode of Exercise	Frequency	Intensity	Duration	Class and Level of Evidence
Cardiorespiratory (large-muscle activities)	3–7 d/wk	Moderate intensity OR	150 min/wk	I (A)
Cardiorespiratory (large-muscle activities)	3 d/wk	Vigorous intensity AND ENCOURAGE	90 min/wk	I (A)
Resistance (large-muscle group, multijoint exercises)	3 d/wk	Moderate to high intensity: 2–4 sets of 8–10 repetitions at a weight that cannot be lifted >8–10 times, with 1–2 minute rest periods between sets		I (A)

been identified in peripheral arterial disease,[122] attention should be paid to minimizing the risk of foot trauma.

Walking exposes the feet to impact forces, and although plantar pressure is variable between people, it is an important contributor to the development and maintenance of foot ulceration, especially in subjects with neurovascular disease. It might be considered paradoxical, therefore, that active individuals are less likely to develop foot ulceration; this probably reflects better glycemic control and vascular function in active individuals.[123] Indeed, when foot ulceration does occur, it appears to be associated with greater variability in activity, and it is possible that a feedback system to reduce this variability might decrease the risk for ulceration.

An established strategy of injury prevention relates to the avoidance of high-impact activity. Reduction of load may be attained by reduction of walking speed, reduction of weight bearing (eg, by aquatic exercise, cycle ergometry, recumbent cycle ergometry, careful selection of footwear, or use of prostheses to transfer load from affected areas to other areas of the foot or the lower leg), and steps to alter foot rollover during gait.[124] Furthermore, regular inspection of the feet by the patient and their partner may be useful. Some new approaches may prove useful; for example, monitoring of skin temperature (temperatures elevated >4°F compared with the opposite foot) may be a marker of inflammation and risk of ulceration, and the restriction of activity at times of inflammation may prevent ulceration.[125]

Microvascular Disease

Individualized exercise recommendations are required not only in patients with peripheral arterial disease but also in those with microvascular disease.[126] Individuals with proliferative retinopathy should avoid anaerobic exercise or activities that may result in a Valsalva maneuver.[126] Current recommendations do not call for activity restrictions in individuals with nephropathy.[127] Severe peripheral neuropathy, however, may increase the risk of skin ulceration and development of Charcot joint, and individuals with this condition should not engage in weight-bearing exercise.[127]

5. Exercise Training Guidelines

Exercise advice should be a component of prevention advice in every patient encounter in patients with T2DM. The primary care environment (physicians, physician's assistants, advanced practice nurses, and diabetes educators) is the logical first location for education on activity in T2DM.[128–131] Advice received from primary care clinicians is likely to be followed.[132–134] Unfortunately, the lack of specific guidance about prescribing an exercise training program for primary care physicians is a major limitation.[135,136] Alternatively, providers should refer patients to an appropriate clinical exercise physiologist who has the specific skills and knowledge to apply exercise training principles to the T2DM population. In most circumstances in the United States, physician referral is required to access reimbursement from Medicare, Medicaid, and most commercial insurance plans. In other countries, supervision by an exercise physiologist is a component of a chronic disease management plan.

Patients with T2DM who were previously sedentary should aim to accumulate a minimum energy expenditure of 1000 kcal/wk.[137,138] This equates to the current physical activity guidelines for physical activity and public health of a minimum of 30 minutes of accumulated moderate-intensity physical activity on 5 days of the week[139]; however, higher levels of energy expenditure have the potential to yield greater benefits.[40] Table 8 summarizes the exercise recommendations for patients with T2DM. To improve cardiovascular risk, it is recommended that patients with T2DM accumulate a minimum of 150 min/wk of at least moderate-intensity physical activity and/or 90 min/wk of at least vigorous-intensity cardiorespiratory exercise [I (A)]. Additionally, resistance training 3 times per week should be encouraged [I (A)]. These guidelines can be achieved with varying contributions of moderate-to-vigorous cardiorespiratory exercise. For example, patients may exercise for 20 minutes at a vigorous intensity twice per week and for an additional 30 minutes at moderate intensity on 2 more occasions that same week. Exercise should be completed on at least 3 days per week, with there being no more than 2 consecutive days without training [I (A)]. During the resistance exercises, all muscle groups should be used, and patients need to progress to 8 to 10 repetitions per set for a total of 3 sets. An increase in other lifestyle activities should also be encouraged.[140] Contraindications and complications (discussed previously) need to be accounted for in the individual prescription of exercise for patients with T2DM. Table 9 details the classification of different intensities of exercise. This table should be used to define the intensity of exercise being performed according to different measures.

