

Diabetes Mellitus and Exercise

AMERICAN DIABETES ASSOCIATION

During exercise, whole-body oxygen consumption may increase by as much as 20-fold, and even greater increases may occur in the working muscles. To meet its energy needs under these circumstances, skeletal muscle uses, at a greatly increased rate, its own stores of glycogen and triglycerides, as well as free fatty acids (FFAs) derived from the breakdown of adipose tissue triglycerides and glucose released from the liver. To preserve central nervous system function, blood glucose levels are remarkably well maintained during exercise. Hypoglycemia during exercise rarely occurs in nondiabetic individuals. The metabolic adjustments that preserve normoglycemia during exercise are in large part hormonally mediated. A decrease in plasma insulin and the presence of glucagon appear to be necessary for the early increase in hepatic glucose production during exercise, and during prolonged exercise, increases in plasma glucagon and catecholamines appear to play a key role. These hormonal adaptations are essentially lost in insulin-deficient patients with type 1 diabetes. As a consequence, when such individuals have too little insulin in their circulation due to inadequate therapy, an excessive release of counterinsulin hormones during exercise may increase already high levels of glucose and ketone bodies and can even precipitate diabetic ketoacidosis. Conversely, the presence of high levels of insulin, due to exogenous insulin administration, can attenuate or even prevent the increased mobilization of glucose and other substrates induced by exercise, and hypoglycemia may ensue. Similar

concerns exist in patients with type 2 diabetes on insulin or sulfonylurea therapy; however, in general, hypoglycemia during exercise tends to be less of a problem in this population. Indeed, in patients with type 2 diabetes, exercise may improve insulin sensitivity and assist in diminishing elevated blood glucose levels into the normal range.

The purpose of this position statement is to update and crystallize current thinking on the role of exercise in patients with types 1 and 2 diabetes. With the publication of new clinical reviews, it is becoming increasingly clear that exercise may be a therapeutic tool in a variety of patients with, or at risk for diabetes, but that like any therapy its effects must be thoroughly understood (1–3). From a practical point of view, this means that the diabetes health care team will be required to understand how to analyze the risks and benefits of exercise in a given patient. Furthermore, the team, consisting of but not limited to the physician, nurse, dietitian, mental health professional, and patient, will benefit from working with an individual with knowledge and training in exercise physiology. Finally, it has also become clear that it will be the role of this team to educate primary care physicians and others involved in the care of a given patient.

EVALUATION OF THE PATIENT BEFORE EXERCISE

— Before beginning an exercise program, the individual with diabetes mellitus should undergo a detailed medical evaluation with appropriate diagnostic studies. This examination should

carefully screen for the presence of macro- and microvascular complications that may be worsened by the exercise program. Identification of areas of concern will allow the design of an individualized exercise prescription that can minimize risk to the patient. Most of the following recommendations are excerpts from *The Health Professional's Guide to Diabetes and Exercise* (3).

A careful medical history and physical examination should focus on the symptoms and signs of disease affecting the heart and blood vessels, eyes, kidneys, and nervous system.

Cardiovascular system

A graded exercise test may be helpful if a patient, about to embark on a moderate- to high-intensity exercise program (Table 1) (4–6), is at high risk for underlying cardiovascular disease, based on one of the following criteria:

- age >35 years
- type 2 diabetes of >10 years' duration
- type 1 diabetes of >15 years' duration
- presence of any additional risk factor for coronary artery disease
- presence of microvascular disease (retinopathy or nephropathy, including microalbuminuria)
- peripheral vascular disease
- autonomic neuropathy

In some patients who exhibit nonspecific electrocardiogram (ECG) changes in response to exercise, or who have nonspecific ST and T wave changes on the resting ECG, alternative tests such as radionuclide stress testing may be performed. In patients planning to participate in low-intensity forms of exercise (<60% of maximal heart rate) such as walking, the physician should use clinical judgment in deciding whether to recommend an exercise stress test. Patients with known coronary artery disease should undergo a supervised evaluation of the ischemic response to exercise, ischemic threshold, and the propensity to arrhythmia during exercise. In many cases, left ventricular systolic function at rest and

Originally approved February 1990. Revised in 1997.

The initial draft of this revision was prepared by Bernard Zinman, MD (co-chair); Neil Ruderman, MD, DPhil (co-chair); Barbara N. Campagne, PhD; John T. Devlin, MD; and Stephen H. Schneider, MD. The paper was peer-reviewed, modified, and approved by the Professional Practice Committee and the Executive Committee, June 1997, as well as by the American College of Sports Medicine's Pronouncements Committee and Board of Trustees, July 1997.

