2

Diabetes and Physical Activity

PAMELA DYSON
Oxford Centre for Diabetes, Endocrinology and Metabolism, Oxford, UK

INTRODUCTION

It is now widely accepted that increasing physical activity leads to great health benefits whether or not people have diabetes (1). Increased physical activity has been associated with physical, mental and social benefits including the following:

- Reduction in all-cause mortality (2,3).
- Reduction in cardiovascular disease (CVD) including coronary heart disease (CHD), stroke and heart attack (4).
- Blood pressure reduction (5).
- Improved weight loss in the obese and weight maintenance in those of normal weight (6).
- Prevention of Type 2 diabetes and improved glycaemic control (7–10).
- Prevention of osteoporosis (11).
- Improved flexibility and strength (12).
- Increased self-esteem and confidence (13).

These benefits apply to all people whether they have diabetes or not, but the benefits of improved glycaemic control are especially appropriate to people with diabetes. In addition, a reduction in the incidence of CVD and the positive effect on body weight associated with physical activity can only benefit the health of people with diabetes.

Nutritional Management of Diabetes Mellitus. Edited by G. Frost, A. Dornhorst and R. Moses
 ISBN 0 471 49751 7

PREVENTION OF TYPE 2 DIABETES

There is now unequivocal evidence that physically fit people are less likely to develop Type 2 diabetes and some intervention trials have shown that encouraging people with impaired glucose tolerance (IGT) to increase their physical activity significantly reduces their risk of developing diabetes (14–16). This benefit is independent of body mass index (BMI) and there is some evidence that physical activity has a greater protective effect as BMI increases (17). It may be of more importance for people at risk of Type 2 diabetes to increase their physical fitness rather than concentrate on weight reduction.

GLYCAEMIC CONTROL

The benefits associated with improved glycaemic control are related to changes in insulin sensitivity, and are more pronounced in people who have Type 2 diabetes (18) or who are overweight (19). For many people with Type 1 diabetes, who do not exhibit insulin resistance, the main benefits of exercise may be related to improvements in dyslipidaemia, enhanced cardiovascular function and blood pressure reduction (10).

CARDIOVASCULAR RISK FACTORS

The role of exercise and the prevention of coronary heart disease in the general population have been well documented, but there is less evidence of a similar effect in people with diabetes. Modification of risk factors for CHD, including decreased total and LDL (low-density lipoprotein) cholesterol and triglyceride concentrations, have been demonstrated in Type 1 diabetes (20). People with Type 2 diabetes have two to four times the cardiovascular risk of those without diabetes and low cardiorespiratory fitness has been shown to be a predictor of mortality in men with diabetes (21).

BODY WEIGHT MANAGEMENT

Physical activity has a role in weight reduction and aids weight maintenance in those of normal weight. As 80% of people with Type 2 diabetes are overweight, most individuals would benefit from weight reduction.

EXERCISE AND DIABETES

Despite the widespread beliefs of the benefits of physical activity and the promotion of exercise by many health professionals, people with diabetes are reluctant to increase their physical activity (22). This is not restricted to those with diabetes as it applies to the British population as a whole. A UK study in 1990 showed that only 15–30% of British adults are taking sufficient exercise for optimum health and that there is a large discrepancy between people's perception of their fitness and the amount of exercise they actually take (23). A recent Canadian study has shown that while 84% of people with diabetes thought they should be exercising, only 45% were actually doing so (24). Against this background of reluctance to exercise there is also a lack of knowledge of the physiology of exercise. In order to maximise the advice given to people with diabetes who wish to increase their physical activity, it is essential to gain an understanding of the physiology of physical activity, exercise and sport.

PHYSICAL ACTIVITY, EXERCISE AND SPORT

DEFINITIONS

Physical activity refers to any body movement made by the skeletal muscles and resulting in energy expenditure, e.g. walking, gardening, housework.

