Physical activity: Efficacy and application in the management of type 2 diabetes

Thomas Yates, Kamlesh Khunti, Melanie Davies

Physical activity is known to be a powerful antidiabetes therapeutic agent. There is now unequivocal evidence that increased physical activity improves metabolic health, with factors involved in glucose regulation particularly sensitive to its action. This article gives an overview of the evidence surrounding the use of physical activity in the management of type 2 diabetes and highlights key ways of initiating physical activity behaviour change.

Physical activity is essential in maintaining healthy metabolic regulation. A lack of sufficient physical activity is estimated to contribute directly to the development of at least 20 common health conditions and diseases (Department of Health [DH], 2004). As such, physical inactivity is one of the most important lifestyle factors contributing to the high levels of chronic disease and premature mortality witnessed globally. Indeed, the World Health Organization (WHO, 2009) ranks physical inactivity as the fourth leading cause of mortality, ahead of both obesity and dietary factors. Others have reported that low cardio-respiratory fitness, an objective measure of insufficient physical activity, is associated with the largest population level attributable risk for all-cause mortality when compared with other known risk factors such as smoking, obesity and hypertension (Blair, 2009).

It has been estimated that 1.5–3% of national healthcare costs are directly incurred through levels of physical inactivity in industralised countries (Oldridge, 2008). The magnitude of the attributable risk and economic burden associated with physical inactivity are, in part, driven by a high population prevalence; for example, 50–80% of individuals across different regions of the world, including the UK, fail to meet the minimum recommendations for health (Sisson and Katzmarzyk, 2008; NHS Information Centre, 2009; Carlson et al, 2010). This rises to 95% when activity levels are measured objectively (Troiano et al, 2008; NHS Information Centre, 2009). Therefore, physical inactivity can be considered a near universal condition, especially in those with a chronic disease.

Article points

1. Physical inactivity can be considered a near universal condition, especially in those with a chronic disease.
2. Findings from observational and mechanistic studies have been confirmed by numerous clinical intervention studies that have repeatedly demonstrated that exercise training leads to improved glycaemic control in those with type 2 diabetes.
3. To be effective, physical activity interventions need to promote forms of activity that are widely available and acceptable to the target population.

Key words

- Exercise
- Lifestyle
- Obesity
- Type 2 diabetes

Authors' details can be found at the end of the article.

Page points

1. Observational research has consistently demonstrated that physical activity is associated with a reduced risk of diabetes and a reduced risk of mortality and complications in those with diagnosed type 2 diabetes.
2. Findings from observational and mechanistic studies have been confirmed by numerous clinical intervention studies that have repeatedly demonstrated that exercise training leads to improved glycaemic control in those with type 2 diabetes.
3. General physical activity recommendations for health and those specifically aimed at individuals with type 2 diabetes typically recommend engaging in at least 150 minutes per week of moderate- to vigorous-intensity physical activity.

Evidence for physical activity in the management of type 2 diabetes

There is now unequivocal evidence that increased physical activity improves metabolic health, with factors involved in glucose regulation particularly sensitive to its action. The unequivocal nature of the evidence stems from that fact that, somewhat rarely for lifestyle factors, it is supported by the full spectrum of research needed to infer causality, from observational research to experimental mechanistic investigation to randomised controlled trials.

Observational research has consistently demonstrated that physical activity is associated with a reduced risk of diabetes and a reduced risk of mortality and complications in those with diagnosed type 2 diabetes (Church et al, 2004; Bassuk and Manson, 2005; Telford, 2007). For example, it has been shown that there is a strong inverse dose–response relationship between cardio-respiratory fitness and mortality in those with type 2 diabetes; individuals in the lowest quartile of fitness were over four times more likely to die compared with those in the highest quartile (Church et al, 2004).

Mechanistic studies have identified multiple insulin-dependent and independent pathways linking physical activity to glucose utilisation (Ivy et al, 1999; Hawley, 2004; Hawley and Lessard, 2008). For example, exercise training results in acute and long-term changes to insulin action and fuel utilisation through mitochondrial biogenesis, increased fatty acid oxidation, and the increased expression and translocation of key signalling proteins involved in insulin-mediated glucose uptake, particularly glucose transporter type 4 (GLUT-4) (Ivy et al, 1999; Hawley, 2004; Hawley and Lessard, 2008).

