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Review

Reducing Sitting Time in Type 1 Diabetes: Considerations and Implications

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Key Messages

- Interventions targeting prolonged sitting time in individuals with type 2 diabetes improve glucose management and reduce complication risks.
- We discuss the potential applications of such a strategy in people living with type 1 diabetes.

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A B S T R A C T

Sedentary behaviours are ubiquitous in modern society, with Western populations spending approximately 50% of their waking hours in low levels of energy expenditure. This behaviour is associated with cardiometabolic derangements and increased morbidity and mortality. In individuals living with or at risk of developing type 2 diabetes (T2D), "breaking up" sedentariness by interrupting prolonged periods of sitting has been shown to acutely improve glucose management and cardiometabolic risk factors related to diabetes complications. As such, current guidelines recommend interrupting prolonged periods of sitting with short, frequent activity breaks. However, the evidence underpinning these recommendations remains preliminary and is focussed on those with or at risk of developing T2D, with little information regarding whether and how reducing sedentariness may be effective and safe in those living with type 1 diabetes (T1D). In this review, we discuss the potential application of interventions that target prolonged sitting time in T2D within the context of T1D.

Mots clés:
contrôle de la glycémie
position assise interrompue
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R É S U M É

Les comportements sédentaires sont omniprésents dans nos sociétés modernes, les populations occidentales restant environ ∼50% de leurs heures d'éveil à de faibles niveaux de dépense énergétique. Ce comportement est associé à des dérèglements cardiométaboliques et à une morbidité et une mortalité accrues. Chez les personnes atteintes de diabète de type 2 (DT2) ou risquant de le développer, il a été démontré que le fait de " rompre " la sédentarité en interrompant les périodes assises prolongées

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améliore de manière significative le contrôle glycémique et les facteurs de risque cardiométaboliques liés aux complications du diabète. À ce titre, les lignes directrices actuelles recommandent d'interrompre les périodes prolongées en position assise par des pauses d'activité courtes et fréquentes. Cependant, les évidences qui sous-tendent ces recommandations restent préliminaires et se concentrent sur les personnes atteintes ou à risque de développer le DT2, avec peu d'informations sur l'efficacité et la sécurité de la réduction de la sédentarité chez les personnes atteintes de diabète de type 1 (DT1). Dans cette revue, nous discutons de l'application potentielle des interventions qui ciblent le temps prolongé en position assise dans le DT2 dans le contexte du DT1.

Introduction

Sedentary behaviour is defined as any waking, reclining, or sitting behaviour with a low energy expenditure of ≤1.5 metabolic equivalents (METs) [1]. This is distinct from physical inactivity, which is defined as failing to achieve recommended amounts of physical activity [2]. The prevalence of sedentary behaviour is increasing worldwide, with Western populations spending approximately 50% of their waking hours at low levels of energy expenditure [3,4].

It is well-established that sedentary behaviour increases risk of morbidity and mortality [5,6]. For example, watching television, a common proxy of sedentary behaviour, is associated with obesity and metabolic disturbances in a dose-dependent manner [7,8], and total sitting for >4 to 8 hours/day is significantly associated with a higher risk of mortality (i.e. 2% increase per 1-hour increase in sitting time per day) [6]. Furthermore, *prolonged periods of sedentariness* (i.e. remaining sedentary for 2 hours or longer at a time, as opposed to total volume of sedentariness) [9] is also associated with obesity and cardiometabolic derangements [10].

In individuals with diabetes, sitting for long periods of time has been shown to positively associate with worsening diabetes management, as determined by glycated hemoglobin (A1C) levels [11,12], which may contribute to an increased risk of diabetes-related complications. In people without type 1 diabetes (T1D), watching television uninterrupted for >2 hours/day is strongly associated with overweight and obesity in children and adolescents [13]—a risk factor that has been shown to predict both macro- and microvascular complications in people with T1D independent of glucose management [14].

Conversely, the benefits of increased physical activity for individuals with diabetes, including those with T1D, are well-established and have been reviewed elsewhere [11,15]. Physical activity is widely promoted for all individuals with diabetes [16–20], with guidelines recommending ≥150 minutes of moderate-to-vigorous physical activity (3.0 to 5.9 METs) for 3 days/week [20]. In addition, all individuals with diabetes are recommended to limit sedentary time and incorporate frequent episodes of low-intensity physical activity [21]. However, despite physical activity being acknowledged as a critical element of diabetes care, most individuals with T1D do not meet recommended physical activity levels [22]. Indeed, research suggests that <20% of individuals with T1D achieve physical activity guidelines and ∼60% of individuals remain inactive [23], with one study showing that 21% of the cohort surveyed exercised less than once per week [24].