The recommendations in this paper are based on the evidence reviewed in the following publications: Exercise and NIDDM. *Diabetes Care* 13:785–789, 1990, and Exercise in individuals with NIDDM. *Diabetes Care* 17:924–937, 1994.

Guidelines of the American Diabetes Association and the American College of Sports Medicine.

This position statement is being published simultaneously in the journal *Medicine and Science in Sports and Exercise*.

Abbreviations: CAN, cardiac autonomic neuropathy; ECG, electrocardiogram; FFA, free fatty acid; PDR, proliferative diabetic retinopathy; PN, peripheral neuropathy.

during its response to exercise should be assessed.

Peripheral arterial disease

Evaluation of peripheral arterial disease (PAD) is based on signs and symptoms, including intermittent claudication, cold feet, decreased or absent pulses, atrophy of subcutaneous tissues, and hair loss. The basic treatment for intermittent claudication is nonsmoking and a supervised exercise program. The presence of a dorsalis pedis and posterior tibial pulse does not rule out ischemic changes in the forefoot. If there is any question about blood flow to the forefoot and toes on physical examination, toe pressures as well as Doppler pressures at the ankle should be carried out.

Retinopathy

The eye examination schedule should follow the American Diabetes Association's Clinical Practice Guidelines. For patients who have proliferative diabetic retinopathy (PDR) that is active, strenuous activity may precipitate vitreous hemorrhage or traction retinal detachment. These individuals should avoid anaerobic exercise and exercise that involves straining, jarring, or Valsalva-like maneuvers.

On the basis of the Joslin Clinic experience, the degree of diabetic retinopathy has been used to stratify the risk of exercise, and to individually tailor the exercise prescription. Table 2 is reproduced, with minor modifications, from *The Health Professional's Guide to Diabetes and Exercise* (3).

Nephropathy

Specific exercise recommendations have not been developed for patients with incipient (microalbuminuria >20 mg/min albumin excretion) or overt nephropathy (>200 mg/min). Patients with overt nephropathy often have a reduced capacity for exercise, which leads to self-limitation in activity level. Although there is no clear reason to limit low- to moderate-intensity forms of activity, high-intensity or strenuous exercises should probably be discouraged in these individuals.

Neuropathy: peripheral

Peripheral neuropathy (PN) may result in loss of protective sensation in the feet. Significant PN is an indication to limit weight-bearing exercise. Repetitive exercise on insensitive feet can ultimately lead to ulceration and fractures. Evaluation of PN can be made by checking the deep tendon

Table 1—Classification of physical activity intensity, based on physical activity lasting up to 60 min

Intensity	Relative intensity		
	VO _{2max} (%)	Maximal heart rate (%) ^a	RPE [†]
Very light	<20	<35	<10
Light	20–39	35–54	10–11
Moderate	40–59	55–69	12–13
Hard	60–84	70–89	14–16
Very hard	>85	>90	17–19
Maximal [‡]	100	100	20

Modified by Haskell and Pollock from *Physical Activity and Health: A Report of the Surgeon General* (4). ^aMaximal heart rate (HR_{max}) = 220 – age (Note: It is preferable and recommended that HR_{max} be measured during a maximal graded exercise test when possible); [†]Borg rating of relative perceived exertion (RPE) 6–20 scale; [‡]maximal values are mean values achieved during maximal exercise by healthy adults.

reflexes, vibratory sense, and position sense. Touch sensation can best be evaluated by using monofilaments. The inability to detect sensation using the 5.07 (10 g) monofilament is indicative of the loss of protective sensation. Table 3 lists contraindicated and recommended exercises for patients with loss of protective sensation in the feet.

Neuropathy: autonomic

The presence of autonomic neuropathy may limit an individual's exercise capacity and increase the risk of an adverse cardiovascular event during exercise. Cardiac autonomic neuropathy (CAN) may be indicated by resting tachycardia (>100 beats per minute), orthostasis (a fall in systolic blood pressure >20 mmHg upon standing), or other disturbances in autonomic nervous system function involving the skin, pupils, gastrointestinal, or genitourinary systems. Sudden death and silent myocardial ischemia have been attributed to CAN in diabetics. Resting or stress thallium myocardial scintigraphy is an appropriate noninvasive test for the presence and extent of macrovascular coronary artery disease in these individuals. Hypotension and hypertension after vigorous exercise are more likely to develop in patients with autonomic neuropathy, particularly when starting an exercise program. Because these individuals may have difficulty with thermoregulation, they should be advised to avoid exercise in hot or cold environments and to be vigilant about adequate hydration.

