TECHNICAL REVIEW

Exercise and NIDDM

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Regular exercise has generally been recommended as an important component of the treatment of all patients with diabetes mellitus. However, in recent years, this recommendation has been questioned, and many different opinions and practices regarding the role and value of exercise in diabetes exist. The purpose of this review is to summarize current knowledge on exercise in people with non-insulin-dependent diabetes mellitus (NIDDM) and to provide guidelines for prescribing exercise. Note, however, that these guidelines are based on current knowledge. Not all issues have been resolved, and continued research is needed to answer remaining questions.

POTENTIAL BENEFITS OF EXERCISE

NIDDM affects ~12 million people in the United States. In many of these individuals, diabetes is associated with obesity and insulin resistance. Exercise, like calorie restriction, has long been known to improve insulin sensitivity (1–3). Thus, diet and exercise are frequently recommended together as the initial approach to therapy. Despite this practice, the potential role of exercise in NIDDM therapy has only begun to be clarified (3–7). There are several potential benefits of exercise for NIDDM patients.

Glycemic control. A single bout of exercise frequently results in an acute decrease in plasma glucose levels in NIDDM patients (8,9). More important, improvements in glucose metabolism may persist for hours to days, possibly related to an increase in insulin sensitivity in muscle and other tissues (3,9–11). Improved glycemic control over prolonged periods in patients participating in regular exercise may largely be due to the cumulative effects of the individual acute exercise bouts rather than to a change in fitness per se (3,9). Whether changes in body composition caused by exercise, such as decreased adiposity and increased muscle mass (1,12), independently contribute to improved glucose tolerance and insulin sensitivity remains to be determined. Most, but not all studies (13), suggest that exercise is especially effective in people with impaired glucose tolerance or mild to moderate diabetes, i.e., fasting glucose levels <200 mg/dl (9,10,12,14–16). These studies also suggest that hyperinsulinemic patients respond best, which is consistent with the observation that exercise acts by reversing insulin resistance.

Cardiovascular benefits. Most excess morbidity and mortality in NIDDM patients is attributed to coronary artery disease, strokes, and peripheral vascular disease resulting from accelerated atherosclerosis (17). Epidemiological evidence suggests that regular exercise (18) and physical fitness (20,21) in adult life are associated with decreased coronary disease in the general population. Studies in primates fed an atherogenic diet provide additional evidence for a protective effect of exercise (21). Although no direct evidence is available for patients with NIDDM, effects of regular exercise on known risk factors for coronary heart disease suggest a beneficial effect. Risk factors that may improve include plasma lipoprotein levels, hyperinsulinemia, hyperglycemia, some blood coagulation parameters, and blood pressure. (4).

Weight loss. A diet-induced decrease in adiposity is frequently associated with improvements in insulin resistance, glycemic control, and risk factors for coronary heart disease in patients with NIDDM (4,23,24). How-

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ever, long-term results with diet therapy have been disappointing, largely because of poor patient compliance. Attempts to substitute exercise for diet therapy to produce weight loss have also been less than successful, although beneficial effects are often underestimated, because changes in body weight may not reflect improvements in body composition. Studies in nondiabetic populations suggest that weight loss may be better maintained in some individuals when exercise is combined with diet therapy (25,26). This could be the result of direct metabolic effects of exercise or of associated psychological benefits.

Psychological benefits. Exercise training and improved cardiorespiratory fitness are associated with decreased anxiety, improved mood and self-esteem, increased sense of well-being, and an enhanced quality of life (27). These effects may improve compliance with diet and/or other therapies, but this remains to be determined.

Disease prevention. Exercise training may be a means of delaying the onset of insulin resistance, cardiovascular disease, and NIDDM in patients at high risk for developing these problems (4,5,7,28–30). Those at risk include individuals with a positive family history of NIDDM or hypertriglyceridemia, women who have had gestational diabetes (28–30), and perhaps all people with android-type obesity. Although a higher level of physical activity has been associated with a decrease in diabetes prevalence in some populations (31), the efficacy of exercise as a preventive measure remains to be established.

RISKS OF EXERCISE

The potential complications of exercise need to be considered in all patients with NIDDM (Table 1). The risk of these complications can be minimized if patients are screened before embarking on an exercise program, the exercise is appropriately prescribed, and the patient is carefully monitored.