Importantly, muscular contractions are also known to induce glucose uptake through mechanisms that are independent of insulin action (Hawley and Lessard, 2008). Finally, findings from observational and mechanistic studies have been confirmed by numerous clinical intervention studies that have repeatedly demonstrated that exercise training leads to improved glycaemic control in those with type 2 diabetes (Boulé et al, 2001; Umpierre et al, 2011).

Amount of exercise required and its clinical impact

General physical activity recommendations for health and those specifically aimed at individuals with type 2 diabetes typically recommend engaging in at least 150 minutes per week of moderate- to vigorous-intensity physical activity (Colberg et al, 2010; DH, 2011). For example, the American Diabetes Association recommends that individuals should perform aerobic exercise of at least moderate intensity in bouts of at least 10 minutes on at least 3 days per week (with no more than 2 consecutive days between bouts) accumulating a total of at least 150 minutes per week (Colberg et al, 2010). Meta-analysis level evidence of exercise training studies have shown that this level of physical activity leads to an absolute reduction in HbA_{1c} level of 0.6–0.7% (6.6–7.7 mmol/mol) – an amount that is comparable with the effect of second-line therapy with non-insulin antidiabetes drugs (Boulé et al, 2001; Umpierre et al, 2011).

The most recent meta-analysis undertook a detailed assessment of factors affecting intervention success to enable a richer interpretation of the results. Interestingly, it was demonstrated that the frequency of exercise sessions and total exercise duration were significantly associated with greater reductions in HbA_{1c} (Umpierre et al, 2011). For example, those undertaking more than 150 minutes per week of structured exercise had a 0.9% (9.9 mmol/mol) absolute reduction in HbA_{1c} level (Umpierre et al, 2011). It was also shown that those with worse glycaemic control at baseline benefited the most, demonstrating that, as with some pharmaceutical agents, those with poor glycaemic control have the most to gain from undertaking physical activity (Umpierre et al, 2011).

Sedentary behaviour: A paradigm shift?

In recent years there has been mounting interest in the role that sitting-related

sedentary behaviour plays in the development of chronic disease and metabolic health, including type 2 diabetes, independent of other lifestyle factors such as physical activity (Katzmarzyk, 2010; Yates et al, 2011). It is now thought that simply sitting less and standing more throughout the day could help reduce the risk of diabetes, regardless of the amount of physical activity undertaken. Observational research, animal models and bed-rest studies all support this hypothesis (Katzmarzyk, 2010). However, there remains an absence of intervention-level evidence in humans for the effect of reducing sitting time and there is consequently a lack of clarity around specific recommendations. Therefore, while the balance of evidence indicates that individuals are likely to benefit from avoiding prolonged periods of sitting throughout the day, it is important that such messages do not supersede or deflect focus from those specifically directed at physical activity.

Physical activity and obesity

Given that it is one of the key determinants of energy expenditure, physical activity is indelibly associated with weight loss. Therefore, interventions aimed at physical activity behaviour change are often judged by the success or failure of resulting weight loss, both within the wider public consciousness and by many healthcare professionals. This is particularly true in type 2 diabetes given the symbiotic link to obesity. However, linking the success of physical activity interventions to weight loss is counterproductive for three important reasons.

First, there is overwhelming evidence, supported by numerous adiposity independent mechanisms (Ivy et al, 1999; Hawley, 2004; Hawley and Lessard, 2008), that increased physical activity promotes metabolic health and improves glycaemic control independent of weight loss. For example, meta-analyses have shown that weight loss did not explain the significant improvements in glycaemic control following exercise intervention (Boulé et al, 2001; Umpierre et al, 2011).

Second, increased physical activity is known to cause an alteration in the distribution of body fat away from regions that are highly metabolically disruptive without effecting overall body weight. For example, exercise training has been shown to reduce the amount of visceral and hepatic adipose tissue without reducing overall weight (Johnson et al, 2009). The amount of fat present in the liver and that stored around key organs has a profoundly deleterious impact on metabolic regulation regardless of overall body fat. Therefore, upon the initiation of increased physical activity, individuals may undergo positive alterations to their fat distribution and metabolic health, but experience no discernable change to their body weight. In the extreme, this is typified by sumo wrestlers who, while training, have normal levels of visceral adiposity and are metabolically healthy despite high levels of total body fat; it is only upon retirement and reduced activity levels that ill health manifests itself (Karelis et al, 2004).