If the recommended levels of exercise cannot be achieved for various medical and personal reasons, some benefits are still likely to occur in patients who achieve lesser amounts of exercise [I (B)]. Although there is limited evidence supporting the role of low levels of exercise in improving cardiovascular function, the reductions in risk associated with limited

Table 9. Classification of Exercise Intensity, Based on Exercise Lasting up to 60 Minutes

Intensity	Cardiorespiratory or Endurance-Type Training			Resistance-Type Training*: Maximal Voluntary Contraction, % (1RM)
	$\dot{V}O_2R$ (%) HRR (%)	%HR_{max}	RPE†	
Very light	<20	<35	<10	<30
Light	20–39	35–54	10–11	30–49
Moderate	40–59	55–69	12–13	50–69
Hard (vigorous)	60–84	70–89	14–16	70–84
Very hard	≥85	≥90	17–19	≥85
Maximal	100	100	20	100

$\dot{V}O_2R$ indicates oxygen uptake reserve; HRR, heart rate reserve; HR_{max}, maximum heart rate; RPE, rating of perceived exertion; and 1RM, maximum weight that can be lifted in 1 repetition.

Adapted from the American College of Sports Medicine Position Stand.[141]

*Based on 8 to 12 repetitions for persons under age 50 to 60 years and 10 to 15 repetitions for persons 50 to 60 years old and older.

†Borg rating of perceived exertion, scale ranging from 6 to 20.

amounts of exercise are likely to be better for the individual than remaining completely sedentary, at least on the basis of evidence in other populations.[142] Further, new data available suggest that greater levels of exercise than these guidelines may be required to improve myocardial function,[142a] although as yet this hypothesis remains untested.

Preparation for Exercise

Many individuals, particularly older individuals with T2DM, are deconditioned and have limited strength and flexibility. Engagement in any activity may be made more challenging by the presence of osteoarthritis, obesity, and peripheral or autonomic neuropathy. In addition, a goal of 30 minutes of activity during a single session may not be achievable and may deter these individuals from any participation. Shorter, more frequent periods of brisk activity may be better tolerated. This approach, in combination with resistance exercise, may allow many individuals to gradually increase their level of endurance to achieve the recommended goals. Sedentary individuals should always initiate exercise programs at a low level and gradually increase the intensity of exercise [IIa (C)].

All individuals with T2DM should be educated about the typical and atypical symptoms of myocardial ischemia and instructed to report these symptoms to their care provider if they occur. Patients with T2DM may have reduced circulation, and often, this is exacerbated by poor vascular function or atherosclerosis.[143,144] A good warm-up promotes blood supply via vasodilation of blood vessels in and around the exercising muscle. Preparation for exercise should also include considerations regarding hydration and foot care,[144] as discussed above.

Frequency

Different exercise frequencies may have differential effects on various metabolic aspects of T2DM. Frequent exercise has the potential to maintain the acute increases in insulin-mediated and insulin-independent glucose uptake. However, a high volume of exercise is not necessary to improve glycemic control, nor does total weekly energy expenditure appear to influence either aerobic capacity or HbA_{1c}.[145] These acute benefits on glycemic control can last up to 48 to 72 hours after exercise[58,146,147] and appear to be cumulative in nature,[148] so even twice-weekly training periods may favorably influence control,[149,150] although more frequent training is recommended. The effect of detraining in patients with T2DM has been shown to be rapid,[151] which further stresses the importance of long-term exercise maintenance.

Weight loss is related to exercise dose (or caloric expenditure) and may produce additional improvements with regard to glycemic control and CVD risk factors; however, improvements in both CVD risk factors and glycemic control have been seen without the concomitant decrease in body mass index.[51] A high frequency of exercise training will maximize caloric expenditure (with benefits for weight management and other CVD risk factors), and daily exercise sessions are recommended for weight loss.[152]

Patients with T2DM should exercise a minimum of 3 days each week. More frequent exercise training (ie, 5 days per week or more) may maximize both the acute glucose-lowering effect and the effect on CVD [II (B)].