Although many individuals with T1D do little to no exercise, they are often willing to increase participation in lower intensity physical activity and are keen to learn how to reduce sedentary behaviours [25]. However, little information is available for individuals with T1D or for the health-care professionals who support them [26]. Historically, physical activity guidelines have focussed predominantly on exercise (e.g. a planned, structured, repetitive, and purposeful physical activity in the sense of improving or enhancing physical fitness and overall health) rather than activities of everyday living (including sedentary behaviours) that contribute significantly to an individual's daily physical activity levels (e.g. any physical movement produced by skeletal muscles that leads to increased energy expenditure) [27]. It should be noted that exercise is not synonymous with physical activity, but rather a subcategory of physical activity. However, exercise-specific recommendations of moderate-to-vigorous physical activity translate poorly to general daily physical activity levels, including daily living and recreational activities, from which most individuals with T1D have most to gain [25]. Within the context of T1D, exercise is often viewed as daunting and unachievable by most and its promotion can often discourage individuals from becoming active [25]. For example, many people with T1D report fear of hypoglycemia and an inability to manage their diabetes as major barriers to regular participation [28,29], yet few mention this fear when asked about general day-to-day physical activities [25]. In support of this notion, rather than promoting exercise per se, it seems logical and important for inactive individuals with T1D to start with achievable and positive behavioural routines that can increase overall physical activity.

Recently, physical activity guidelines for individuals with diabetes have evolved to include recommendations specifically targeting prolonged periods of sitting time by "breaking-up" sedentary periods with bouts of standing and/or frequent, short, low-intensity physical activity intervals, termed "interrupted sitting" [1,30]. This simple and acceptable approach may help to enable these inactive individuals to carry out physical activity throughout the day and may serve as an effective way to more easily incorporate physical activity into everyday life and improve health. Interruption of sitting with light activities could be particularly useful for those who are unable or unwilling to engage in structured exercise, and this approach can be seen as an important "stepping-stone" toward regular participation in physical activity or exercise [31]. Despite this, the evidence underpinning these recommendations remains preliminary and focussed solely on individuals with or at risk of developing type 2 diabetes (T2D) [1,30–34]. Herein we focus on the potential utility and implications of applying interrupted sitting interventions within the context of adults with T1D.

Could Interruption of Sitting Time Be an Effective Health-promoting Strategy for T1D?

Interrupting sitting and glycemic management

Emerging evidence in individuals with T2D suggests that interruption of prolonged periods of time spent sitting with short, frequent activity breaks may be a promising strategy for improving acute glycemic management. Dempsey and colleagues [32] demonstrated that interrupting 7-hour prolonged sitting time with brief bouts of low-intensity walking for 3 minutes every 30 minutes significantly reduced the 22-hour glycemia in individuals with T2D, with nocturnal hyperglycemia and glycemic improvements continuing until the next morning. Time spent in nocturnal hyperglycemia was approximately 60% greater under an uninterrupted sitting condition compared with an interrupted sitting condition [32]. This suggests that the acute metabolic improvements associated with interrupted sitting carry over into the evening and sleeping periods until the next morning. Furthermore, interruption of prolonged sitting with frequent 3-minute bouts of walking every 15 minutes has also been shown to improve fasting glucose and limit the "dawn phenomenon" [35]. This is a particularly important consideration should a similar glycemic pattern be observed within the context of T1D, wherein the dawn phenomenon is a common issue.

The dawn phenomenon is defined as elevated blood glucose during early waking hours, and, to a large extent, persists after breakfast in individuals with T1D [36]. The phenomenon results from increased hormone-stimulated glucose output and impaired glucose utilization [37] and represents a feature of dysglycemia and increased basal insulin requirements in T1D [38]. Campbell and colleagues [39] found that nocturnal surges in growth hormone secretion drive the dawn phenomenon, whereas nocturnal increases in catecholamine levels do not appear to be sufficient by themselves to be responsible [37]. Accordingly, Clarke and colleagues [40] demonstrated that a 2- to 3-fold increase in insulin level is needed to maintain euglycemia overnight in some T1D individuals. Importantly, Zheng and colleagues [41] noted that moderate-intensity aerobic exercise before breakfast reduced the rate at which blood glucose increased in individuals with T2D, partially counteracting the dawn phenomenon. Although morning exercise is commonly recommended for people with diabetes to improve early morning rises in glucose [42], it is unknown whether interrupted sitting may serve as an effective strategy to attenuate the dawn phenomenon, especially in individuals with T1D.