Exercise is planned, structured repetitive body movements usually taken as a leisure time pursuit, e.g. aerobics, jogging, swimming.

Sport is physical activity which involves competitive situations which are usually governed by rules, e.g. football, rugby, netball.

The effects of physical activity programmes depend upon the intensity, frequency and duration of exercise.

INTENSITY

Physical activity, exercise and sport can all be classified as either light, moderate or vigorous.

Light activities require little exertion and do not cause a significant change in breathing.

Moderate activities require sustained muscular movements and will result in heavier breathing and a feeling of warmth.

Vigorous activities require sustained muscular movements and result in a feeling of being sweaty or out of breath.

Examples of different activities and their intensity are shown in Table 2.1.

Table 2.1 Intensity of various activities

Intensity of activity	Examples
Light	Slow walking, light gardening (weeding, mowing with power mower), light housework (dusting, hoovering), light DIY (decorating), bowls, golf, snooker
Moderate	Brisk walking, heavy housework (scrubbing, spring cleaning), heavy gardening (digging), heavy DIY (sawing, mixing cement), football, tennis, cycling, swimming, aerobics, all at a level to produce some breathlessness and a feeling of warmth, working as a labourer, roofer or refuse collector
Vigorous	Sport and exercise at a level to induce sweating and breathlessness, e.g. squash, running, football, rugby, swimming, tennis, aerobics, cycling, gym work, any work or occupation involving frequent climbing, lifting, carrying, e.g. mining, forestry

FREQUENCY AND DURATION

The exercise guidelines issued by the American College of Sports Medicine (ACSM) in 1978 recommend at least three sessions of 20–40 min of vigorous activity each week. This was revised in 1990 and 30 min of moderate activity daily is now recommended (25).

In 1994, the UK Health Education Authority (HEA) adopted an international consensus statement and recommended the following:

moderate intensity activity;
of 30 minutes duration or more;
at a frequency of 5 or more days each week (1).

The majority of research has concentrated upon the effect of physical activity on CHD rates and as a result the emphasis has been on increasing aerobic or vigorous activity. Recent research has shown the benefit of moderate activity and for many people with diabetes the greatest health benefit may be in changing from a sedentary lifestyle to a moderately active lifestyle (26).

PHYSIOLOGY OF EXERCISE

In people without diabetes, a precise endocrine response ensures that the energy needs of the exercising muscle are met and glucose homeostasis is maintained. This metabolic response is ameliorated in Type 2 diabetes and lost in Type 1 diabetes and the challenge is to reproduce the physiological state of the non-diabetic individual. A brief review of the metabolic, hormonal and physiological responses to exercise is given below.

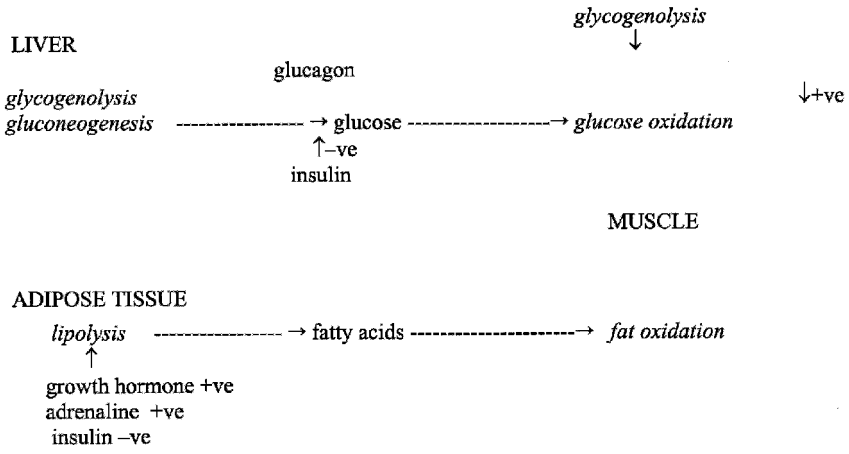

Figure 2.1

Metabolic changes provide the energy required for exercise. Glucose uptake by exercising muscle increases and at the onset of exercise, muscle glycogen is converted to lactate to provide the energy substrate. When muscle glycogen is exhausted, energy is provided by glucose from the liver following glycogenolysis and eventually from metabolism of free fatty acids in adipose tissue. The metabolic response depends on a number of factors:

- *Intensity and duration of exercise*. High intensity/short duration of exercise, e.g. sprinting, will utilise carbohydrate (glycogen) as energy substrate and low intensity/long duration, e.g. marathon running, will utilise carbohydrate (glycogen) initially, but predominately fat (FFA).
- *Exercise timing*. The amount of available glucose will depend upon whether exercise is taken in the fasting or post-prandial state.
- *Level of fitness*. Athletes who train for endurance events show reduced rates of glycogen breakdown and are able to utilise FFA more efficiently.
- *Dietary intake*. The amount and type of carbohydrate consumed routinely and pre- and post-events will affect performance.

Hormonal responses to exercise are characterised by the action of insulin and its counter regulatory hormones glucagon, cortisol and catecholamines. The key response to exercise is the suppression of insulin secretion, accompanied by a rise in catabolic hormones (Figure 2.1). This stimulates release of glucose from the liver and FFA from adipose tissue and maintains energy levels during exercise.

Physiological responses are shown by the increased heart rate, stroke volume and cardiac output which accompanies exercise and which facilitates increased oxygen delivery and removal of carbon dioxide.

At the end of a period of exercise, recovery takes place as hormone concentrations return to their pre-exercise levels and glycogen stores are replenished. There is continued oxidation of fat, which limits the use of glucose as an energy substrate and allows replenishment of liver and muscle glycogen. Muscle uptake of glucose is enhanced through increased glucose transporters (GLUT-4) and this process of glycogen storage can last up to 12–18 h after exercise. The speed of this process depends upon the type and duration of exercise.

People with Type 2 diabetes usually have sufficient circulating insulin to precipitate the normal metabolic response to exercise and any risk of hypoglycaemia is associated with the use of either insulin or oral hypoglycaemic agents.

People with Type 1 diabetes depend upon exogenous supplies of insulin and any exercise may pose some risk of hypoglycaemia. When a person with Type 1 exercises with too little insulin the counter-regulatory hormonal response may elevate both circulating glucose and ketone levels. On the other hand, too much insulin increases the risk of hypoglycaemia by blocking the exercise-induced increase in glycogenolysis and gluconeognesis. The risk of hypoglycaemia can continue for 6–14 h after strenuous exercise as glucose is synthesised to replace lost glycogen stores and insulin sensitivity is increased during the recovery period.

Advice to people with diabetes who wish to increase their physical activity or improve performance will cover the whole range of activities from a gentle stroll to competing at the top level. Advice should take into consideration the following:

- Perceptions and beliefs
- Type, intensity, frequency and duration of exercise
- Medication
- Contraindications to exercise
- Dietary intake

Perceptions and beliefs

Barriers to increasing physical activity include time constraints, usually linked to domestic or work commitments, health status, age, performance expectations and lack of will power. The emphasis should be on adapting advice to fit in with the individual's lifestyle and avoiding prescriptive advice, which may fail to address the individual's perceptions and beliefs.

People with Type 2 diabetes who wish to increase their levels of general activity will need encouragement, motivation and the choice of a physical activity or sport which matches their individual needs. For the majority of this

middle-aged sedentary population, an increase in gentle exercise, e.g. walking, can be safely recommended. Exercise at this level has been shown to have health benefits for people with Type 2 diabetes (27). It is feasible for people with Type 2 to increase physical activity at a higher intensity, but recommendations should include checking with their physician before beginning a programme of vigorous exercise and exercising under supervision.

