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ACTIVITY LEVELS AND HEALTHCARE UTILIZATION: ASSOCIATIONS IN INDIVIDUALS WITH TYPE 2 DIABETES

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Approval of Thesis

The undersigned certify that they have read the thesis entitled

ASSOCIATIONS OF DAILY ACTIVITIES AND SEDENTARY TIME WITH HEALTHCARE UTILIZATION IN INDIVIDUALS WITH TYPE 2 DIABETES: DATA FROM ALBERTA'S CARING FOR DIABETES COHORT

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Abstract

Background: This study's objective was to examine cross-sectional associations of device-measured physical activity with healthcare utilization among adults with Type 2 Diabetes.

Methods: Healthcare utilization data included number of physician claims, type of physician service, number of emergency department visits, number of ambulatory care visits, and number of hospitalizations. Device-based physical activity and sedentary time were assessed using the ActiGraph® GT3X+ accelerometer.

Results: For moderate vigorous physical activity and sedentary time, no statistically significant associations were found with healthcare utilization. For daily steps, ANOVA suggested higher step counts were associated with fewer physician claims and emergency department visits.

Conclusion: Device-based MVPA and sedentary time were not associated with healthcare utilization. Daily steps was found to be significantly associated with physician claims and emergency department visits. Increasing walking may help reduce healthcare utilization in adults with T2D.

Keywords: Type 2 Diabetes, active lifestyle, daily activities, physical inactivity, sedentary time, healthcare utilization

Table of Contents

Chapter 1. Literature Review

In Canada, the prevalence of T2D diabetes has increased approximately 70% over the last decade (Weisman et al., 2018) with Canadian adults over the age of 60 accounting for more than 20% of those diagnosed with T2D (Government of Canada, 2017). The Canadian National Diabetes Surveillance System (NDSS) indicated that between 2005-2006, approximately 1.9 million Canadians were diagnosed with diabetes, or approximately 1 in 17 Canadians (Health Canada, 2007). Statistics Canada (2018) reports that in 2017, 7.3% (2.3 million) of Canadians were newly diagnosed with diabetes, results which identify the increasing prevalence of T2D cases. Further, 10.8% (4.2 million) of the Canadian population is expected to have diabetes by 2020, the majority of which will be T2D (Diabetes Canada, 2011). Between 1995-2009, 197,569 new cases of diabetes were identified in Alberta and in 2009, approximately 206,000 adults were living with diabetes, a value which has doubled over the last 15 years (Johnson et al., 2011a).

Diabetes is an umbrella term for multiple metabolic diseases characterized by elevated blood glucose. The mechanisms by which blood glucose levels become elevated vary and depend on individual physiology and propensity for disease development. Most often, it is a lack of insulin production, resistance to insulin produced, or both that contributes to the development of high glucose levels and subsequent diabetes (Shafran-Tikva & Kluger, 2018). Diabetes has traditionally been divided into three main types: Type 1 diabetes (T1D), otherwise known as insulin-dependent or juvenile onset diabetes, Type 2 diabetes (T2D), commonly referred to as non-insulin dependent or adult-onset diabetes, and gestational diabetes (GDM), which refers to hyperglycemia that occurs during pregnancy (Casperson, Thomas, Boseman, Beckles, & Albright, 2012). Diabetes Canada (2018) suggests diabetes exists in adults when either fasting blood glucose is greater than 7mmol/L, a 2-hour plasma glucose value of >11.1 mmol/L in a 75g oral glucose tolerance test, or glycosylated hemoglobin (HbA1C) is greater than 6.5%. It is important to note that some individuals with T2D do progress in their disease to require insulin administration for appropriate management.