Interrupted sitting interventions can also improve meal-time glucose management. For example, Dempsey and colleagues [1] showed that 3-minute bouts of low-intensity walking on a treadmill every 30 minutes attenuated postprandial glucose by 39% in T2D. Furthermore, Paing and colleagues [43] demonstrated, in 12 individuals with T2D, that interrupting sitting time through performing 3-minute, low-intensity walking breaks after meals every 15 minutes resulted in a 48% reduction in glucose after breakfast (3.5±0.9 mmol/L), a 62% reduction in cumulative 10.5-hour postprandial glucose (5.6±2.4 mmol/L), and a 34% reduction in 21-hour glucose (101.5±12.6 mmol/L) compared with interrupted sitting every 60 minutes. As such, the frequency of interrupted sitting may be an important factor in achieving better glucose management, but the optimal time and frequency of these low-intensity bouts remain unknown.

Short activity breaks from sitting have been shown to result in improvements in postprandial glucose responses and daily glycemic management, albeit with varying efficacy, when compared with traditional forms of exercise [44,45]. For example, Peddie and colleagues [46] reported regular activity breaks to be more effective than continuous physical activity at decreasing postprandial glycemia and insulinemia in normal-weight individuals without diabetes, whereas Blankenship et al [44] showed continuous walking to be comparable with activity breaks for lowering postprandial glucose in people with T2D. Blankenship et al also showed that continuous physical activity was more effective at lowering daily hyperglycemia when compared with regular activity breaks in people with T2D. Freire and colleagues [47] demonstrated lower daily glucose in response to breaks in sitting time when compared with low-volume, high-intensity interval exercise in adults living with overweight.

Given that different forms of physical activity, performed at different times of day, induce divergent metabolic responses, it is likely that differences in study methodology, as well as the metabolic health of sampled participants, were confounding factors and contributed to mixed study findings. For example, a recent meta-analysis [45] exclusively involving individuals without diabetes showed that interrupting sitting time with short, frequent bouts of walking activity was more effective at reducing postprandial glucose than a single continuous session of isoenergetic exercise. A possible explanation for this difference could be that glucose counter-regulatory hormones increase during prolonged exercise, which promotes increased hepatic glucose production at a rate that can exceed glucose uptake, an effect that is further mediated by the fasted vs postprandial state as shown by recent work in T1D [48]. Although yet untested, the net effect of interrupted sitting within a T1D setting may be an overall increase in blood glucose levels [45]. For example, this may be the case for those patients who may be unaccustomed to physical activity or who would likely be performing activity breaks at a higher relative intensity, whereby the impacts of counter-regulatory hormones are additive with short successive bouts of activity. The potential for exercise to induce transient hyperglycemia in T1D has obvious negative consequences; however, manipulating activity type to diminish the counter-regulatory response may consequently increase the risk of hypoglycemia, particularly late-onset hypoglycemia [49,50]. As such, it is important that research establishes the impact of frequent, short bouts of activity on risk of hypo- and hyperglycemia in T1D, and whether and what adjustments to treatment are necessary to maintain glucose management. For example, Campbell and colleagues [51] demonstrated that reducing pre- and postexercise rapid-acting insulin is an effective strategy in terms of preventing exercise-induced hypoglycemia and does not cause adverse hormonal disturbances in individuals with T1D, but it is unknown whether insulin dosing adjustments would be necessary for lower intensity physical activity. Furthermore, research is needed to identify the glycemic management requirements of reduced sitting interventions specifically in children and adolescents with T1D with and without technologies such as closed-loop systems, which are likely to require greater input from health-care professionals.

