SEDENTARY BEHAVIOUR: A NEW TARGET IN THE PREVENTION AND MANAGEMENT OF DIABETES?

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Disclosure: The authors have declared no conflicts of interest.
Received: 27.06.16 **Accepted:** 18.10.16
Citation: EMJ. 2016;1[4]:12-17.

INTRODUCTION

Since the early 2000s, an increasing number of studies have focussed on the adverse health effects of sitting. Sitting, together with other activities characterised by a low energy expenditure while being in a sitting or reclining position, such as watching television (TV) or using the computer, are denoted as sedentary behaviour.[1] It has been shown that adults spend up to 60% of their waking hours in sedentary positions.[2] Large amounts of sedentary behaviour have been associated with unfavourable levels of cholesterol and triacylglycerol,[3-5] markers of insulin resistance,[3,5,6] and metabolic syndrome.[4,7-9] Interestingly, these associations have been demonstrated to be independent of moderate-to-vigorous physical activity. Notably, it may be possible that high levels of daily physical activity attenuate or reduce the adverse effects of sitting on metabolic outcomes. However to date, such effects of high levels of physical activity have only been demonstrated for the increased mortality risks associated with high total sitting time.[10]

In contrast to physical activity, sedentary behaviour is currently not incorporated in the prevention and management strategies of Type 2 diabetes mellitus (T2DM). Since sedentary behaviour has consistently been associated with risk factors for T2DM and the majority of adults spend most of the day being sedentary,[2,11] it could be argued that this behaviour may also be relevant for the prevention and treatment of the disease. This paper therefore provides an overview of the current sedentary behaviour literature in order to provide insight into its importance in the prevention and management of T2DM. First, we discuss the possibilities and issues of the measurement of sedentary behaviour, then the evidence linking sedentary behaviour to T2DM will be provided, as well as the underlying biological mechanisms. Finally, we consider directions for future research and implications for public health and clinical practice.

SEDENTARY BEHAVIOUR MEASUREMENT: ACCELEROMETRY

The measurement of sedentary behaviour has usually been based on self-reporting methods, such as questionnaires (self-administered or interviewer-administered), diaries, and short-term recalls. Questionnaires that focus on a specific domain, for example leisure time, or a specific type of sedentary behaviour, for example watching TV, have most often been used. Although TV viewing time can be seen as a significant part of the total daily sedentary time,[12] it is not entirely representative; other types of sedentary behaviour, for example using the computer or travelling by car, bus, or train, should also be taken into account. Also, specific domains cannot account for the whole day. Furthermore, self-reporting methods are limited due to issues of recall and reporting bias.[13,14] Nevertheless, TV viewing has shown to be strongly and consistently associated with several adverse outcomes, including metabolic syndrome,[9,15-17] T2DM,[18,19] cardiovascular disease,[18-20] and premature mortality.[18,19,21]

During the late 2000s, accelerometry was introduced within observational studies on physical

activity and sedentary behaviour. This provided researchers with a measurement tool able to overcome the limitations of self-reporting methods. Accelerometers are small, lightweight, portable devices that provide information on the frequency, duration, and intensity of activity of an individual.[13,14] The ActiGraph accelerometer (ActiGraph, Fort Walton Beach, Florida, USA) is a commonly used device usually worn on the waist or hip during waking hours for the duration of 1 week. The device measures motion (acceleration) in three directions: vertical (up-and-down), anteroposterior (back-to-front), and mediolateral (side-to-side). Usually, acceleration data of the vertical direction are used to determine activity levels by converting the raw acceleration data into 'counts'. These counts are summed for a specific time period, usually a minute, and these counts per minute (cpm) are then used to classify activity; the more cpm, the higher the activity intensity. For each type of activity, ranging from sedentary behaviour to high intensity physical activity, specific value ranges have been determined. Since sedentary behaviour is characterised by low intensity levels, <100 cpm is usually used to identify sedentary time.[22] In contrast, moderate-to-vigorous physical activity, such as running, is characterised by high intensity activity levels and identified when ≥2,020 cpm are recorded.[23]