Intensity

Many studies have shown positive health benefits with moderate-intensity exercise.[24,28,55,72,153] Greater intensities of exercise tend to yield even greater benefits,[154] particularly changes in HbA_{1c} and aerobic capacity.[26] Very high intensities of cardiorespiratory exercise (eg, 75% of $\dot{V}O_{2max}$) have been associated with considerable improvements in HbA_{1c} and cardiorespiratory fitness, but such demanding exercise intensities may not be well tolerated in all patients with T2DM. Despite this, higher intensities of resistance exercise have been shown to be well tolerated and produce positive benefits in patients with T2DM.[29,30] This suggests that even patients who already exercise at moderate levels should be encouraged to increase their intensity of exercise, although as indicated, a recent meta-analysis of 6 studies showed that exercise intensity of <70% $\dot{V}O_{2max}$ still yielded improvements in $\dot{V}O_{2max}$, glycemic control and CVD risk factors in T2DM.[145] Caution should be applied to prescribing walking, because it can easily be performed at lower intensities. In such cases, the intensity must be brisk and must be regarded as an exercise walk rather than simply as a walk. Vigorous intensities should be targeted if tolerated and with consideration of contraindications. To maintain the required intensity of resistance training, patients should increase the weight lifted progressively if they successfully perform an additional 2 repetitions above what is intended.

In consideration of the duration of exercise performed, higher intensities of exercise may allow for shorter durations while still performing the same volume of exercise, because effects appear to be related to total energy expenditure.[155] Furthermore, high-intensity exercise has shown to be more effective in reversing left ventricular remodeling in heart failure patients,[156] increasing cardiomyocyte contractility in rat models (without T2DM),[157] and improving aerobic capacity and risk factors in patients with metabolic syndrome.[158] The application of this training in T2DM remains unknown, and research is warranted.

Duration

The duration of the exercise prescription can be divided into the duration of each exercise session, as well as the period of training required to have a desired effect.

Session Duration

Patients with T2DM should accumulate a minimum of 150 minutes of moderate-intensity exercise or 90 minutes of vigorous-intensity exercise each week [I (A)]. The duration of each individual session can vary, although the aim should be a minimum of 10 minutes per session.[154,159] Longer sessions (30 to 90 minutes) have typically been used in intervention studies,[147] although recent research has indicated that 3 short sessions (10 minutes) per day may be preferable to longer sessions (30 minutes) with regard to glycemic control in patients with T2DM [IIa (B)].

Program Duration

Beneficial effects have been reported over short durations. Improvements in arterial stiffness and insulin resistance (measured by the clamp technique) have been documented after only 3 weeks of aerobic exercise training, despite the lack of measurable changes in anthropometric factors (body mass index or body fat).[160] Thus, improvement in glycemic control and CVD seen in T2DM are not dependent on changes in body composition, because these typically require >3 weeks of intervention. However, to maintain a long-term effect, any lifestyle changes need to become permanent.[145]

Type

Both aerobic and resistance training have important roles in T2DM.[49] Recent work comparing the individual and combined effects of aerobic and/or resistance training revealed that both forms of exercise were equally beneficial for glycemic control, although aerobic training had a greater effect on body composition (except with regard to increasing muscle cross-sectional area).[40] The combination of both forms of training was twice as effective for improving glycemic control. Caution should be used when interpreting these results given double the volume of exercise performed in the combined training. It is recommended that patients with T2DM perform both aerobic and resistance training.

Aerobic

For most patients with T2DM, the goal of exercise is to increase energy expenditure, and this is directly related to the amount of muscle mass used during exercise. For this reason, exercises that use a large muscle mass and those that can be performed safely offer the best results for T2DM patients. Aerobic exercises such as walking and cycling are typically included in this category.

There are strong correlations between changes in aerobic fitness ($\dot{V}O_{2max}$) and improvements in glycemic control and insulin sensitivity.[153] These effects may be mediated via changes in visceral adiposity.[55] However, not all studies have been able to show positive effects of aerobic exercise training on glycemic control,[21,22] and this may pertain to levels of exercise intensity or compliance.

The main advantages of swimming training are that non–weight-bearing exercise can minimize the limitations of exercise caused by obesity and poor foot care. For example, obese individuals often have joint pain due to heavier loads placed on them while walking or running, and thus low-impact environments, such as in a pool, enable the effective performance of intense exercise. However, the effect of swimming per se, as a mode of exercise, has not been assessed in patients with T2DM.

Resistance

Resistance training has been shown to induce a hypertrophic response and a muscle-fiber type shift in exercising muscles,[161] which allows for a potential increase in whole-body glucose utilization. A consequent increase in GLUT4 proteins may in turn improve glycemic control.[162] However, it is debatable whether a training effect would have a chronic influence on GLUT4 expression, because it has been reported that GLUT4 protein content decreases rapidly (within 40 hours), even after 5 weeks of training. This is attributed to the short-half life of the protein (≈8 to 10 hours).[163] An increased capillary-to-muscle ratio further favors improved glucose control.[51] The use of resistance training to improve glycemic control in T2DM is supported by the American College of Sports Medicine and ADA position statements.[49,127,164] Furthermore, the potential benefits of increases in muscle mass on body composition[30,150] and other CVD risk factors[25,27,29,68] have also been reported.