Third, increases in physical activity to levels that are consistent with the minimum physical activity recommendations are unlikely to result in meaningful weight loss. Recent physical activity guidelines have recognised this and have started to advise that around 60 minutes per day of moderate-intensity physical activity is needed to initiate and maintain weight loss (Haskell et al, 2007; Colberg et al, 2010; DH, 2011). This is important, because it means that those attempting physical activity behaviour change are likely to become demotivated and revert to a sedentary lifestyle if the desired end-product of weight loss is not achieved, despite the fact that it will be promoting other, more clinically relevant benefits. Therefore, it is important that the preoccupation of judging physical activity behaviour change with weight loss is challenged and that physical activity is promoted for its own sake.

Translating evidence into practice

Now that the effectiveness of physical activity in the management of type 2

Page points

1. There is overwhelming evidence, supported by numerous adiposity independent mechanisms, that increased physical activity promotes metabolic health and improves glycaemic control independent of weight loss.
2. Increases in physical activity to levels that are consistent with the minimum physical activity recommendations are unlikely to result in meaningful weight loss.
3. Increases in physical activity to levels that are consistent with the minimum physical activity recommendations are unlikely to result in meaningful weight loss.

Page points

1. To be effective, physical activity interventions need to promote forms of activity that are widely available and acceptable to the target population.
2. As with other lifestyle behaviours, physical activity promotion needs to centre on effective self-regulatory strategies such as setting personalised goals, forming action plans and self-monitoring performance.
3. To be effective, it is important that realistic and personalised step-per-day goals are used that take account of current activity levels, as generic goals that are too ambitious can be de-motivating and lead to failure.

diabetes has been clearly established, it is key that physical activity interventions become an integral part of routine self-management programmes. While the format that physical activity interventions should take will depend on the type of self-management programmes available, such as structured education and local resources, there are several fundamental considerations and components that should be universal to all physical activity interventions.

Type of activity promoted

To be effective, physical activity interventions need to promote forms of activity that are widely available and acceptable to the target population. Data from the UK and other developed countries have consistently shown walking to be the preferred choice of physical activity in the general population as well as among those with pre-diabetes and diabetes (Laaksonen et al, 2005; Di Loreto et al, 2003; NHS Information Centre, 2009). Walking is also associated with fewer barriers than other forms of physical activity in black and minority ethnic populations, such as south Asian (Johnson, 2000). Importantly, walking, even at a relatively modest pace of 2.5 mph or higher, is classified as a moderate-intensity activity and can therefore count towards total activity targets when conducted in bouts of at least 10 minutes (Ainsworth et al, 2000). Therefore, physical activity interventions should include a focus on promoting walking activity within daily life. For people who have significant barriers to walking, such as severe joint problems, alternatives such as cycling, swimming and gym-based activities can be encouraged instead.

Table 1. Physical activity categories based on steps per day (adapted from Tudor-Locke and Bassett, 2004).

Category	Steps per day
Sedentary	<5000
Low (typical of daily activity excluding volitional activity)	5000–7499
Moderate (likely to incorporate the equivalent of around 30 minutes per day of moderate intensity physical activity)	7500–9999
High (likely to incorporate the equivalent of around 45 minutes per day of moderate intensity physical activity)	10 000–12 499
Very high (likely to incorporate the equivalent of over 45 minutes per day of moderate intensity physical activity)	>12 500

Self-regulation

As with other lifestyle behaviours, physical activity promotion needs to centre on effective self-regulatory strategies such as setting personalised goals, forming action plans and self-monitoring performance. Given the relevance of walking activity, pedometers (step counters) are a powerful self-regulatory tool in the promotion of physical activity as they raise awareness of current activity levels, provide objective feedback to the wearer and facilitate clear and simple goal setting. Interventions based on pedometer use have been shown to be highly successful at promoting increased physical activity in multiple populations (Bravata et al, 2007; Yates et al, 2009).