Type, Intensity, Frequency and Duration

Advice to people with diabetes will depend upon the type of exercise they wish to do. Gentle exercise at light or moderate intensity does not place the same demands upon diabetes management as that caused by vigorous exercise. People with Type 1 diabetes may be at risk of hypoglycaemia and it is important to consider the effect of the type, intensity, frequency and duration of exercise and its effect on blood glucose. Timing of meals and sessions of physical activity should be planned wherever possible and exercise should avoid the peak action of insulin as this has been shown to precipitate hypoglycaemia. The majority of people with Type 1 who take exercise find that they may have to adjust their insulin, their carbohydrate intake or a combination of both. People who are taking part in competitive sports or who wish to take part in endurance races or increase their activity to a vigorous level are strongly recommended to consult a specialist diabetes professional.

Medication

People with Type 2 diabetes who are controlled by diet alone, or who take metformin or acarbose, are able to exercise without risk of hypoglycaemia. They do not need to make any adjustment to their medication when increasing physical activity. Those taking insulin or oral hypoglycaemic agents will need to time exercise sessions to avoid peak action of agents and may need to take extra carbohydrate during training to prevent hypoglycaemia. It is difficult to adjust insulin for exercise in people taking an insulin mixture twice daily and in Type 2 diabetes this is further complicated by an inability to measure accurately insulin resistance. Because of the action of increasing insulin sensitivity, people with Type 2 diabetes who increase their physical activity may find that their insulin requirements decrease over time and that they may need less insulin. This is best measured on an individual basis and should be monitored by frequent blood glucose tests.

People with Type 1 diabetes will need to plan ahead for exercise and make appropriate insulin adjustment. One study has shown that moderately intensive exercise sessions lasting 45 min can lead to hypoglycaemia and this was effectively overcome by a reduction in insulin by 30–50% before exercise (28). The effects of exercise are mediated by the timing of exercise (pre- or post-

prandial) and the blood glucose levels at the start of exercise. It is impossible to formulate precise guidelines for insulin adjustment for those with Type 1 wishing to exercise, but consultation and experimentation accompanied by frequent blood glucose tests can help to identify the most effective strategies in individuals with Type 1 diabetes.

The absorption of insulin injected subcutaneously can be accelerated by exercise and may precipitate hypoglycaemia. To prevent this, it is advised that insulin is injected away from the site of exercising muscle, e.g. into the abdomen in the case of runners and cyclists, and that exercise does not take place at the time of peak insulin action.

Contraindications to Exercise

Although the health benefits of exercise are well established, there are certain areas where caution must be observed. Encouragement to increase physical activity for people with diabetes will be affected by some underlying features and physical exercise is not without risk in diabetes. All people with diabetes are advised to have a medical examination prior to beginning an exercise programme to identify any complications which may be adversely affected by exercise. Those wishing to take part in strenuous activity will find the following are relative contraindications: poor glycaemic control, the presence of ketones, proliferative retinopathy, microangiopathy, neuropathy, nephropathy and cardiovascular disease. Although strenuous activity may be contraindicated, some individuals may be able to increase general everyday physical activity.

Practical implications of increasing physical activity include consideration of possible damage to the soft tissues and joints, especially in the feet, and it is recommended that those with diabetes consult a podiatrist and purchase good, supportive footwear.

Precipitation of cardiac events is possible, especially in those with Type 2 diabetes, and exercise should not be encouraged without giving the following guidelines: avoid irregular, strenuous exercise, do not exercise when unwell and stop exercise immediately if any pain, especially chest pain, is experienced. It is also important to warm up and cool down thoroughly before and after exercise sessions.

