Role of physical activity in the management of obesity and type 2 diabetes

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Article points

1. This article focuses on elucidating the role of physical activity in the treatment of type 2 diabetes, the interplay with obesity, and lessons learnt from recent large intervention trials.
2. It is clear that the promotion of physical activity significantly improves metabolic health in the absence of weight loss, even in the presence of obesity.
3. Lifestyle interventions should form a cornerstone of diabetes management pathways and should incorporate a holistic approach with physical activity at its core.

Key words

- Exercise
- Metabolic health
- Pedometer
- Walking

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Physical activity and weight loss are considered cornerstones in the management of type 2 diabetes. However, the interaction between these factors and their relative importance in the treatment of type 2 diabetes are often misunderstood. This article looks at the independent role of physical activity in the treatment of type 2 diabetes, its interplay with obesity and lessons learnt from recent interventions.

The high levels of physical inactivity and obesity associated with modern industrialised environments are the two leading causes of the type 2 diabetes (T2D) epidemic witnessed over recent decades. More generally, the World Health Organization (WHO) estimates that physical inactivity and obesity are the fourth and fifth leading causes of premature mortality, respectively (WHO, 2009).

Through increased risk of T2D and other chronic diseases, both physical inactivity and obesity exert a staggering economic burden on healthcare systems and economic productivity; the direct and indirect cost of physical inactivity and obesity on healthcare expenditure and the economy in England have been estimated at between £8 billion and £16 billion annually for each condition (Department of Health [DH], 2004; Foresight, 2007).

This article focuses on elucidating the role of physical activity in the treatment of T2D, the interplay with obesity, and lessons learnt from recent large intervention trials.

Physical activity and diabetes: Clinical benefits

There is now unequivocal evidence that physical activity is directly involved in the processes governing glucose regulation. Indeed, somewhat rarely for lifestyle factors, evidence for a causal link between physical activity and the prevention and treatment of T2D is supported by the full spectrum of methodology needed to infer causality, from observational research, to experimental mechanistic investigation to randomised controlled trials (RCTs).

For example, mechanistic studies have identified multiple pathways linking physical activity to improved glucose transport (Ivy et al, 1999; Hawley, 2004; Hawley and Lessard, 2008). With increased physical activity, acute and long-term changes in insulin action and fuel utilisation occur through mitochondrial biogenesis, increased fatty acid oxidation and increased expression and translocation of key signalling proteins involved in the insulin-mediated glucose uptake pathway,

particularly glucose transporter type-4 (Ivy et al, 1999; Hawley, 2004). Interestingly, muscular contractions are also known to induce glucose update through insulin-independent pathways, which are likely to involve the upregulation of adenosine monophosphate-activated kinase (Hawley and Lessard, 2008).

RCTs and meta-analyses have demonstrated that physical activity interventions result in improved blood glucose regulation and a reduced risk of T2D in high-risk individuals, and improved glycaemic control in those with established diabetes (Boulé et al, 2001; Gillies et al, 2007; Umpierre et al, 2011). For example, meta-analyses of exercise training studies have demonstrated an absolute reduction in HbA_{1c} level of 6.6–7.7 mmol/mol (0.6–0.7 percentage points), an amount that is comparable to the effect of second-line therapy with non-insulin antidiabetes drugs (Boulé et al, 2001; Umpierre et al, 2011).

To achieve sustained and meaningful clinical benefits, those with T2D should aim to 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 two consecutive days between bouts), accumulating a total of at least 150 minutes per week (Colberg et al, 2010). It is widely acknowledged that this is the minimal level needed to improve health in a meaningful and sustained manner and that higher levels will result in greater benefit. For example, a recent meta-analysis demonstrated that those undertaking more than 150 minutes per week of structured exercise were found to have a 9.8 mmol/mol (0.9 percentage point) absolute reduction in HbA_{1c} level (Umpierre et al, 2011).

One of the central benefits of using physical activity in the treatment of T2D is the so called "halo effect", the phenomenon whereby a treatment has many additional positive effects over and above simply treating the primary defect characterising the condition – in this case, poor glycaemic control. Physical inactivity is known to be associated with many chronic conditions (*Table 1*) and directly targets many of the most serious comorbidities associated with T2D, such as cardiovascular (CV) mortality and depression (Colberg et al, 2010). For example, individuals with T2D who reported walking for at least 2 hours per week were found to have a 34% lower CV mortality rate, the primary cause of reduced life-expectancy in this group, compared with those who reported no walking (Hu et al, 2001).