To be effective, it is important that realistic and personalised step-per-day goals are used that take account of current activity levels, as generic goals that are too ambitious can be demotivating and lead to failure. This is particularly relevant to those with chronic disease who are likely to start from a lower base than the general population. Sedentary individuals should aim for an average increase in ambulatory activity of around 2000 steps per day, which is roughly equivalent to an additional 150 minutes of moderate walking activity per week (Tudor-Locke and Bassett, 2004); this goal should be broken down into proximal targets, such as an increase of 500 steps every fortnight.

The categories of ambulatory activity shown in *Table 1* can also be used to guide lifestyle interventions. For example, those in the sedentary or inactive categories should initially aim to increase their ambulatory activity by at least 2000 steps per day. Those in the moderate category should be encouraged to try and enter the high category, whereas the small minority

achieving the high or very high categories should be helped to at least maintain their activity levels.

Barriers and contraindications

As well as the common barriers to physical activity reported in the general population, such as lack of time and the weather, those with type 2 diabetes are subject to a wide range of barriers, complications and contraindications that are specific to the condition. However, it should be emphasised that for the vast majority of individuals with type 2 diabetes, physical activity is both achievable and safe (Colberg et al, 2010). For example, even in those with established peripheral neuropathy it has been shown that moderate walking activity combined with foot self-care is not associated with an increase in complications or foot ulcer rates (Lemaster et al, 2008). This is reflected in exercise recommendations for those with type 2 diabetes that state that individuals with peripheral neuropathy, without acute ulceration, may participate in moderate weight-bearing exercise (Colberg et al, 2010).

Hypoglycaemia is another common barrier to physical activity in those with type 2 diabetes. The risk of physical activity induced hypoglycaemia in people with type 2 diabetes who are not using insulin or insulin secretagogues is minimal, especially during moderate-intensity activity (Colberg et al, 2010). For those taking insulin or insulin secretagogues, hypoglycaemia is a real concern; however, it should not prevent participation in physical activity as long as preventative action is taken. For example, up to 15 g of carbohydrate should be consumed prior to physical activity if blood glucose levels are <5.5 mmol/L and 5–30 g of carbohydrate consumed during and within 30 minutes of vigorous-intensity exhaustive exercise will help replete muscle glycogen stores and lower the risk of hypoglycaemia (Colberg et al, 2010). Recent recommendations for exercise in type 2 diabetes provide greater detail of the consideration for those with other long-term complications (Colberg et al, 2010).

Conclusion

Physical activity has been shown to improve glycaemic control to levels that are comparable to pharmaceutical intervention and should be a fundamental component in the arsenal of therapeutic interventions used in the management of type 2 diabetes. ■

Authors' details

Thomas Yates is Senior Researcher, Department of Cardiovascular Sciences; Kamlesh Khunti, is Professor of Primary Care Diabetes and Vascular Medicine, Department of Health Sciences; and Melanie Davies is Professor of Diabetes Medicine, Department of Cardiovascular Sciences, University of Leicester, Leicester.

"Physical activity has been shown to improve glycaemic control to levels that are comparable to pharmaceutical intervention and should be a fundamental component in the arsenal of therapeutic interventions used in the management of type 2 diabetes."

Ainsworth BE, Haskell WL, Whitt MC et al (2000) Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* **32**(Suppl 9): S498–504

Bassuk SS, Manson JE (2005) Epidemiological evidence for the role of physical activity in reducing risk of type 2 diabetes and cardiovascular disease. *J Appl Physiol* **99**: 1193–1204

Blair SN (2009) Physical inactivity: the biggest public health problem of the 21st century. *Br J Sports Med* **43**: 1–2

Boulé NG, Haddad E, Kenny GP et al (2001) Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: a meta-analysis of controlled clinical trials. *JAMA* **286**: 1218–27

Bravata DM, Smith-Spangler C, Sundaram V et al (2007) Using pedometers to increase physical activity and improve health: a systematic review. *JAMA* **298**: 2296–304

Carlson SA, Fulton JE, Schoenborn CA, Loustalot F (2010) Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. *Am J Prev Med* **39**: 305–13

Church TS, Cheng YJ, Earnest CP et al (2004) Exercise capacity and body composition as predictors of mortality among men with diabetes. *Diabetes Care* **27**: 83–8