PREPARING FOR EXERCISE —

Preparing the individual with diabetes for a safe and enjoyable exercise program is as important as exercise itself. The young indi-

vidual in good metabolic control can safely participate in most activities. The middle-aged and older individual with diabetes should be encouraged to be physically active. The aging process leads to a degeneration of muscles, ligaments, bones, and joints, and disuse and diabetes may exacerbate the problem. Before beginning any exercise program, the individual with diabetes should be screened thoroughly for any underlying complications as described above.

A standard recommendation for diabetic patients, as for nondiabetic individuals, is that exercise includes a proper warm-up and cool-down period. A warm-up should consist of 5–10 min of aerobic activity (walking, cycling, etc.) at a low-intensity level. The warm-up session is to prepare the skeletal muscles, heart, and lungs for a progressive increase in exercise intensity. After a short warm-up, muscles should be gently stretched for another 5–10 min. Primarily, the muscles used during the active exercise session should be stretched, but warming up all muscle groups is optimal. The active warm-up can either take place before or after stretching. Following the activity session, a cool-down should be structured similarly to the warm-up. The cool-down should last about 5–10 min and gradually bring the heart rate down to its pre-exercise level.

There are several considerations that are particularly important and specific for the individual with diabetes. Aerobic exercise should be recommended, but taking precautionary measures for exercise involving the feet is essential for many patients with diabetes. The use of silica gel or air midsoles as well as polyester or blend (cotton-polyester) socks to prevent blisters and keep the feet dry is important for minimiz-

Table 2—Considerations for activity limitation in diabetic retinopathy (3)

Level of DR	Acceptable activities	Discouraged activities	Ocular reevaluation
No DR	Dictated by medical status	Dictated by medical status	12 months
Mild NPDR	Dictated by medical status	Dictated by medical status	6–12 months
Moderate NPDR	Dictated by medical status	Activities that dramatically elevate blood pressure Power lifting Heavy Valsalva	4–6 months
Severe NPDR	Dictated by medical status	Activities that substantially increase systolic blood pressure, Valsalva maneuvers, and active jarring Boxing Heavy competitive sports	2–4 months (may require laser surgery)
PDR	Low-impact, cardiovascular conditioning Swimming Walking Low-impact aerobics Stationary cycling Endurance exercises	Strenuous activities, Valsalva maneuvers, pounding or jarring Weight lifting Jogging High-impact aerobics Racquet sports Strenuous trumpet playing	1–2 months (may require laser surgery)

DR, diabetic retinopathy; NPDR, nonproliferative diabetic retinopathy.

ing trauma to the feet. Proper footwear is essential and must be emphasized for individuals with peripheral neuropathy. Individuals must be taught to monitor closely for blisters and other potential damage to their feet, both before and after exercise. A diabetes identification bracelet or shoe tag should be clearly visible when exercising. Proper hydration is also essential, as dehydration can effect blood glucose levels and heart function adversely. Exercise in heat requires special attention to maintaining hydration. Adequate hydration prior to exercise is recommended (e.g., 17 ounces of fluid consumed 2 h before exercise). During exercise, fluid should be taken early and frequently in an amount sufficient to compensate for losses in sweat reflected in body weight loss, or the maximal amount of fluid tolerated. Precautions should be taken when exercising in extremely hot or cold environments. High-resistance exercise using weights may be acceptable for young individuals with diabetes, but not for older individuals or those with long-standing diabetes. Moderate weight training programs that utilize light weights and high repetitions can be used for maintaining or enhancing upper body strength in nearly all patients with diabetes.

EXERCISE AND TYPE 2 DIABETES

— The possible benefits of exercise for the patient with type 2 diabetes are substantial, and recent studies strengthen

the importance of long-term exercise programs for the treatment and prevention of this common metabolic abnormality and its complications. Specific metabolic effects can be highlighted as follows.

Glycemic control

Several long-term studies have demonstrated a consistent beneficial effect of regular exercise training on carbohydrate metabolism and insulin sensitivity, which can be maintained for at least 5 years. These studies used exercise regimens at an intensity of 50–80% VO_{2max} three to four times a week for 30–60 min a session. Improvements in HbA_{1c} were generally 10–20% of baseline and were most marked in patients with mild type 2 diabetes and in those who are likely to be the most insulin resistant. It remains true, unfortunately, that most of these studies suffer from inadequate randomization and controls, and are confounded by associated lifestyle changes. Data on the effects of resistance exercise are not available for type 2 diabetes although early results in normal individuals and patients with type 1 disease suggest a beneficial effect.