Most often, adults with T2D experience comorbid conditions and complications that contribute to increased morbidity, mortality, and decreased functional capacity (Nilsen, Bakke, Rohde, & Gallefoss, 2014). While overall mortality rates due to diabetes have declined, adults with diabetes are still two to four times more likely to die than those without diabetes (Johnson et al., 2011a). Compared to individuals without diabetes, those with T2D are at significant risk of death due to cardiovascular disease (CVD), specifically myocardial infarction, stroke, and heart failure (Einarson, Acs, Ludwig, & Panton, 2018). Andersson et al. (2018) found an almost two-fold increased risk of death from CVD when diabetes is present. Notably, this increased risk is often associated with high prevalence of other modifiable risk factors contributory to CVD including hypertension, obesity, and dyslipidemia (Ji et al., 2017). Petrie, Guzik, and Touyz (2018) suggested hypertension as a risk factor for CVD is twice as frequent in people with diabetes citing lack of adherence to appropriate management strategies and health behaviours as the likely cause. The increased morbidity and mortality associated with T2D can be attributed to acceleration of normal anatomical and physiological processes that occur with aging thus life expectancy is shorter because of these changes (Casperson et al., 2012; McGinley, Armstrong, Khandwala, Zanuso, & Sigal, 2015).

Physical Activity and Type 2 Diabetes

Physical activity plays an important role in both the prevention and management of T2D and, when higher levels of cardiorespiratory fitness (CRF) are obtained, may decrease the negative effects of sedentary time on health (Cooper et al., 2014) and reduce all-cause mortality in adults with T2D (Bakrania et al., 2017). Activity can influence outcomes by directly affecting factors that contribute to diabetes development, such as obesity and insulin resistance, or reducing the effects of comorbid complications, such as hypertension and cardiovascular disease (Colberg et al., 2016; Schroeder, 2018). Diabetes Canada (2018) recommends those with diabetes should accumulate 150 min/week of moderate to vigorous physical activity (MVPA) and at least two sessions per week of resistance exercise. Physical activity, at a level that increases CRF, is important for those with T2D because of increased risk of functional disability, CVD, and risk of premature death associated with T2D (Nguyen et al., 2007; Diabetes Canada, 2018). Additionally, the beneficial effects of activity on hypertension, dyslipidemia, and hyperglycemia have been well documented (Boule et al., 2003; Colberg et al., 2016).

Hyperglycemia, identified as blood glucose values greater than 13mmol/L, has numerous negative effects on body systems due to the hyper-inflammatory state it precipitates (de Rekeneire et al., 2006) and is a significant contributor to cardiovascular disease (Kodama et al., 2013). Regular physical activity that increases CRF prevents and can change the negative physiological effects T2D has on body systems by enhancing glycemic control (Colberg et al., 2010) through increased pancreatic beta cell function (Ramos et al., 2017) and improves HbA1c levels in adults with T2D (Umpierre et al., 2011; Umpierre et al., 2013). Nojima et al. (2017) found after 12 months of exercise training, improvements in aerobic capacity, as measured by peak $V0_2$max, significantly improved glycemic control in adults with T2D. It has been found aerobic MVPA decreases insulin resistance and increases insulin sensitivity (Motahari-Tabari et al., 2015), thus lowering blood sugar levels by promoting glucose uptake by fatigued, glucose depleted muscle tissue (Praet & van Loon, 2009; Teixeira-Lemos et al., 2011; Bird & Hawley, 2017). Weight loss associated with increased activity improves glycemic control by reducing the amount of insulin needed by fat cells to store and process nutrients (Alghafri et al., 2017). Fat reduction causes improved lipid profiles, which lowers blood pressure and subsequent risk of adverse cardiovascular events (Kuznetsov et al., 2013; Alghafri et al., 2017; Alexandre & Paule, 2018). While lowering body weight in addition to improving CRF is most beneficial, improvements in CRF in the absence of weight loss can still have positive affects for glycemic control (Boule et al., 2001; Fogelholm, 2010; Barry et al., 2014; Bird & Hawley, 2017).

Increased intensity of aerobic exercise has also been shown to improve CRF and decrease HbA1c levels allowing for improved glycemic control in adults with T2D (Boule et al., 2003). Specifically, interval training, the alternation between high and low intensity exercise, has been shown to have the most positive effect on CRF and improvement in glycemic control (Curry et al., 2015; Francois & Little, 2015; Jelleyman et al., 2015). Literature pertaining to exercise and metabolic outcomes focusing on aerobic exercise, resistance exercise, and combined aerobic and resistance exercise has found benefits of activity and effects on CRF are dependent on activity intensity: the higher the intensity, the more positive the effect (Zanuso et al., 2010; Viana et al., 2019; Cox et al., 2020). Additionally, improved HbA1c levels and CRF (i.e. $V0_2$max) were found with higher intensities of aerobic activity and intensity was more predictive of these improvements compared to volume (Zanuso et al., 2010; Viana et al., 2019; Cox et al., 2020). Similar results were found by Liubaoerjijin et al. (2016) in a meta-analysis of head-to head trials comparing high vs. low aerobic exercise intensity on HbA1c levels. Rees et al. (2017) found similar improvements with aquatic activity compared to land-based activity suggesting aquatic MVPA may be just as efficacious as land-based MVPA for glycemic control providing a viable alternative when land-based activity may not be appropriate. The added benefit of resistance from water also allows participants to reach higher intensity levels during exercise providing benefit to glycemic control (Rees et al., 2017).

