Physical Activity/Exercise and Diabetes Mellitus

AMERICAN DIABETES ASSOCIATION

During physical activity, 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 physical activity. Hypoglycemia during physical activity rarely occurs in nondiabetic individuals. The metabolic adjustments that preserve normoglycemia during physical activity 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 physical activity, 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 physical activity 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 physical activity, and hypoglycemia may ensue. Similar concerns exist in patients with type 2 diabetes on insulin or sulfonylurea therapy; however, in general, hypoglycemia during physical activity tends to be less of a problem in this population. Indeed, in patients with type 2 diabetes, physical activity 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 physical activity in patients with types 1 and 2 diabetes. With the publication of new clinical reviews, it is becoming increasingly clear that physical activity 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 physical activity 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.

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

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

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

EVALUATION OF THE PATIENT BEFORE EXERCISE

— Before increasing usual patterns of physical activity or 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, feet, and nervous system.

Cardiovascular system

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

- Age >35 years
- Age >25 years and
  - 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 (proliferative 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 physical activity (<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 during its response to exercise should be assessed.

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

Intensity	Relative intensity		
	Vo_{2max} (%)	Maximal heart rate (%)*	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). *Maximal 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.

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 physical activity 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 Recommendations. 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 physical activity 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 physical activity and to individually tailor the physical activity prescription. Table 2 is reproduced, with minor modifications, from *The Health Professional's Guide to Diabetes and Exercise* (3).

Nephropathy

Specific physical activity 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 physical activity, 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 physical activity should probably be discouraged in these individuals unless blood pressure is carefully monitored during exercise.

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 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 physical activity for patients with loss of protective sensation in the feet.

Neuropathy: autonomic

The presence of autonomic neuropathy may limit an individual's physical activity capacity and increase the risk of an adverse cardiovascular event during physical activity. 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 diabetes. 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 physical activity are more likely to develop in patients with autonomic neuropathy, particularly when starting a physical activity program. Because these individuals may have difficulty with thermoregulation, they should be advised to avoid physical activity 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 physical activity program is as important as physical activity itself. The young individual 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 physical activity 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 physical activity 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

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.

should be gently stretched for another 5–10 min. Primarily, the muscles used during the active physical activity session should be stretched, but warming up all muscle groups is optimal. The active warm-up can either take place before or after stretching. After 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 physical activity should be recommended, but taking precautionary measures for physical activity 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 minimizing trauma to the feet. Proper footwear is essential and must be emphasized for individuals with PN. Individuals must be taught to monitor closely for blisters and other potential damage to their feet, both before and after physical activity. A diabetes identification bracelet or shoe tag should be clearly visible when exercising. Proper hydration is also essential, as dehydration can affect blood glucose levels and heart function adversely. Physical activity in heat requires special attention to maintaining hydration. Adequate hydration prior to physical activity is recommended (e.g., 17 ounces of fluid consumed 2 h before physical activity). During physical activity, 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 physical activity for the patient with type 2 diabetes are substantial, and recent studies strengthen the importance of long-term physical activity 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 physical activity training on carbohydrate metabolism and insulin sensitivity, which can be maintained for at least 5 years. These studies used physical activity 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 physical activity are indeed feasible for patients with impaired glucose

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

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 physical activity programs with regular, frequent follow-up assessments. A number of such programs have demonstrated sustained relative improvements in $V_{O_{2max}}$ 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. 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 physical activity on cardiovascular risk are related to improvements in insulin sensitivity.

Hyperlipidemia

Regular physical activity has consistently been shown to be effective in reducing levels of triglyceride-rich VLDL. However, effects of regular physical activity 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 physical activity 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 (t-PA). 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 physical activity 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 physical activity 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 physical activity, among other therapies, may be useful in preventing or delaying the onset of type 2 diabetes. There are now three published trials documenting that with lifestyle modification (weight loss, regular moderate physical activity), diabetes can be delayed or prevented (7–9).

EXERCISE AND TYPE 1 DIABETES

EXERCISE AND TYPE 1 DIABETES — All levels of physical activity, 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 medical nutrition therapy) 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 physical activity 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 physical activity, can be avoided. This requires that the patient has both an adequate knowledge of the metabolic and hormonal responses to physical activity 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 physical activity, without regard to glycemic level at the start of physical activity, the previously measured metabolic response to physical activity, and the patient's insulin therapy, is no longer appropriate. Such an approach not infrequently neutralizes the beneficial glycemic lowering effects of physical activity in patients with type 1 diabetes.

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

1. Metabolic control before physical activity

- Avoid physical activity if fasting glucose levels are >250 mg/dl and ketosis is present, and use caution if glucose levels are >300 mg/dl and no ketosis is present.
- Ingest added carbohydrate if glucose levels are <100 mg/dl.

2. Blood glucose monitoring before and after physical activity

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

3. Food intake

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

Because diabetes is associated with an increased risk of macrovascular disease, the benefit of physical activity in improving known risk factors for atherosclerosis is to be highly valued. This is particularly true in that physical activity 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 physical activity training on improving glycemic control as measured by the A1C test in patients with type 1 diabetes. Indeed, these studies have been valuable in changing the focus for physical activity 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 physical activity 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, physical activity can be a safe and rewarding experience for the great majority of children and adolescents with type 1 diabetes.

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 physical activity. 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 physical activity 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 physical activity 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 physical activity.

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. Devlin JT, Ruderman N. Diabetes and exercise: the risk-benefit profile revisited. In *Handbook of Exercise in Diabetes*. Ruderman N, Devlin JT, Schneider SH, Krisra A, Eds. Alexandria, VA, American Diabetes Association, 2002
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
7. Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Illanne-Parikka P, Keinanen-Kiukaaniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M: Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 344:1343–1350, 2001
8. Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, Hu ZX, Lin J, Xiao JZ, Cao HB, Liu PA, Jiang XG, Jiang YY, Wang JP, Zheng H, Zhang H, Bennett PH, Howard BV: Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The DaQing IGT and Diabetes Study. *Diabetes Care* 20:537–544, 1997
9. Diabetes Prevention Program Research Group: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 346:393–403, 2002