It now appears that long-term programs of regular exercise are indeed feasible for patients with impaired glucose tolerance or uncomplicated type 2 diabetes with acceptable adherence rates. Those studies with the best adherence have used an initial period of supervision followed by relatively informal home exercise programs with reg-

ular, frequent follow-up assessments. A number of such programs have demonstrated sustained relative improvements in VO_{2max} over many years with little in the way of significant complications.

Prevention of cardiovascular disease

In patients with type 2 diabetes, the insulin resistance syndrome continues to gain support as an important risk factor for premature coronary disease, particularly with concomitant hypertension, hyperinsulinemia, central obesity, and the overlap of metabolic abnormalities of hypertriglyceridemia, low HDL, altered LDL, and elevated FFA. Most studies show that these patients have a low level of fitness compared with control patients, even when matched for levels of ambient activity, and that poor aerobic fitness is associated with many of the cardiovascular risk factors.

Table 3—Exercises for diabetic patients with loss of protective sensation

Contraindicated exercise	Recommended exercise
Treadmill	Swimming
Prolonged walking	Bicycling
Jogging	Rowing
Step exercises	Chair exercises
	Arm exercises
	Other non-weight-bearing exercise

Improvement in many of these risk factors has been linked to a decrease in plasma insulin levels, and it is likely that many of the beneficial effects of exercise on cardiovascular risk are related to improvements in insulin sensitivity.

Hyperlipidemia

Regular exercise has consistently been shown to be effective in reducing levels of triglyceride-rich VLDL. However, effects of regular exercise on levels of LDL cholesterol have not been consistently documented. With one major exception, most studies have failed to demonstrate a significant improvement in levels of HDL in patients with type 2 diabetes, perhaps because of the relatively modest exercise intensities used.

Hypertension

There is evidence linking insulin resistance to hypertension in patients. Effects of exercise on reducing blood pressure levels have been demonstrated most consistently in hyperinsulinemic subjects.

Fibrinolysis

Many patients with type 2 diabetes have impaired fibrinolytic activity associated with elevated levels of plasminogen activator inhibitor-1 (PAI-1), the major naturally occurring inhibitor of tissue plasminogen activator (TPA). Studies have demonstrated an association of aerobic fitness and fibrinolysis. There is still no clear consensus on whether physical training results in improved fibrinolytic activity in these patients.

Obesity

Data have accumulated suggesting that exercise may enhance weight loss and in particular weight maintenance when used along with an appropriate calorie-controlled meal plan. There are few studies specifically dealing with this issue in type 2 diabetes, and much of the available data is complicated by the simultaneous use of unusual diets and other behavioral interventions. Of particular interest are studies suggesting a disproportionate effect of exercise on loss of intra-abdominal fat, the presence of which has been associated most closely with metabolic abnormalities. Data on the use of resistance exercise in weight reduction are promising, but studies in patients with type 2 diabetes in particular are lacking.

Prevention of type 2 diabetes

A great deal of evidence has been accumulated supporting the hypothesis that exer-

cise, among other therapies, may be useful in preventing or delaying the onset of type 2 diabetes. Currently, a large randomized prospective National Institutes of Health (NIH) study is under way to clarify the feasibility of this approach.

EXERCISE AND TYPE 1 DIABETES

— All levels of exercise, including leisure activities, recreational sports, and competitive professional performance, can be performed by people with type 1 diabetes who do not have complications and are in good blood glucose control (note previous section). The ability to adjust the therapeutic regimen (insulin and diet) to allow safe participation and high performance has recently been recognized as an important management strategy in these individuals. In particular, the important role played by the patient in collecting self-monitored blood glucose data of the response to exercise and then using these data to improve performance and enhance safety is now fully accepted.

Hypoglycemia, which can occur during, immediately after, or many hours after exercise, can be avoided. This requires that the patient have both an adequate knowledge of the metabolic and hormonal responses to exercise and well-tuned self-management skills. The increasing use of intensive insulin therapy has provided patients with the flexibility to make appropriate insulin dose adjustments for various activities. The rigid recommendation to use carbohydrate supplementation, calculated from the planned intensity and duration of exercise, without regard to glycemic level at the start of exercise, the previously measured metabolic response to exercise, and the patient's insulin therapy, is no longer appropriate. Such an approach not infrequently neutralizes the beneficial glycemic lowering effects of exercise in patients with type 1 diabetes.