DIETARY ADVICE FOR EXERCISE

PRACTICAL MANAGEMENT

Dietary advice to people with diabetes wishing to increase physical activity is individual and will depend upon many factors including medication, type, frequency and duration of exercise and for many people it is a process of experimentation. For those taking insulin, there is more than one way to

regulate blood sugar levels during exercise either by reducing insulin, increasing carbohydrate intake or a combination of the two. Advice should be tailored to the individual depending upon the following:

- Dietary intake
- Insulin regime
- Blood glucose levels
- Type of activity
- Timing of activity

Dietary Intake

It is now universally accepted that the best diet for maximising exercise tolerance and performance is one that is high in carbohydrate (50–60% energy from carbohydrate). Athletes routinely use high-carbohydrate diets when training. The Diabetes UK recommendations for all people with diabetes encourage a high-carbohydrate diet and this should apply whether people are exercising or not. This diet should help protect against the risk of hypoglycaemia during periods of increased physical activity.

There is some discussion about the type and amount of carbohydrate. The glycaemic index (GI) of carbohydrate foods has been shown to be a useful tool in maximising performance in athletes and sportsmen and women and there may be a role for it in people with diabetes who exercise at a strenuous level for more than 60 min (29). It is recommended that low GI foods are consumed at the meal or snack before exercise takes place and that high GI foods are consumed during endurance events and after exercise to replenish glycogen stores. Examples of low GI foods, which can be eaten before an exercise session and high GI foods/drinks, which can be taken during or after an event, are given in Table 2.2.

Table 2.2 Examples of high and low GI carbohydrate foods

GI	Examples of food	Timing
Low	Pasta, Basmati rice, couscous, instant noodles, barley, wholegrain products, porridge, muesli, All-Bran, oat-based cereal bars, lentils and pulses including baked beans, chick peas and kidney beans, dried apricots	2–3 h before exercise, especially endurance events
High	Isotonic sports drinks, fruit juice, ordinary squash, jelly beans, ripe bananas, honey sandwich	During an exercise session (if required)
High	Corn Flakes, Rice Krispies, sugared cereals, white bread, rice (other than Basmati), potatoes	Within 30–60 mins of completing an exercise session

It is recommended that people with diabetes eat before exercising and that they should exercise approximately 3 h after a large meal to ensure digestion and absorption of food. Additional carbohydrate may be needed immediately before exercise, during exercise and after exercise to replenish glycogen stores. The amount of carbohydrate will depend upon blood glucose levels.

Intake of sufficient fluid should be advised to avoid dehydration. Water, sugar-free squashes and sugar-free sports drinks are suitable for rehydration if fluid only is required. Fruit juice, ordinary squash and isotonic sports drinks are useful for replenishing fluid and carbohydrate. Hypertonic drinks, e.g. Lucozade, are not suitable for rehydration and should be used only to treat hypoglycaemia. Fizzy drinks and sodas may cause problems with bloating and wind and are best avoided.

Insulin Regime

For those who are on a basal/prandial regimen it may be necessary to reduce insulin by 30–50% before strenuous activity. Extra carbohydrate should be taken when engaging in unplanned activity where it is impossible to reduce insulin. It is advisable that people avoid periods of strenuous physical activity when short-acting insulin is peaking, i.e. within 2 h of use. People with Type 1 diabetes may find they can reduce their insulin after an endurance event, e.g. marathon running, and that it may take several days before they return to their pre-race insulin dose. This process should be supported by frequent blood glucose tests.

Blood Glucose Levels

It is recommended that people with diabetes monitor their blood glucose levels before, during and after exercise. Optimum blood glucose levels are those between 6–13 mmol/l before exercise begins. If blood glucose levels are < 6 mmol/l, people should be advised to take some carbohydrate with a high glycaemic index, e.g. isotonic sports drinks, ripe bananas. If blood glucose levels are above 13 mmol/l, then exercise should be delayed until blood glucose falls to the acceptable levels. If blood glucose drops below 5 mmol/l during exercise, fast-acting carbohydrate should be taken immediately to prevent hypoglycaemia.