The cut-off point of <100 cpm to identify sedentary time has been widely used, however classification of sedentary time based on acceleration (activity counts) only could easily result in misclassification. For example, when standing still activity counts are low, which will also be seen when sedentary. Thus when activity counts are low (e.g. <100 cpm), the actual behaviour executed could be standing still, but could also be sedentary time. The validity of a cut-off point of <100 cpm to classify sedentary time is thus limited when only acceleration data are used.[24,25] To obtain more accurate estimations of sedentary behaviour, posture-based data should be used. The activPAL™ physical activity monitor (PAL Technologies, Glasgow, UK) is an accelerometer that measures both acceleration and posture and is usually attached directly to the skin on the front of the thigh. Therefore, it can accurately detect a sedentary (sitting/lying) posture (horizontal thigh) versus an upright posture (vertical thigh). The assessment of sedentary time using this technology has indeed been shown to be more accurate than the assessment of sedentary time based only on low activity counts.[25,26] Furthermore, due to the small dimensions of the activPAL and the possibility of a waterproof attachment, a complete assessment of all daily activity, 24 hours per day on multiple days, is feasible.

As well as the total amount of sedentary time per day, accelerometers can be used to assess other constructs of sedentary behaviour such as sedentary behaviour patterns, i.e. how sedentary time is accumulated, for example, multiple short sedentary periods versus one prolonged period. The parameters used to quantify these patterns are sedentary breaks, sedentary bouts, and average sedentary bout duration (Figure 1). A sedentary break is an interruption of sedentary time, representing the transition from a sedentary to an upright position. A sedentary bout is a continuous sedentary period without interruption, which can have any duration. The average sedentary bout duration is calculated by dividing total sedentary time by the total number of sedentary bouts. In addition, accelerometry can be used to study patterns of sedentary behaviour over time, i.e. through the course of the day, during the week (weekdays versus weekend days), or over a year (seasonal variation).

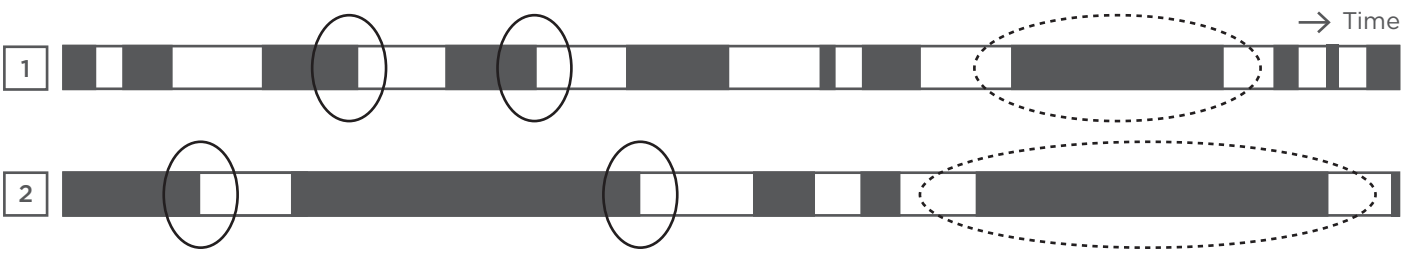

Figure 1: Two examples of sedentary behaviour patterns.
Dark bars indicate sedentary time; light bars indicate non-sedentary time. Solid lines represent sedentary breaks (interruptions of sedentary time); dashed lines represent sedentary bouts (uninterrupted periods of sedentary time).