General guidelines that may prove helpful in regulating the glycemic response to exercise can be summarized as follows:

1. Metabolic control before exercise

- Avoid exercise if fasting glucose levels are >250 mg/dl and ketosis is present or if glucose levels are >300 mg/dl, irrespective of whether ketosis is present.
- Ingest added carbohydrate if glucose levels are <100 mg/dl.

2. Blood glucose monitoring before and after exercise

- Identify when changes in insulin or food intake are necessary.
- Learn the glycemic response to different exercise conditions.

3. Food intake

- Consume added carbohydrate as needed to avoid hypoglycemia.
- Carbohydrate-based foods should be readily available during and after exercise.

Since diabetes is associated with an increased risk of macrovascular disease, the benefit of exercise in improving known risk factors for atherosclerosis is to be highly valued. This is particularly true in that exercise can improve the lipoprotein profile, reduce blood pressure, and improve cardiovascular fitness. However, it must also be appreciated that several studies have failed to show an independent effect of exercise training on improving glycemic control as measured by HbA_{1c} in patients with type 1 diabetes. Indeed, these studies have been valuable in changing the focus for exercise in diabetes from glucose control to that of an important life behavior with multiple benefits. The challenge is to develop strategies that allow individuals with type 1 diabetes to participate in activities that are consistent with their lifestyle and culture in a safe and enjoyable manner.

In general, the principles recommended for dealing with exercise in adults with type 1 diabetes, free of complications, apply to children, with the caveat that children may be prone to greater variability in blood glucose levels. In children, particular attention needs to be paid to balancing glycemic control with the normalcy of play, and for this the assistance of parents, teachers, and athletic coaches may be necessary. In the case of adolescents, hormonal changes can contribute to the difficulty in controlling blood glucose levels. Despite these added problems, it is clear that with careful instructions in self-management and the treatment of hypoglycemia, exercise can be a safe and rewarding experience for the great majority of children and adolescents with insulin-dependent diabetes mellitus.

EXERCISE IN THE ELDERLY

— Evidence has accumulated suggesting that

the progressive decrease in fitness and muscle mass and strength with aging is in part preventable by maintaining regular exercise. The decrease in insulin sensitivity with aging is also partly due to a lack of physical activity. Lower levels of physical activity are especially likely in the population at risk for type 2 diabetes. A number of recent studies of exercise training have included significant numbers of older patients. These patients have done well with good training and metabolic responses, levels of adherence at least as good as the general population, and an acceptable incidence of complications. It is likely that maintaining better levels of fitness in this population will lead to less chronic vascular disease and an improved quality of life.

CONCLUSIONS — The recent Surgeon General's Report on Physical Activity and Health (4) underscores the pivotal role physical activity plays in health promotion and disease prevention. It recommends that individuals accumulate 30 min of moderate physical activity on most days of the week. In the context of diabetes, it is

becoming increasingly clear that the epidemic of type 2 diabetes sweeping the globe is associated with decreasing levels of activity and an increasing prevalence of obesity. Thus, the importance of promoting exercise as a vital component of the prevention, as well as management of type 2 diabetes must be viewed as a high priority. It must also be recognized that the benefit of exercise in improving the metabolic abnormalities of type 2 diabetes is probably greatest when it is used early in its progression from insulin resistance to impaired glucose tolerance to overt hyperglycemia requiring treatment with oral glucose-lowering agents and finally to insulin.

For people with type 1 diabetes, the emphasis must be on adjusting the therapeutic regimen to allow safe participation in all forms of physical activity consistent with an individual's desires and goals. Ultimately, all patients with diabetes should have the opportunity to benefit from the many valuable effects of exercise.

References

1. Schneider SH, Ruderman NB: Exercise and

NIDDM (Technical Review). *Diabetes Care* 13:785-789, 1990

2. Wasserman DH, Zinman B: Exercise in individuals with IDDM (Technical Review). *Diabetes Care* 17:924-937, 1994
3. American Diabetes Association: Diabetes and exercise: the risk-benefit profile. In *The Health Professional's Guide to Diabetes and Exercise*. Devlin JT, Ruderman N, Eds. Alexandria, VA, American Diabetes Association, 1995, p. 3-4
4. U.S. Department of Health and Human Services: *Physical Activity and Health: A Report of the Surgeon General*. Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Washington, DC, U.S. Govt. Printing Office, 1996
5. Centers for Disease Control and Prevention and the American College of Sports Medicine: Physical activity and public health: a recommendation. *JAMA* 273:402-407, 1995
6. American College of Sports Medicine: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults (Position Statement). *Med Sci Sports Exercise* 22:265-274, 1990