As well as numerous physiological benefits, increased physical activity has also reduced symptoms of depression (Barbour et al; 2007; Bize et al, 2007), a common comorbidity affecting around one quarter of individuals with T2D (Anderson et al, 2001). Indeed, evidence suggests that achieving the current physical activity recommendations in

Table 1. Evidence for the effect of physical activity in the prevention and management of common chronic conditions.

Disease/condition	Preventative effect	Dose–response	Therapeutic effect
Cardiovascular disease (including coronary heart disease and stroke)	++	++	++
Type 2 diabetes	++	++	++
Metabolic syndrome	++	++	++
Obesity	++	++	+
Osteoarthritis			++
Osteoporosis	++		+
Colon cancer	++	++	
Breast cancer	++	++	
Depression	++		+

Data adapted from Department of Health (2004; 2011) and updated to include Umpierre et al (2011).
++ = strong evidence; + = moderate evidence.

Page points

1. Randomised controlled trials and meta-analyses have demonstrated that physical activity interventions result in improved glucose regulation and a reduced risk of type 2 diabetes (T2D) in high-risk individuals, and improved glycaemic control in those with established diabetes.
2. To achieve sustained and meaningful clinical benefits, those with T2D should aim to 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 two consecutive days between bouts), accumulating a total of at least 150 minutes per week.
3. One of the central benefits of using physical activity in the treatment of T2D is the so called "halo effect", the phenomenon whereby a treatment has many additional positive effects over and above simply treating the primary defect characterising the condition – in this case, poor glycaemic control.

Page points

1. There is overwhelming evidence, supported by numerous adiposity independent mechanisms (specific mechanisms highlighted in the above section), that increased physical activity promotes metabolic health and improves glycaemic control independent of weight loss.
2. In those with established type 2 diabetes, observational-level evidence has demonstrated that the risk of all-cause mortality is four-times greater in those in the bottom quartile of cardiorespiratory fitness compared with those in the highest quartile, even after adjustment for adiposity.
3. Meta-analysis-level evidence has consistently demonstrated that weight loss did not explain observed improvements in glycaemic control following an exercise intervention.
4. Recent physical activity recommendations advise that around 60 minutes per day of moderate-intensity physical activity is needed to initiate and maintain weight loss.

sedentary individuals is as effective as antidepressant medication at treating mild to moderate depression (Dunn et al, 2005).

Physical activity and obesity

Overweight and obesity are ubiquitous with T2D and metabolic dysfunction. It has been shown that 60–90% of all people with T2D are, or have been, obese (Halpern and Mancini, 2005; Stumvoll et al, 2005), and the relative risk of developing T2D has been shown to increase by 4.5–9% for every additional kilogram of weight gain (Ford et al, 1997).

These startling figures have led to the suggestion that T2D should be redefined as "diabesity" (Astrup and Finer, 2000). Therefore, T2D is predominately linked to obesity in the wider public and healthcare professional discourse, despite the importance of other lifestyle factors, not least physical activity. This is not without foundation, as weight loss – which provides a readily definable and measurable construct – is known to substantially improve glycaemic control and metabolic health in those with a high risk of T2D. However, it overlooks the fact that, by definition, those with obesity are also likely to engage in deleterious lifestyle practices, which in themselves may be driving some of the risk, rather than just body fat per se (Telford, 2007). Therefore, weight loss is not the only, or indeed most important, outcome of lifestyle interventions. This idea can be usefully explored when considering physical activity.

There is overwhelming evidence, supported by numerous adiposity independent mechanisms (specific mechanisms highlighted in the above section), that increased physical activity promotes metabolic health and improves glycaemic control independent of weight loss (Telford, 2007). For example, an intervention study in overweight and obese individuals at high risk of T2D demonstrated substantial improvements in glucose regulation following an exercise intervention despite no significant change to body weight or waist circumference (Yates et al, 2009; Yates et al, 2011). Similarly, the Indian Diabetes Prevention Program reported significant reductions in the relative risk of T2D following a lifestyle intervention, largely focused on the promotion of physical activity, despite no change to body weight (Ramachandran et al, 2006).