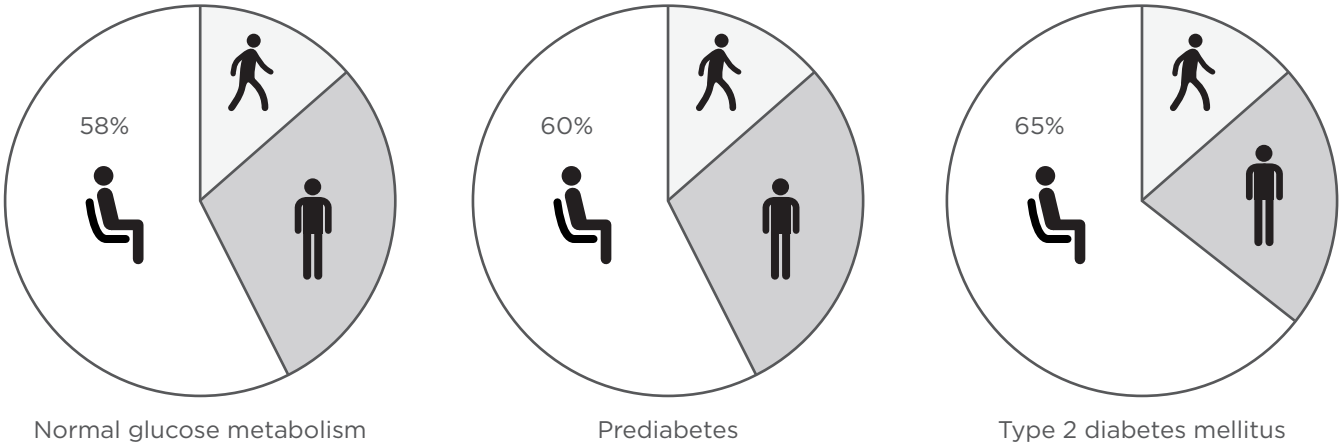

Figure 2: Distribution of waking time spent sedentary, standing, and stepping, according to glucose metabolism status.

SEDENTARY BEHAVIOUR AND TYPE 2 DIABETES MELLITUS

The first study to link sedentary time to diabetes was conducted by Hu et al.[27] in 2001. Within the study, sedentary time (reflected by self-reported TV viewing time) was associated with an increased risk of T2DM. Many other studies using self-reported measures have been published since. These studies have consistently demonstrated an unfavourable association between the amount of sedentary time and T2DM. A meta-analysis that included nine studies using self-reported measures and one study using accelerometry to assess sedentary time demonstrated that larger amounts of time spent sedentary increased the odds of developing metabolic syndrome by 73%.[9] Another meta-analysis showed that sedentary time was associated with a hazard ratio of 1.91 for incident diabetes.[28] In these studies, the role of diet was not incorporated, although high amounts of TV viewing and dietary intake often coexist. However, a recently published study in adolescents did not demonstrate that dietary intake mediated the association between TV viewing and BMI.[29] In contrast, sugar-sweetened beverages and fruit and vegetable intake showed partial mediation effects in conjunction with the TV viewing and metabolic syndrome relationship observed within that study.[29]

Studies using accelerometry to assess sedentary time are scarce. Two studies have used Actigraph[6] and Actiheart®[8] to assess time spent sedentary in British participants with newly diagnosed T2DM (N=528 and N=394, respectively). The studies demonstrated that larger amounts of sedentary time were associated with adverse metabolic outcomes, including waist circumference, high-density lipoprotein (HDL)-cholesterol level, and the level of triacylglycerol.[6,8] Having more sedentary breaks (i.e. more interruptions of sedentary time) was associated with a smaller waist circumference.[6] To our knowledge, only one study has examined the association between posture-based measured sedentary behaviour and T2DM.[30] In our study, we examined both the amount and pattern of sedentary behaviour in 2,497 adults with a normal glucose metabolism, with prediabetes, and with T2DM. We demonstrated that participants with T2DM spent on average 9.7 hours per day in sedentary positions compared to the 9.3 hours of the participants with a normal glucose metabolism and 9.4 hours of participants with prediabetes. This showed that participants with T2DM were sedentary for 65% of their waking time, compared with 58% in participants with a normal glucose metabolism, and 60% in participants with prediabetes (Figure 2). Furthermore, each extra hour of sedentary time was associated with a 22% increased likelihood of T2DM development. The sedentary behaviour pattern was not associated with T2DM or prediabetes, but an association was seen with the diagnosis of metabolic syndrome.

Since sedentary time has been unfavourably associated with risk factors for T2DM and with T2DM itself, studies have started to focus on the effects of reducing sedentary time periods. Reducing sedentary time during waking hours inevitably results in larger amounts of non-sedentary time, which can vary from light physical activity (standing) to vigorous physical

activity (running). The effect of reducing sedentary time may therefore depend on the activity with which it is replaced. Such effects can be examined theoretically using an isotemporal substitution model.[31] To date, two studies have demonstrated, in almost 800 British and Australian participants with newly diagnosed T2DM, that reallocating sedentary time to either light or moderate-to-vigorous intensity activity was associated with reductions in waist circumference and BMI, but not with HDL-cholesterol and glucose levels.[32,33] A few other studies were conducted in non-diabetic, adult populations from the USA (N=923),[34] the UK (N=508),[35] and Australia (N=698),[36] respectively. The studies demonstrated associations with improved markers of insulin sensitivity,[34,35] and improved levels of glucose,[34-36] triacylglycerol,[34,36] and cholesterol.[34-36] In addition, a meta-analysis including 16 experimental studies has provided evidence that breaking up sedentary time by replacing it with light-intensity physical activity has a positive effect on metabolic parameters, including levels of glucose, triglycerides, cholesterol, and insulin.[37] No data have as yet been published on the reallocation effects of sedentary time on cardio-metabolic outcomes, metabolic syndrome, or T2DM in a large sample of adults.