GUIDELINES FOR EXERCISE

An appropriate exercise training program similar to that recommended for the general population can be prescribed as an adjunct to diet and/or drug treatment in NIDDM patients (35). This recommendation is based on experimental evidence demonstrating that improvements in glycemic control and certain cardiovascular risk factors occur in some patients (4,10,12–16,36,37). As noted earlier, people with NIDDM most likely to respond favorably are those with mildly to moderately impaired glucose tolerance and hyperinsulinemia. Psychological benefits may also occur. The recommendation that exercise be used in NIDDM therapy is based on the consideration that the benefits outweigh the risks. Therefore, careful attention should be paid to minimizing potential complications by following the guidelines presented below and in Table 2.

TABLE 1
Potential adverse effects of exercise in non-insulin-dependent diabetes mellitus

Cardiovascular
Cardiac dysfunction and arrhythmias due to ischemic heart disease (often silent) (32)
Excessive increments in blood pressure during exercise (22)
Postexercise orthostatic hypotension
Microvascular
Retinal hemorrhage
Increased proteinuria (34)
Acceleration of microvascular lesions
Metabolic
Worsening of hyperglycemia and ketosis
Hypoglycemia in patients on insulin or sulfonylurea therapy
Musculoskeletal and traumatic
Foot ulcers (especially in presence of neuropathy)
Orthopedic injury related to neuropathy
Accelerated degenerative joint disease
Eye injuries and retinal hemorrhage

References in parentheses.

Preexercise evaluation. Before embarking on an exercise program, all patients should undergo a complete history and physical examination to identify macrovascular, microvascular, and neurological complications. Because there is a high prevalence of silent ischemic heart disease in NIDDM individuals (32), an exercise-stress electrocardiogram is recommended in all subjects >35 yr old. This test is also helpful for identifying pa-

TABLE 2
Summary of exercise recommendations for patients with non-insulin-dependent diabetes mellitus

Screening	Search for vascular and neurological complications including silent ischemic heart disease
	Stress electrocardiogram in patients >35 yr of age
Exercise program	
Type	Aerobic
Intensity	50–70% of maximum aerobic capacity
Duration	20–60 min
Frequency	3–5 times/wk
Avoid complications	Warm up and cool down
	Careful selection of exercise type and intensity
	Patient education
	Monitoring of blood glucose by patient and overall program by medical personnel
Compliance	Make exercise enjoyable
	Convenient location
	Positive feedback from involved medical personnel and family

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tients who have an exaggerated hypertensive response to exercise (33) and/or develop postexercise orthostatic hypotension. Young active patients with diabetes of brief duration and no evidence of vascular complications usually do not require a formal exercise prescription, although they still need specific recommendations.

Type of exercise. If no contraindications exist, the types of exercise a patient performs are a matter of personal preference. Rhythmic aerobic exercises, e.g., swimming and jogging, are generally preferred. Resistance exercises, e.g., weight lifting, may also lead to improved glucose disposal and plasma lipid profiles (38,39), but they have been discouraged because of concern that orthopedic and vascular side effects might be more common. Recent studies suggest that properly designed programs of resistance exercise may be safer and more effective than previously thought (40). Exercise that traumatizes the feet, e.g., jogging, should be limited in patients with peripheral neuropathy.

Warm-ups. Patients should warm up with low-intensity aerobic exercise for 5–10 min to prevent musculoskeletal injuries. Stretching exercises are also useful to prevent these injuries, but they must be done properly, i.e., without breath holding, which can result in large increases in systolic pressure due to a Valsalva effect. Such increases in systolic pressure are potentially detrimental to patients with microvascular or coronary disease.

Intensity of exercise. To achieve optimum cardiovascular benefits, exercise at 50–70% of an individual's VO_{2max} is usually prescribed if the complications of diabetes permit and the blood pressure response is not excessive. Exercise at <50% VO_{2max}, e.g., walking and dancing, may also be beneficial for cardiovascular status (18,18a), particularly if carried out for prolonged periods. In general, limiting the intensity of exercise so that systolic pressure does not exceed 180 mmHg is prudent (41). Intensity of exercise is best estimated from an individual's maximum heart rate (HR_{max}, determined at exercise testing, and a true basal rate (HR_{rest}), determined before arising in the morning. Fifty percent of a subject's maximal effort ($ME_{50\%}$) can be estimated by the equation

$$ME_{50\%} = 0.5(HR_{max} - HR_{rest}) + HR_{rest}$$

When the true maximal heart rate is unknown, it can be estimated by the equation

$$HR_{max} = 220 - \text{patient's age}$$

This is less accurate than a direct determination of the maximum heart rate under controlled conditions. The formula may also significantly overestimate the maximum heart rate of some NIDDM patients, particularly those with autonomic neuropathy.