A study by Sardinha et al. (2017) demonstrated that regardless of CRF, total sedentary time is positively associated with higher HbA1c levels highlighting the relationship between glycemic control and sedentary time and the need to interrupt or, preferentially, decrease sedentary time in adults with T2D. Studies have demonstrated that adults with T2D who spend more time in unbroken and continuous sedentary behaviour have higher incidence of hyperglycemia and have poorer glucose control compared to those who interrupt sedentary time with frequent breaks (Fritschi et al., 2016; Paing et al., 2018). Prolonged sitting has been linked to increase blood sugar levels after meals (post-prandial) which contributes to pancreatic beta cell failure and the progression of T2D (Dempsey et al., 2018). Dempsey et al. (2016) performed a randomized cross-over trial on 24 inactive obese adults with T2D to determine if interrupting prolonged sitting with short periods of light intensity aerobic activity or resistance training would improve post-prandial cardiometabolic risk markers, namely glucose, insulin, c-peptide, and triglycerides. Results demonstrated that improvement in these markers post-prandially does occur when prolonged sedentary time is interrupted by the assessed activities, which is significant when considering mechanisms by which to improve health and physical function in adults with T2D who are more prone to be inactive (Cichosz et al., 2013) and not adherent to exercise programming (Dempsey et al., 2016). Similarly, Rossen et al. (2017) demonstrated interrupting prolonged sedentary behaviour with 30 minutes of MVPA was most significant for improved waist circumference, BMI, and HDL cholesterol levels supporting the necessity of MVPA in adults with T2D.

Prevalence of Physical Inactivity in Type 2 Diabetes

Research demonstrates adults with T2D are physically inactive (Mathe et al., 2017; Thiel et al., 2017) and as a result are more predisposed to secondary chronic health conditions that affect morbidity and mortality (Zhao, Ford, Li, & Balluz, 2011; Hallal et al., 2012). Nelson, Reiber, and Boyko (2002) utilized data from the National Health and Nutrition Examination Survey (NHANES III) to explore physical activity practices of a nationally representative sample of American adults with T2D. Of 1,480 adults with T2D, 31% (n=459) reported no regular physical activity and 38% (n=562) reported less than recommended levels. Comparatively, Plotnikoff et al. (2006) conducted the Alberta Longitudinal Exercise and Diabetes Research Advancement (ALEXANDRA) study to understand correlates of physical activity in adults with T2D. Using the Godin Lesiure-Time Exercise questionnaire (GLTQ), the study revealed 72% of participants with T2D (n=1162 of 1614) were insufficiently active and did not meet physical activity guidelines. Mathe et al. (2017) and Thiel et al. (2017) support these findings; both studies utilized data from the Alberta's Caring for Diabetes (ABCD) cohort study and found study participants, 90% (assessed via accelerometer) and 78% (assessed via self-report) respectively, were physically inactive and did not meet physical activity guidelines. In the US, Morrato et al. (2007) utilized the Medical Expenditure Panel Survey (MEPS) to delineate the prevalence of physical activity amongst adults who had or were at risk of diabetes. Findings showed only 39% of adults with diabetes reported being physically active compared to 58% of adults without diabetes. As can be seen, results from multiple sources identifies the need for increased intervention to promote MVPA in adults with T2D.