Unlike aerobic training, higher intensities of resistance training (3 sets of 8 to 10 repetitions at 75% to 85% of 1 repetition maximum) have not only shown benefits but also have been well tolerated by patients with T2DM [I (B)].[29,30] However, for some patients, lower exercise intensities may be more appropriate [IIa (C)].

6. Approaches to Adherence

Health Behavior

As with other lifestyle interventions, patient commitment to exercise training in T2DM is preceded by contemplation and a willingness to move forward in the change process through preparation, action, and maintenance of behavioral change.[165] It is clear from behavioral research that a variety of factors contribute to the adoption of healthy exercise patterns, including perceived barriers and benefits, self-efficacy (ie, patients' perceived ability to affect their own life) or competence, motivation, past experiences, social support, access, and provider support, as well as the presence of anxiety and depression.[166–171] Additionally, strategies that have shown to be effective include the use of ongoing, individual counseling; exercise consultation; group support; stress management; coping skills training; and motivational interviewing techniques.[172–178] Community-based interventions aimed at increasing levels of physical activity, including some with T2DM, have been shown to be successful.[179]

The use of a World Wide Web–based program has increased the number of patients with a readiness for exercise, as well as improving physical activity, blood glucose profiles, glycemic control, and cardiorespiratory fitness.[180] Self-efficacy is a trait that appears to be strongly associated with successful adoption of an exercise program.[181] A strategy that

has been shown to be effective in other situations, such as cardiac risk factor intervention, has been the use of patients as coaches.[182]

Counseling

Physical activity advice may be particularly pertinent for patients with T2DM given that they comply less with physical activity recommendations.[183] As with all lifestyle modification strategies, counseling is of pivotal importance and has been studied widely; however, the evidence for its efficacy is less than that for lifestyle advice in curtailing smoking and alcohol abuse and even dietary advice.[184] Numerous training studies have shown beneficial effects of supervised exercise training in patients with T2DM; however, the feasibility of this approach long-term is questionable.[185] Home-based exercise training with exercise counseling offers convenience, flexibility, cost-effectiveness, and greater general appeal in population settings. Other previous work has suggested that exercise adherence is difficult to maintain outside of formal class or group settings, particularly in patients with T2DM.[186] However, given appropriate counseling, supervision, support, and motivation, this is not necessarily the case.[187]

Telephone exercise counseling after a period of gym-based training was reasonably effective in maintaining exercise compliance in previous work, improving glycemic control, body habitus, and functional capacity in patients with T2DM compared with control subjects.[142a] Other work has shown that a similar approach can increase physical activity levels, maintain exercise compliance, and improve cardiorespiratory fitness in previously sedentary but healthy individuals.[187–189] One of the other few studies to assess the effect of telephone exercise counseling in patients with T2DM reported 63% compliance (20 to 30 minutes of walking, 4 to 6 days per week for 17.2 months).[190] Patients who failed to comply with the regimen (exercising ≤3 days per week) had a 10-fold increase in CVD (assessed by clinical symptoms and diagnostic procedures) compared with those who did comply. Another study showed that patients with T2DM failed to maintain the improvements in glycemic control seen during gym-based resistance training for 6 months when training continued at home for an additional 6 months, despite regular (weekly, then fortnightly) telephone exercise counseling.[36] There has been previous work that suggested that telephone exercise counseling combined with face-to-face consultations can increase physical activity levels, improve glycemic control, and improve metabolic function,[35,191] although not all studies have shown this approach to be effective.[192]

Advice regarding physical activity may not need to be provided by a physician and could be given by a physician's assistants, exercise specialists, advanced practice nurses, or diabetes educators.[193] Both the original advice and the subsequent follow-up are important, with 1 study showing improved physical activity and metabolic sequelae in response to baseline counseling and follow-up phone calls after 1, 3, 6, and 9 months.[191] There is also evidence to suggest that once an exercise program has been established, the frequency of contact may not need to be maintained.[187,188] Because the prevalence of both anxiety and depression is high in the population with T2DM, and their presence may interfere with engagement in physical activity, psychological assessment should be routine, and referral for psychiatric care should be provided when appropriate.

Long-Term Efficacy

Unfortunately, the long-term efficacy of behavioral weight loss and weight control interventions in adults with T2DM is not well defined. In a meta-analysis, the pooled weight loss for any intervention was 1.7 kg (95% CI 0.3 to 3.2 kg), or 3% of baseline body weight,[194] although the control groups in these trials also frequently lost weight. As a consequence, improvements in glycemic control (evidenced by HbA_{1c}), which generally corresponded to changes in weight, were small once between-group differences were examined. The Look AHEAD trial is expected to provide guidance on this issue when it is completed.