Interrupting sitting and cardiovascular risk

Interruption of prolonged sitting has also been shown to improve cardiovascular risk factors in T2D. In one study, 3-minute bouts of light-intensity walking every 30 minutes in 24 inactive individuals with T2D and living with overweight or obesity elicited a reduction in systolic blood pressure by 14 mmHg and diastolic blood pressure by 8 mmHg during the condition [33]. In one study, participants replaced ~5 hours/day of sitting with 2 hours of walking and 3 hours of standing; this was shown to improve plasma triacyclglycerols when compared with the sedentary condition (mean ± standard error of the mean: 1.46 [0.12] vs 1.93 [0.17] mmol/L) [52]. Reducing sitting time by engaging in low-intensity activity breaks may be effective for improving features of metabolic syndrome in both T2D and T1D, given the similarities in underlying disease pathology. Metabolic syndrome is a cluster of conditions defined as central obesity plus 2 additional factors [53], including increased triglyceride levels (>1.7 mmol/L), blood pressure (≥130/85 mmHg), and fasting plasma glucose (>5.6 mmol/L), and reduced high-density lipoprotein cholesterol (<1.03 mmol/L in males and <1.29 mmol/L in females) [54]. Data from several studies suggest that excessive sitting time was associated with reversible changes in components of the metabolic symptoms [55,56]. Given the high prevalence of insulin resistance and metabolic syndrome in T1D [14,57–59], an interrupted prolonged sitting strategy may be a practical way of helping to reduce the risk of vascular complications.

Potential mechanisms

Consistent with previous studies in people with and at risk of T2D, the improvement in glycemic management in response to frequent sitting interruption interventions is likely due to a combination of enhanced insulin sensitivity [60] and/or a greater dependence on insulin-independent contraction-mediated glucose uptake pathways. Acute exercise/physical activity–induced insulin sensitivity has clear clinical significance in the prevention and treatment of chronic insulin resistance in peripheral tissue, which has direct impacts on glucose management and vascular risk [60]. For example, skeletal muscle is a major site of glucose uptake in the postabsorptive state, and thus an improvement in peripheral insulin sensitivity results in improved glucose tolerance during and after meals [61]. Indeed, recent investigations have demonstrated that skeletal muscle contraction-mediated glucose uptake is associated with improved postprandial glucose levels during 1-day interventions employing frequent interruptions in sedentary time [62]. Although exercise is a known potent mediator of insulin-independent glucose uptake in T1D, there are no data assessing glucose kinetics in people with T1D in response to lower intensity physical activity. Recent research has shown alterations in the mitochondrial ultrastructure and bioenergetics of skeletal muscle in active young adults with T1D [63]. For example, mitochondrial oxidative capacity was significantly lower and the size and number of autophagic remnants in skeletal muscle were higher in individuals with T1D when compared with control subjects. As such, it may be that lower intensity physical activity is insufficient to completely prevent or reverse skeletal muscle metabolic deficiencies and, therefore, more vigorous forms of activity are needed to achieve comparable glycemic improvements. Furthermore, given that muscle mitochondrial impairments have been implicated in insulin resistance [64], it may be that those individuals requiring intervention the most are the ones who respond the least.

Future research opportunities

There is currently no research on interrupted sitting with light-intensity activity in T1D. Also, there is minimal evidence for longer term effects on glucose management and complication risks in people with or at risk of T2D. Further research is required to assess the impact of interrupted sitting strategies with low-intensity physical activity on short- and long-term glucose management in individuals with T1D, and whether such interventions yield beneficial effects on complication risk. Indeed, sedentary time is associated with premature mortality and cardiovascular risk factors for T2D, as well as cardiovascular disease and some types of cancer [65]. Therefore, interrupted sitting interventions in individuals with T1D are urgently needed. It would be particularly beneficial to investigate the utility of such interventions across a broad demographic of people with T1D, such as those with insulin resistance, which is known to mediate glucose management and vascular risk in T1D [59,66,67]. It should also be established whether laboratory-based interventions can be translated into a remote, home-based environment.

In conclusion, regular physical activity, including structured exercise, provides numerous benefits for individuals with diabetes. In individuals with T2D, these benefits are well acknowledged, as frequent interruption of sitting time improves acute glycemic management and reduces cardiovascular risk. To date, there are no published studies assessing the impact of interrupted sitting on glycemic, metabolic, or vascular parameters in people with T1D. As such, it is unknown whether the benefits of such a strategy observed in T2D are comparable in T1D. Ongoing research should attempt to provide greater insight into the role of interrupted sitting interventions in T1D, with a particular focus on postprandial and nocturnal glucose management and the potential risk of provoking hypoglycemic episodes. Should such an intervention yield positive results, this simple and acceptable approach may help enable individuals to incorporate physical activity more easily into everyday life and improve health. Similar interventions are needed with longer term evidence and in free-living conditions.

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Author Contributions

A.M.A. performed searches, contributed to the selection of the references, and was involved in manuscript creation. M.H., M.A.Z., P.C.D., and M.F. critically appraised the work and were involved in editing of the final manuscript. All authors have reviewed and approved the final manuscript submitted for publication. M.D.C. had overall oversight of the work, performed searches, contributed to the selection of the references, and formulated the hypothesis for investigation.

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