As reducing sedentary time is associated with favourable metabolic health outcomes, the research focus is also on effective strategies to achieve these reductions. A recently published review by Gardner et al.[38] stated that self-monitoring and problem solving were promising techniques and should be used in the development of interventions to reduce sedentary time. Furthermore, sit-to-stand workstations could be used, as it has been shown that such workstations can achieve reductions in sedentary time.[39,40]

BIOLOGICAL MECHANISMS

Due to the relatively recent interest in sedentary behaviour as a risk factor for T2DM and other health outcomes, mechanisms that could explain how sedentary behaviour affects health are largely unknown. Bed rest studies have been used as models to examine the harmful effects of inactivity. Although these models do not accurately reflect daily patterns of sedentary behaviour, such studies do provide leads regarding physiological mechanisms of inactivity. A possible mechanism may be a reduction of lipoprotein lipase due to inactivity of muscle cells, which has been seen in animal studies.[41,42] Since lipoprotein lipase is an essential enzyme that contributes to the metabolism and transport of lipids, it can be hypothesised that a change in activity of this enzyme has a variety of effects on metabolism. Reductions in lipid phosphate phosphatase-1 (LPP1) and decreased adenosine monophosphate-activated protein kinase (AMPK) activity due to inactive muscle cells may also be underlying mechanisms, as both are involved in glucose metabolism.[41] Other possible mechanisms may be changes in vascular function due to the absence of muscular contractions, and increased blood flow. For example, it has been suggested that sedentary behaviour causes low mean shear stress within the vasculature, which may affect endothelial function.[43] In addition, sedentary behaviour may influence the activity of the renin-angiotensin system, which regulates blood pressure and extracellular fluid volume.[44] Lastly, it has been suggested that low-grade inflammation is a pathway through which sedentary behaviour could unfavourably affect health.[45,46] Clearly, physiological studies are warranted to unravel the mechanisms and pathways through which sedentary behaviour affects health.

FUTURE RESEARCH DIRECTIONS

As mentioned earlier, mechanisms and pathways underlying the harmful effects of sedentary behaviour are largely unknown, so there is a need for further physiological studies. In addition, the number of studies that have examined the associations of objectively measured sedentary behaviour with T2DM incidence is limited. Studies using posture-based data in participants with T2DM are thus warranted. These should include longitudinal, dose-response, and intervention studies. Longitudinal studies in which both sedentary behaviour and glucose metabolism status are repeatedly measured over time can provide insight into the temporality of the association. Dose-response studies are needed to obtain insight into the amount of sedentary time that is harmful. Subsequently, intervention studies can provide data on the effectiveness and feasibility of reducing sedentary time with light, moderate, or vigorous activity. Ideally, these studies will also assess information on the type of activity (for example watching TV or doing desk work), the social aspect (with whom), and environmental context (for example, leisure, work, or transportation) as this helps in understanding the nature of sedentary behaviour better.

IMPLICATIONS FOR PUBLIC HEALTH AND CLINICAL PRACTICE

A number of studies have consistently shown that large amounts of sedentary time are associated with several risk factors for T2DM.[3-9] Furthermore, sedentary time has been associated with T2DM itself.[30] Therefore, consideration should be given to developing strategies that reduce the amount of sedentary behaviour in diabetes prevention and management programmes. These strategies should be an addition to those of physical activity as undoubtedly, physical activity is an important factor in the prevention and management of T2DM. Nevertheless, a growing body of evidence shows that sedentary behaviour is a relevant risk factor for health. In addition, sedentary behaviour is highly prevalent on both an inter and intra-individual level, as the majority of individuals have been shown to spend on average more than half of the waking day in sedentary positions.[2] Recommendations regarding sedentary behaviour are thus important in preventing a highly sedentary lifestyle and its adverse effects on health.

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