Type of Activity

The amount of carbohydrate to be taken during exercise depends upon the type of activity. People with Type 2 diabetes who are increasing physical activity at low/moderate intensity by going for a walk often need to make no change to their medication or dietary intake. However, if they take insulin and are

planning on taking up strenuous exercise, they may need to reduce their insulin dose. As they become physically fitter, insulin sensitivity will improve and overall insulin requirements may decrease. This can be judged by frequent blood glucose monitoring.

People with Type 1 diabetes are unlikely to require extra carbohydrate if blood glucose levels are above 10 mmol/l at the start of exercise and if they are taking part in light or moderate activity for 20–30 min. During moderate activity lasting 30–60 min, an additional 10–20 g carbohydrate may be required. During strenuous activity lasting 30–60 min, an extra 30–50 g carbohydrate may be required. A general rule of thumb is that 10–20 g carbohydrate should be taken every 30 min during moderate or strenuous exercise lasting more than 30 min.

Timing of Activity

It is important to consider the timing of exercise or physical activity sessions in order to reduce the risk of hypoglycaemia. For those taking oral hypoglycaemic agents exercise should be avoided at high-risk times, e.g. immediately before the mid-day meal. For those taking insulin, exercise should be avoided at peak action of short-acting insulin. The risk of hypoglycaemia appears to be lowest if exercise is taken in the morning, before taking any insulin or food. Conversely, late afternoon or early evening exercise may increase the risk of late hypoglycaemia during the night. The adjustment of diet and insulin for exercise is facilitated if the timing of exercise from day to day is consistent.

Summary of advice for people with diabetes wishing to exercise

Before exercise:

- Monitor blood glucose regularly – before, during and after exercise.
- Eat a low GI meal 2–3 h before an endurance event.
- Reduce insulin by 30–50% for strenuous or endurance training.
- Optimum blood glucose levels are 6–13 mmol/l.
- If blood glucose < 6 mmol/l, take 10–20 g fast-acting carbohydrate.
- If blood glucose > 13 mmol/l, delay exercise.

During exercise:

- 20–30 min of light/moderate activity should not require extra carbohydrate.
- 30–60 min of moderate activity may require an extra 10–20 g high GI carbohydrate.
- 30–60 min of strenuous activity may require an extra 30–50 g high GI carbohydrate.

- Endurance training may require an additional 10–20 g high GI carbohydrate for each 30 min of exercise.
- Remember to consume adequate fluid to prevent dehydration.

After exercise:

Replenish glycogen stores by consuming high GI carbohydrate-rich foods within 30–60 min of exercise. After endurance training, e.g. marathon running, cycling, monitor blood glucose levels, replenish glycogen stores with high GI carbohydrate and adjust insulin accordingly.

REFERENCES

1. Health Education Authority. *Health Update 5. Physical Activity*. London: Health Education Authority 1995.
2. Paffenbarger RS Jr, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality and longevity of college alumni. *New Engl J Med* 1986; 314: 605–613.
3. Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB. The association of changes in physical activity levels and other lifestyle characteristics with mortality among men. *New Engl J Med* 1993; 328: 538–545.
4. Morris JN. The role of exercise in the prevention of coronary heart disease: today's best buy in public health. *Med Sci Sport Ex* 1994; 26: 807–813.
5. Fagard RH. Physical fitness and blood pressure. *J Hypertens* 1993; 11 Suppl 5: S47–S52.
6. Garrow J, Summerball C. Meta-analysis: effect of exercise, with and without dieting, on the body composition of overweight subjects. *Eur J Clin Nutr* 1995; 49: 1–10.
7. Manson JE, Rimm EB, Stampfer HJ, Colditz GA, Willett EC *et al*. Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *Lancet* 1991; 338: 774–778.
8. Helmrich SP, Ragland DR, Leung RW and Paffenbarger RS Jr. Physical activity and reduced occurrence of non-insulin-dependent diabetes. *New Engl J Med* 1991; 325: 147–152.
9. Wei M, Gibbons LW, Mitchell TL, Kampert JB, Lee CD, Blair SN. The association between cardiorespiratory fitness and impaired fasting glucose and Type 2 diabetes mellitus in men. *Ann Intern Med* 1999; 130: 89–96.
10. Pierce NS. Diabetes and exercise. *Br J Sports Med* 1999; 33: 161–172.
11. Wolman R. Osteoporosis and exercise. *Br Med J* 1994; 309: 400–403.
12. Young A, Dinan S. Fitness for older people. *Br Med J* 1994; 309: 331–333.
13. MacAuley E. Physical activity and psychosocial outcomes. In: *Physical Activity, Fitness and Health; International Proceedings and Consensus Statement*, ed. C Bouchard. Human Kinetics Publishers Inc., 1994.
14. Pan XR, Li GW, Hu YH, Wang WY, An ZW *et al*. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. *Diabetes Care* 1997; 20: 537–544.