In those with established T2D, observational-level evidence has demonstrated that the risk of all-cause mortality is four-times greater in those in the bottom quartile of cardiorespiratory fitness compared with those in the highest quartile, even after adjustment for adiposity (Church et al, 2004). Meta-analysis-level evidence has consistently demonstrated that weight loss did not explain observed improvements in glycaemic control following an exercise intervention (Boulé et al, 2001; Umpierre et al, 2011).

Therefore, it is clear that the promotion of physical activity significantly improves metabolic health in the absence of weight loss, even in the presence of obesity. However, given that physical activity forms an instantly modifiable determinant of energy expenditure, interventions are often judged by their effect on body fat. Not only does this ignore the wider health benefits of increased physical activity, it is also counter-productive for several other important reasons.

First, when considering the interplay between these factors, it is well established that achieving levels of physical activity that are consistent with the minimum recommendations for health is unlikely to result in meaningful weight loss. Recent physical activity recommendations advise that around 60 minutes per day of moderate-intensity physical activity is needed to initiate and maintain weight loss (WHO, 2010; DH, 2011). This means that those attempting physical activity behaviour change as a method of losing weight are likely to become demotivated and revert to a sedentary lifestyle if their desired end-product is not achieved, despite gaining other, more clinically relevant health benefits such as improved glycaemic control.

Second, increased physical activity is also known to alter the distribution of body fat without affecting overall body weight. For example, exercise training has been shown to reduce visceral and hepatic adipose tissue without impacting overall weight (Johnson et al, 2009). High levels of visceral and hepatic adipose tissue have a profoundly deleterious impact on metabolic regulation regardless of overall body fat. Therefore, upon initiation of increased physical activity, individuals may undergo positive alterations to their fat distribution and metabolic health, but experience no discernible change to their body weight.

The historic preoccupation of judging lifestyle interventions aimed at the management of T2D solely by the effects on body weight need to challenged, both among healthcare professionals and the general public, in order for physical activity to be used to its full potential. This message will often find resonance with those who have tried and failed to lose weight on numerous occasions. Shifting the emphasis away from body image to a positive message of embracing a healthy lifestyle for its own sake is often met with enthusiasm and relief.

This should not be taken to imply that weight loss is not an important aspect of diabetes prevention and treatment, because it is. Rather, it should not be the primary or singular focus of lifestyle interventions, but should be incorporated into a holistic approach and failure should not automatically be assumed if weight loss is not achieved.

Recent trials: What can we learn?

Over the past decade there have been several large RCTs of lifestyle interventions in those with T2D that hint at the scale of potential benefits gained from using physical activity and lifestyle in the treatment of T2D, as well as some of the challenges faced.

In the UK, the recent Early ACTID (Early Activity in Diabetes) study demonstrated that regular dietary interventions at 3-monthly intervals produced modest improvements in glycaemic control with limited or no benefit to other measures of cardiovascular health (Andrews et al, 2011). There was no additional benefit of adding physical activity counselling to the dietary intervention. However, this was hardly surprising given that the intervention only increased activity levels by 5 minutes per day compared with the diet-only or control group, which is far below the amount needed to improve health. Therefore, this study should be viewed as failing to elicit physical activity behaviour change, rather than a failure of physical activity to provide an additive effect over and above diet and weight loss. This study is consistent with previous interventions that have demonstrated that traditional motivational interviewing is an ineffective strategy for promoting sustained increases in physical activity in a healthcare or community setting within the UK and points to the scale of the challenge involved in promoting long-term physical activity behaviour change in clinical populations and the need for other novel approaches (Yates et al, 2008).

For example, a recent study in those with prediabetes demonstrated that an interactive group-based intervention aimed at promoting increased physical activity was highly effective at promoting improved glycaemic control over the longer-term, despite no change to body weight or waist circumference (Yates et al, 2009; 2011).