Contributing Factors to Physical Inactivity. Several possibilities exist for the high prevalence of inactivity and sedentary behaviour amongst adults with T2D. Firstly, symptom severity may be a key determinant for engagement in physical activity (Green & Kreuter, 2005). Johnson et al. (2019) found adults with T2D who have neuropathies engage less in aerobic physical activity secondary to discomfort, decreased sensation, and the fear of causing foot ulcerations. Specifically, Huebschmann et al. (2011) surveyed n=129 adults with diabetes (T1D and T2D) and found ‘fear of injury’ to be a limiting factor for engagement in physical activity compared to adults without diabetes. The experience of pain, fatigue, depression, shortness of breath related to CVD, poor vision, or loss of a limb negatively affect an individual’s physical health and capacity for function (Kuznetsov et al., 2013). Finally, the effects of polypharmacy related to diabetes and comorbid condition management can create unpleasant symptoms that affect patient well-being and willingness to engage in physical activity (Caspersen et al., 2012).

Diabetes has been found to be an independent risk factor for reduced muscle strength and, subsequently, functional status (Anton, Karabetian, Naugle, & Buford, 2013; Fritschi, Bronas, Park, Collins, & Quinn, 2017) highlighting the importance of physical activity for this population. Diabetes contributes to impaired protein synthesis pathways and increased protein degradation pathways in muscles contributing to states of disability and decline in functional status (Kalyani, Corriere, & Ferrucci, 2014). Adults with T2D are often physically weak making it challenging to engage in physical activity and meet activity guidelines as muscle mass is lost at a higher rate than the general population (Hamasaki, 2016). Specifically, thigh muscle mass deteriorates significantly, which therefore inhibits participation in aerobic activity potentiating comorbid complications (Kalyani et al., 2013; Alexandre & Paule, 2018). Balducci et al. (2014) suggest muscle strength deteriorates in advanced stages of the disease making participation in physical activity by adults with T2D more difficult. As a result of muscle weakness, adults with T2D have a lower physical performance threshold which may result in cessation of physical activity interventions (Hamasaki, 2016). Additionally, Plotnikoff et al. (2006) found that perceived level of disability had a significantly strong negative correlation to physical activity levels with greater perception of disability resulting in decreased physical activity. Finally, adults with T2D may associate physical activity with increased risk of injury or death secondary to the presence of comorbid conditions, such as CVD (Li, Ng, Cheng, & Fung, 2017), despite evidence indicating aerobic activity is safe and effective for disease management (Cai, Li, Zhang, Xu, & Chen, 2017).

Sedentary Behaviour and Type 2 Diabetes

Understanding the relationship between sedentary time and diabetes requires acknowledgement that ‘sedentary’ and ‘inactivity’ are not synonymous but are distinct constructs that may exist with or without the presence of the other (Sedentary Behaviour Research Network, 2012). Sedentary behaviour is defined as ‘any waking behaviour done while lying, reclining, sitting, or standing, with no ambulation, irrespective of energy expenditure’ while inactivity is more generally identified as an insufficient activity level (measured as total energy expenditure) to meet current physical activity recommendations (Sedentary Behaviour Research Network, 2012). Daily sedentary time, light physical activity (LPA), and MVPA share an interactive relationship: a decrease or increase in one will often produce the opposite effect in the other (Dohrn, Kwak, Oja, Sjostrom, & Hagstromer, 2018). An individual can be physically inactive but still perform LPA and therefore not be considered sedentary. Alternatively, individuals can engage in recommended levels of physical activity and be sedentary for the remainder of waking hours (Pate, O’Neill, & Lobelo, 2008).

Prevalence of Sedentary Time. Research shows that individuals with T2D are more likely to be inactive and sedentary compared to those without T2D. Cooper et al. (2012) performed a cross-sectional longitudinal study investigating the effects of sedentary time on metabolic factors in people with T2D. The data demonstrated participants engaged in MVPA for only 3.2% of the day and were sedentary for 61.5%. Utilizing the Italian Diabetes and Exercise Study_2 (IDES_2), Balducci et al. (2017) objectively assessed the level and correlates of physical activity and sedentary time in adults with T2D. Results demonstrated participants were sedentary for 11.6 hours/day with values reaching as high as 15.28 hours/day where physical inactivity was also present. Healy et al. (2008b) objectively measured sedentary time in adults with T2D and found participants (n=168) spent 57% of waking hours sedentary. Bankoski et al. (2011) utilized information from the 2003-2006 NHANES to assess sedentary time in older adults at risk of metabolic syndrome. Using accelerometer data, it was found 9.5 hours (67% of wear time) was spent sedentary. Additionally, in comparison to individuals not at risk of metabolic syndrome, those at risk had a higher percentage, longer duration, and fewer breaks in sedentary time.