15. Bourn DM. The potential for lifestyle change to influence the progression of impaired glucose tolerance to non-insulin-dependent diabetes mellitus. *Diabet Med* 1996; 13: 938–945.
16. Eriksson J, Lindstrom J, Valle T, Aunola S, Hamalainen H *et al*. Prevention of Type 2 diabetes in subjects with impaired glucose tolerance: The Diabetes Prevention Study (DPS) in Finland. *Diabetologia* 1999; 42: 793–801.
17. Sato Y. Diabetes and life-styles: role of physical exercise in primary prevention. *Br J Nutr* 2000; 84: S187–S190.
18. Braun B, Zimmerman MB, Kretchmer M. Effects of exercise on insulin sensitivity in women with non-insulin-dependent diabetes mellitus. *J Appl Physiol* 1995; 78: 300–306.
19. Rice B, Janssen I, Hudson R, Ross R. Effects of aerobic or resistance exercise and/or diet on glucose tolerance and plasma insulin levels in obese men. *Diabetes Care* 1999; 22: 684–691.
20. Wasserman DH, Zinman B. Exercise in individuals with IDDM. *Diabetes Care* 1994; 8: 924–937.
21. Wei M, Gibbons FW, Kampert JB, Nichaman MZ, Blair SB. Low cardiorespiratory fitness and physical activity as predictors of mortality in men with Type 2 diabetes. *Ann Intern Med* 2000; 132: 605–611.
22. Hays LM, Clark DO. Correlates of physical activity in a sample of older adults with Type 2 diabetes. *Diabetes Care* 1999; 22: 706–712.
23. Health Education Authority and Sports Council. *Allied Dunbar National Fitness Survey: Main Findings*. London: Sports Council and HEA, 1992.
24. Plotnikoff RC, Brez S, Hotz SB. Exercise behavior in a community sample with diabetes: understanding the determinants of exercise behavioral change. *Diabetes Educ* 2000; 26: 450–459.
25. American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Med Sci Sports Ex* 1990; 22: 265–274.
26. Hu FB, Sigal RJ, Rich-Edwards JW, Colditz JA, Solomon CG *et al*. Walking compared with vigorous physical activity and Type 2 diabetes in women. *J Am Med Assoc* 1999; 282: 1433–1439.
27. Yamanouchi K, Shinozaki T, Chikada K, Nishikawa T, Ito K *et al*. Daily walking combined with diet therapy is a useful means for obese NIDDM patients to not only reduce body weight but also to improve insulin sensitivity. *Diabetes Care* 1995; 18: 775–778.
28. Schiffrin A, Pankh S. Accommodating planned exercise in Type 1 diabetic patients on intensive treatment. *Diabetes Care* 1985; 8: 337–343.
29 Leeds A, Brand Miller J, Foster-Powell K and Colagiri S. *The Glucose Revolution*. London: Hodder and Stoughton 2000.