Colberg SR, Sigal RJ, Fernhall B et al (2010) Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. *Diabetes Care* **33**: e147–67

Department of Health (2004) *At Least Five a Week: Evidence on the Impact of Physical Activity and its Relationship to Health.* DH, London. Available at: http://bit.ly/r14ZGx (accessed 28.09.11)

Department of Health (2011) *Start Active, Stay Active: A Report on Physical Activity from the Four Home Countries' Chief Medical Officers.* DH, London. Available at: http://bit.ly/qeeAwC (accessed 28.09.11)

Di Loreto C, Fanelli C, Lucidi P (2003) Validation of a counseling strategy to promote the adoption and the maintenance of physical activity by type 2 diabetic subjects. *Diabetes Care* **26**: 404–8

Haskell WL, Lee IM, Pate RR et al (2007) Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* **39**: 1423–34

Hawley JA (2004) Exercise as a therapeutic intervention for the prevention and treatment of insulin resistance. *Diabetes Metab Res Rev* **20**: 383–93

Hawley JA, Lessard SJ (2008) Exercise training-induced improvements in insulin action. *Acta Physiol (Oxf)* **192**: 127–35

Ivy JL, Zderic TW, Fogt DL (1999) Prevention and treatment of non-insulin-dependent diabetes mellitus. *Exerc Sport Sci Rev* **27**: 1–35

Johnson M (2000) Perceptions of barriers to healthy physical activity among Asian communities. *Sport, Education and Society* **5**: 51–70

Johnson NA, Sachinwalla T, Walton DW et al (2009) Aerobic exercise training reduces hepatic and visceral lipids in obese individuals without weight loss. *Hepatology* **50**: 1105–12

Karelis AD, St-Pierre DH, Conus F et al (2004) Metabolic and body composition factors in subgroups of obesity: what do we know? *J Clin Endocrinol Metab* **89**: 2569–75

Katzmarzyk PT (2010) Physical activity, sedentary behavior, and health: paradigm paralysis or paradigm shift? *Diabetes* **59**: 2717–25

Laaksonen DE, Lindström J, Lakka TA et al (2005) Physical activity in the prevention of type 2 diabetes: the Finnish diabetes prevention study. *Diabetes* **54**: 158–65

Lemaster JW, Mueller MJ, Reiber GE (2008) Effect of weight-bearing activity on foot ulcer incidence in people with diabetic peripheral neuropathy: feet first randomized controlled trial. *Phys Ther* **88**: 1385–98

NHS Information Centre (2009) *Health Survey for England—2008: Physical Activity and Fitness.* NHS Information Centre, London. Available at: http://bit.ly/ppHYGJ (accessed 28.09.11)

Oldridge NB (2008) Economic burden of physical inactivity: healthcare costs associated with cardiovascular disease. *Eur J Cardiovasc Prev Rehabil* **15**: 130–9

Sisson SB, Katzmarzyk PT (2008) International prevalence of physical activity in youth and adults. *Obes Rev* **9**: 606–14

Telford RD (2007) Low physical activity and obesity: causes of chronic disease or simply predictors? *Med Sci Sports Exerc* **39**: 1233–40

Troiano RP, Berrigan D, Dodd KW et al (2008) Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* **40**: 181–8

Tudor-Locke C, Bassett DR Jr (2004) How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med* **34**: 1–8

Umpierre D, Ribeiro PA, Kramer CK et al (2011) Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: a systematic review and meta-analysis. *JAMA* **305**: 1790–9

World Health Organization (2009) *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risk Factors.* World Health Organization, Geneva. Available at: http://bit.ly/qV0shC (accessed 28.09.11)

Yates T, Davies M, Gorely T et al (2009) Effectiveness of a pragmatic education program designed to promote walking activity in individuals with impaired glucose tolerance: a randomized controlled trial. *Diabetes Care* **32**: 1404–10

Yates T, Wilmot EG, Khunti K et al (2011) Stand up for your health: Is it time to rethink the physical activity paradigm? *Diabetes Res Clin Pract* **93**: 292–4

Reader survey

Let us know what you think – we value your feedback

Visit http://svy.mk/DPCsurvey to complete the survey online or turn to page 266.