Yates et al. (2015) objectively measured sedentary time in adults with T2D in a study investigating insulin sensitivity and reallocation of sedentary time into LPA or MVPA. Findings revealed participants wore accelerometers for 859.4 minutes/day and spent 607 minutes/day sedentary, 205.3 minutes/day in LPA, and only 29.8 minutes/day in MVPA highlighting the prevalence of participants to be sedentary versus active. Healy et al. (2015) also found increased levels of prolonged and unbroken sedentary time in adults with T2D (n=302) where 63% of waking hours were spent being sedentary while only 2% were spent engaged in MVPA; 25% of sedentary time was prolonged (≥30min). Similarly, Falconer et al. (2015) used accelerometers to assess sedentary time in 519 participants with T2D and found 65% of waking hours were spent sedentary, 45% of which was prolonged beyond 30 minutes. Berg et al. (2016) utilized data from the Maastricht Study, an observational, prospective, population-based cohort study, to evaluate associations between total amount and patterns of sedentary behaviour and T2D and found adults with T2D had up to 26 min more per day sedentary time compared to control groups. A study performed by Mathe et al. (2017) used accelerometers to assess activity levels of study participants with T2D. Results showed participants had an average of 543.6 minutes (9.1 hours) per day of sedentary time, 273.4 minutes (4.6 hours) per day of LPA, and 22.4 minutes per day of MVPA. Overall, participants were sedentary for 64.7% of waking hours with only 10% meeting current physical activity guidelines.

Health Outcomes and Sedentary Behaviour. Research suggests sedentary behaviour has emerged as a distinct behavioural paradigm independent from physical activity (Westerterp, 2001; Healy et al., 2008a). Over a period of 12 years, Katzmarzyk et al. (2009) prospectively compared daily self-reported sitting time in 17,013 Canadians aged 18-90 who were deemed active or inactive to assess for associated mortality rates. Results showed those who were inactive and sedentary 'almost all the time' had increased rates of mortality compared to those who were active and sedentary 'almost all the time'. Those who were considered active and sedentary still had increased risk of mortality suggesting sedentary time has an independent association with mortality rates beyond that explained by physical activity levels: an individual cannot compensate for high levels of sedentary time with occasional physical activity, or perhaps even low intensity activity, even if the volume exceeds current recommendations (Katzmarzyk et al., 2009). A systematic review by Wilmot et al. (2012) also found a positive association between sitting time and the risk of premature mortality in not only adults with diabetes but also the general population even after adjusting for time spent in MVPA. While these studies do not pertain specifically to adults with T2D, their findings support the distinct and independent nature of sedentary time and physical activity and highlight the necessity to change both behaviors to avoid negative effects on health, especially in vulnerable populations, such as adults with T2D.

Sedentary time in adults with T2D, especially when prolonged in bouts greater than 30 minutes, is detrimental to health (Falconer, 2015) and increases morbidity and mortality associated with the poor metabolic profile that accompanies comorbid conditions (Einarson et al., 2018). Studies have associated sedentary time with increased risk of CVD events (Sattelmair et al., 2011; Sindone & Chen, 2018; Zaman et al., 2019) highlighting the importance of replacing sedentary time with physical activity in adults with T2D (Paing et al., 2018). Cooper et al. (2014) determined sedentary time in adults with T2D, independent of time spent in MVPA, is positively associated with increased waist circumference, triacyclglycerol, HbA1c, systolic blood pressure, and LDL-cholesterol, factors identified as contributory to metabolic risk. Cooper et al. (2012) determined each hour of sedentary time in adults with newly diagnosed T2D is associated with larger waist circumference and lower levels of HDL cholesterol, factors known to increase risk of coronary artery disease and myocardial infarction (Ahn & Kim, 2016). Increased waist circumference and low HDL levels are more prevalent when bouts of sedentary time are prolonged and greater than 30 minutes (Falconer et al., 2015; Healy et al., 2015) and remain significant for metabolic risk despite adjustments for MVPA and achievement of physical activity guidelines (Qi et al., 2014). Additionally, higher levels of inflammation, as measured by c-reactive protein (CRP), interleukin-6 (IL-6), adiponectin, and soluble intracellular adhesion molecule-1 (sICAM-1) are found in sedentary adults with T2D compared to those with T2D who meet physical activity recommendations (Falconer, 2014). These inflammatory factors may be contributory to microvascular (i.e. retinopathy) and macrovascular (i.e. stroke) complications (Halim & Halim, 2019; Zaman et al., 2019), inhibit the protective function of HDL particles on the cardiovascular system (Onat & Hergenç, 2011), and contribute to depressive symptoms (Stuart & Baune, 2012; Doyle et al., 2013; Laake et al., 2014; Moulton et al., 2015; Herder et al., 2017; Herder et al., 2018).