7. Special/Minority Groups

Ethnicity and gender have an important influence on physical activity. Women are often reluctant to enroll in training programs for other indications, such as heart failure.[91] However, favorable effects of exercise programs are reported in women.[195] The incidence of T2DM and associated complications has been reported to be higher in the black population and indigenous groups around the world.[3] Particular attention should be directed toward these population groups not only to prevent but also to better manage the condition. There is some evidence that blacks may respond differently to different types of training, showing a better response to resistance training than to aerobic training, unlike white Americans,[196] which highlights the fact that different approaches are necessary, although the details of this are limited.

Financial, time, and other barriers may limit uptake in some minority groups. Although leisure-time physical activity is low in patients with T2DM across all racial/ethnic groups in the United States, low levels of physical activity in black women account for most of the observed racial differences between whites and blacks.[197] However, although environmental barriers are often cited as important limitations to activity, including unsafe walking areas, transportation problems, and lack of child care, some evidence suggests that lack of activity is related to the influence of medical conditions and the attitudes and knowledge of the subjects.[198] In contrast, environmental issues such as the availability of many nearby places to walk, the ability to walk to nearby places, and a pleasant local environment may play a more important role in the activity of patients with T2DM in rural areas.[199] Obesity, lower income level, and underestimation of required activity levels appear to be factors that identify blacks with T2DM and lower physical activity levels,[200] and these could be used to target interventions to promote physical activity in high-risk subjects. Recommendations for the provision of exercise advice have been published for various ethnic groups.[201,202]

8. Conclusions

Exercise training in patients with T2DM is feasible, well tolerated, and beneficial. Individualized exercise prescription offers an ideal opportunity to account for both cardiac and noncardiac considerations in T2DM. To improve cardiovascular risk, it is recommended that patients with T2DM accumulate a minimum of 150 minutes per week of at least moderate-intensity and/or 90 minutes per week of at least vigorous-intensity cardiorespiratory exercise. In addition, resistance training should be encouraged. These guidelines can be achieved with varying contributions of moderate- to vigorous-intensity cardiorespiratory exercise. Patients should train on at least 3 nonconsecutive days each week to maximize benefits. Individual sessions should last for no less than 10 minutes. Sedentary behaviors should be minimized. Exercise training should be implemented long-term, with telephone exercise counseling identified as a strategy that is economical, practical, and effective. This counseling provides the opportunity to assess exercise levels, adjust exercise prescriptions, and provide motivation and support. Contact frequency can decrease over time, because maintenance of initial high-frequency contact may not be necessary.

Sources of Funding

This work was supported in part by a Centre of Clinical Research Excellence award (455832) from the National Health and Medical Research Council, Canberra, Australia.

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Thomas H. Marwick	University of Queensland	National Health and Medical Research Council of Australia†; National Heart Foundation of Australia†	AstraZeneca*; GE Medical Systems*; Lantheus Medical Imaging*; Siemens*, Philips*	None	None	None	Philips*	None
Alain G. Bertoni	Wake Forest University	National Institutes of Health†	None	None	None	None	None	None
Roger S. Blumenthal	Johns Hopkins	None	None	None	None	None	None	None
Deborah A. Chyun	New York University, College of Nursing	Bristol Myers Squibb Medical Imaging†	None	None	None	None	None	None
Matthew D. Hordern	University of Queensland	National Health and Medical Research Council of Australia†	None	None	None	None	None	None
Todd Miller	Mayo Clinic	Boehringer Ingelheim*; Boston Scientific*; Bristol Myers Squibb*; KAI Pharmaceuticals*; Lantheus Medical Imaging†; Molecular Insight Pharmaceuticals†; Radiant Medicals*; Spectranetics*; TargeGen*	None	None	None	None	TherOx, Inc.*; The Medicines Company*	None
George Philippides	Boston Medical Center	None	None	None	None	None	None	None
Albert Rocchini	University of Michigan	AGA Medical*	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Gerald Fletcher	Mayo Clinic Jacksonville	None	None	None	None	None	None	None
Theodore Mazzone	University of Illinois–Chicago	None	None	None	None	None	None	None
Darren K. McGuire	University of Texas–Southwestern Medical Center	GlaxoSmithKline†	None	Takeda Pharmaceuticals North America†	None	None	Johnson & Johnson*	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (1) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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KEY WORDS: AHA Scientific Statements ■ exercise ■ diabetes mellitus ■ prevention ■ risk factors