Duration. Exercise sessions at 50–70% $VO_{2\,max}$ should last 20–45 min. Shorter sessions tend not to produce the desired metabolic effect; longer sessions result in a higher incidence of musculoskeletal problems.

Frequency. Available evidence suggests that, to improve insulin sensitivity and glycemic control, patients should exercise at least 3 days/wk or every other day; if weight reduction (i.e., loss of adipose mass) is a major goal, exercise ≥5 days/wk is probably necessary (25). Cessation of exercise in highly trained, nondiabetic athletes leads to decrease in insulin sensitivity within 3 days (42). The duration of glycemic improvement after the last bout of exercise in NIDDM patients is >12 but <72 h (9).

Postexercise cool-down. After exercise, patients should cool down for at least 5–10 min to reduce the risk of postexercise hypotension and other cardiovascular and musculoskeletal complications. Cool-downs are best performed at a heart rate within 10–15 beats/min of the resting value. The cool-down should last for 5–10 min. For runners, it should consist of walking; for cyclists, it should be pedaling with no or low resistance.

Special precautions. Many NIDDM patients must take special precautions when they begin to exercise regularly: *1*) proper footwear and other protective equipment, as dictated by the exercise, should always be used; *2*) exercise in extreme heat or cold should be avoided; *3*) feet should be inspected daily and after exercise; *4*) exercise during periods of poor metabolic control should be avoided; *5*) hydration should be maintained, especially during and after prolonged exercise in a warm environment; and 6) if the patient is taking insulin, blood glucose should be self-monitored before, during, and after exercise, and the same guidelines for avoiding hypoglycemia should be followed as with IDDM patients (43,44). Some patients treated with sulfonylureas may also have to observe these precautions (45). In the light of the high prevalence of occult macrovascular disease in NIDDM patients, monitoring of blood glucose in individuals on insulin or sulfonylurea therapy is especially important during the initial phase of an exercise program.

Compliance. Several maneuvers can improve compliance with an exercise program: *1*) the exercise should be enjoyable, i.e., patients should choose activities that they like and vary the type of exercise and the setting; *2*) the patient should exercise at a convenient time and location; regular exercise performed at a site near the individual's home or workplace has a greater chance of being continued; *3*) the patient's behavior should be reinforced by his/her family and involved medical personnel (participation in exercise groups may be useful); *4*) quantitative indices of progress to provide feedback should be utilized, e.g., measurements of heart rate during submaximal exercise and measurements of body composition; and *5*) unrealistically high performance goals should not be set.

Education. Patients need some understanding of the physiology of physical activity and its potential benefits and complications if an exercise program is to be successful. Physicians, other personnel, and, if available, an exercise physiologist can all serve as teachers.

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Safety. At present, no evidence exists that exercise, prescribed with appropriate precautions, places the NIDDM patient at increased risk.

CONCLUDING REMARKS

Although exercise can be safely performed by most NIDDM patients and individuals at risk for this disorder, many questions about its utility remain unanswered. In particular, additional information is needed concerning the long-term effects of exercise on blood pressure, glucose homeostasis, and coronary risk factors. Also, whether the decreased prevalence of coronary heart disease and cancer observed in nondiabetic individuals who exercise regularly also is observed in NIDDM patients remains to be determined. Other fundamental issues must also be addressed. Subgroups of diabetic individuals in which exercise therapy can be more effectively and economically prescribed must be identified. NIDDM patients with central obesity are at increased risk for atherosclerotic complications (46). Because this group also shows a significant metabolic improvement after exercise (36), it would be a logical candidate for study. Conversely, patient subgroups in which exercise produces little benefit need to be identified (48). The role of exercise in the prevention of NIDDM, hyperinsulinemia, hypertension, and atherosclerosis in high-risk groups should be elucidated. The value of exercise as an adjunct to diet therapy for inducing and maintaining weight loss needs to be determined. Finally, the significance of the reduced aerobic capacity (physical fitness) observed in some patients with impaired glucose tolerance (37) and NIDDM (4,9) needs clarification. In the general population, decreased aerobic capacity is associated with increased cardiovascular mortality (20).

APPENDIX: COUNCIL ON EXERCISE

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