Depression has been shown to have a strong association with T2D and metabolic risk (Cardenas et al., 2017) and is more prevalent in those with diabetes than in the general population (Nouwen et al., 2010; Darwish et al., 2018). It has been demonstrated a bidirectional relationship exists between these conditions (Pan et al., 2012) where depression is a risk factor for future diabetes (Rotella & Mannuci, 2013a) and diabetes is a risk factor for future depression (Rotella & Mannuci, 2013b). Depression in adults with T2D has been associated with increased morbidity, mortality, and healthcare utilization (Hussain et al., 2018; Huang et al., 2019) supporting the negative impact of this relationship on adults with T2D. The heightened psychological impact of depression on diabetes contributes to diabetes-related distress exacerbating the already complex nature of diabetes management (Fisher et al., 2014).

Assessment of Daily Activity Behaviours

Assessment of physical activity and sedentary time in this population has been completed through both self-report and objective measures. Each method yields important information regarding health behaviours, association to health status, and effectiveness of interventions (Prince et al., 2008). Self-report measures, such as surveys or questionnaires, are subjective and provide insight regarding perceived physical activity and sedentary time. These methods are effective for large study groups due to low cost, lower participant burden, and ease of use (Dishman, Washburn, & Schoeller, 2001). However, there is well-documented evidence that these tools have the capacity to over or underestimate these behaviours due to issues with recall and response bias rendering results unreliable and difficult to validate (Sallis & Saelens, 2000; Shephard, 2003; Hidding, Altenburg, Mokkin, Terwee, & Chinapaw, 2017).

As a result, the use of objective (direct) methods for assessing physical activity and sedentary time, such as ActiGraph® accelerometers, have improved precision and accuracy of data collected (Shephard, 2017). An accelerometer is a device that measures non-gravitational acceleration as found in walking or jogging and is beneficial for measuring steps and speed (Sigal et al., 2018). The ability of these tools to overcome the limitations of self-report measures allows for collection of data that is more valid and reliable. However, limitations also exist for accelerometer measures. For example, accelerometer data is dependent on the type of activity performed with little agreement between accelerometer data and physical activity that involves static hip positions, such as lifting and cycling (Slootmaker et al., 2009). Additionally, accelerometers specifically do not provide any contextual information regarding the types of physical activity or sedentary behaviour being performed (Tudor-Locke et al., 2010).

A systematic review of self-report versus objective methods for assessing physical activity assessment by Prince et al. (2008) demonstrated that when objective methods are used in conjunction with self-report measures, results between these two modalities can vary greatly with self-report often producing results that have low significance to objective data; self-report exercise levels often exceed levels obtained objectively (Katzmarzyk et al., 2017). Similar results have been identified using self-report and objective measures to assess both physical activity and sedentary behaviour (Boyle et al., 2015). Colley et al. (2018) examined data from the 2016 Canadian Community Health Survey (CCHS) and found half of Canadian adults reported meeting physical activity recommendations whereas objective accelerometer data from the 2014-2015 Canadian Health Measures Survey (CHMS) found only 17% actually met current physical activity recommendations. Additionally, Kennerly and Kirk (2018) completed a systematic review of PA and sedentary behaviour of adults with T2D and found while both objective and subjective measures identified lower levels of PA and increased sedentary behaviour in adults with T2D compared to those without, there was substantial variability between these two methods. The authors found ActiGraph® accelerometers reported approximately 9% of adults met PA guidelines while subjective methods using the IPAQ questionnaire reported a range from 15-61%, and between 25-75% for other self-report measures. These results highlight the inconsistency that exists with subjective methods in comparison to use of ActiGraph® technology, however, both measures capture important information and, when possible, should be used in conjunction when assessing for sedentary behaviour (Healy et al., 2011).