In contrast to Early-ACTID, the seminal Look-AHEAD (Action for Health in Diabetes) trial from the USA, involving over 5000 overweight and obese individuals with T2D, found that an intensive lifestyle intervention, largely modelled on the well-established Diabetes Prevention Program model, incorporating both physical activity and diet, was highly effective at promoting increased cardiorespiratory fitness (resulting from increased physical activity), reduced body weight, reduced cardiovascular risk, improved glycaemic control and reduced medication usage (Look AHEAD Research Group et al, 2007; Redmon et al, 2010). Encouragingly, these results were sustained over the longer-term at 4 years (Look AHEAD Research Group and Wing, 2010). However, while this study demonstrates the power of lifestyle change in the management of T2D, it is likely to have limited clinical application because of the intensive nature of the intervention, which involved over 40 patient contacts in the first year and then monthly contacts thereafter. Therefore, pragmatic interventions that are specifically designed for usual healthcare settings need to continue to be developed and evaluated. Finally, of relevance to this article, the authors also conducted a baseline analysis assessing the independent association of fitness and fatness with measures of glycaemic control and CV health. Interestingly, when both factors were entered into a regression model simultaneously, only fitness was significantly associated with glycaemic control and CV risk (Wing et al, 2007).

In Italy, Di Loreto et al (2003) demonstrated that a physician-led lifestyle intervention, focused on increased physical activity through a programme underpinned by a detailed theoretical approach to behaviour change, was highly successful at promoting increased physical activity and improved

Page points

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2. A recent study in those with prediabetes demonstrated that an interactive group-based intervention aimed at promoting increased physical activity was highly effective at promoting improved glycaemic control over the longer-term, despite no change to body weight or waist circumference.
3. The Look-AHEAD (Action for Health in Diabetes) study demonstrated that if delivered with the right level of support, intensive lifestyle interventions can be used to promote long-term behaviour change and improved health.

Page points

1. Given the added barriers in those with established type 2 diabetes, it is important to recognise that changing physical activity levels is likely to require substantial effort on the part of the individual and will only be achieved through a rigorous evidence-based framework; simply providing brief advice and informing individuals that they should be more active – as is the case in many healthcare consultations – is ineffectual.
2. 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 prediabetes and diabetes.
3. 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.

glycaemic control over a 2-year period. Subsequent analysis found that the intervention was associated with a reduction in medical and social costs with a total saving of $855 (£539) per annum per person. Even after allowing for the cost of the intervention, this rose to $2000 (£1261) in those who achieved the greatest increases in physical activity (Di Loreto et al, 2005). This study demonstrates the huge cost savings that can be produced when physical activity is successfully incorporated into treatment pathways. This intervention was much more pragmatic and less intensive in nature than LookAHEAD and provides encouraging evidence for the feasibility and cost-effectiveness of integrating a rigorously designed lifestyle intervention as part of usual care in the treatment of T2D.

Translating evidence into practice – get your patients walking

In today's modern environments, multiple factors act to discourage healthy levels of physical activity. Given the added barriers in those with established T2D, it is important to recognise that changing physical activity levels is likely to require substantial effort on the part of the individual and will only be achieved through a rigorous evidence-based framework; simply providing brief advice and informing individuals that they should be more active – as is the case in many healthcare consultations – is ineffectual.

As a starting point, 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 prediabetes and diabetes (Di Loreto et al, 2003; Laaksonen et al, 2005; NHS Information Centre, 2009). 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, walking should form the mainstay of physical activity intervention. For individuals who have significant barriers to walking, such as severe joint problems, alternatives such as cycling, swimming, and gym-based activities should be encouraged instead.

Effective interventions in those with a high risk of, or diagnosed with, T2D have centred on combining traditional motivational approaches with robust and integrated 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, including those with T2D (Bravata et al, 2007). To be effective, it is essential 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

Table 2. 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

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), the minimum recommendations for health in sedentary individuals (DH, 2011). This distal goal should be broken down into proximal targets, such staggered increases of 200 steps per day every fortnight.

Developed categories of ambulatory activity shown in *Table 2* 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.

Conclusion

Lifestyle interventions should form a cornerstone of diabetes management pathways and should incorporate a holistic approach with physical activity at its core. Lifestyle interventions should not be judged by their effect on body weight, even in the obese, but by their effect on the overall health status of the individual. ■

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