Healthcare Utilization and Type 2 Diabetes

Diabetes is the single largest condition related to non-elective hospitalizations secondary to the comorbid conditions that accompany this disease (Dusheiko et al., 2011). In Canada, the prevalence of adults with T2D affected by heart disease has continued to increase: up to 40% of hospital admissions for myocardial infarction, stroke, and heart failure occur in people with T2D (Lipscombe & Hux, 2007; Public Health Agency of Canada, 2011). The management of diabetes and associated health conditions contributes to increased healthcare utilization by this population as well as substantial economic burden (Simpson, Corabian, Jacobs, & Johnson, 2003; Florian et al., 2018); ‘utilization’ refers to the outcome of demand for healthcare services interacting with the supply of healthcare services (Johnson et al, 2011b). A multi-national systematic review by Wolters et al. (2017) showed the number of years with diagnosed diabetes was related to an increased risk of hospitalization, which is an important consideration as T2D accounts for most diabetes cases (Diabetes Canada, 2018) and adults with T2D tend to live longer due to advancements in treatment potentiating the number of years of healthcare utilization. In Canada, the relationship between healthcare utilization and economic burden exists in the form of lost productivity and secondary to a publicly funded health care system where costs associated with chronic disease management are supported by society (Bilandzic & Rosella, 2017).

In 2009, the Canadian Diabetes Association commissioned a research project from which the Canadian Diabetes Cost Model (CDCM) was developed. This model identified that the cost of diabetes will rise from $6.3 billion in 2000 to $16.9 billion by 2020 as the number of people with diabetes increases from 1.3 million to 3.7 million respectively (Doucet & Beatty, 2010). As the number of new diagnoses of T2D grows so too will healthcare utilization and associated costs of this increased use. Compared to those without diabetes, individuals with new-onset diabetes incur CAD$10,000 in excess cost during the first eight years of their diagnosis (Rosella et al., 2016). Adults with T2D have improved long-term outcomes due to medical advancements and improved treatment strategies compounding increasing healthcare costs and utilization (Nichols et al., 2007; Rosella et al., 2016; Sadikot et al., 2017). Increases in T2D prevalence secondary to these improvements ultimately threaten the sustainability of Canada's health care system (Weisman et al., 2018).

In Canada, healthcare utilization includes direct and indirect costs, both of which contribute to the expanding economic burden associated with this disease. Based on the Economic Burden of Illness in Canada report (2005-2008), the total direct cost for diabetes in 2008 was approximately $2 billion (Public Health Agency of Canada, 2014). Five components were identified by the CDCM highlighting the direct costs of diabetes which include: acute care hospitalization, cardiovascular disease costs, family physician costs, specialist costs, and prescription medication costs (Doucet & Beatty, 2010). Additionally, the CDCM identified the indirect costs of diabetes, defined as lost economic productivity secondary to illness or premature death caused by diabetes, accounts for as much as 80% of the cost of diabetes in Canada. By 2020, it is estimated as much as $11 billion will be lost per year from the Canadian economy secondary to premature mortality caused by diabetes (Doucet & Beatty, 2010).

Johnson et al. (2011b) compiled the Alberta Diabetes Atlas to provide information about diabetes in Alberta, Canada, which included pertinent information on diabetes and healthcare utilization in the province. From the period 1995-2009, adults with diabetes saw family physicians 75% more per year compared to adults without diabetes; the total number of family physician visits almost tripled from 809,500 in 1995 to 2.3 million in 2009. Additionally, visits to medical specialists in this population also increased at a faster rate (40%) compared to those without diabetes (20%) during this same time period with those with diabetes seeing specialists more than 3 times as often compared to those without diabetes. The number of emergency department visits also increased from 98,000 in 1998 to almost 186,000 in 2009 with this population also seeing 3 times the average number of hospital days compared to adults without diabetes. With the increased strain on the healthcare system, appropriate management and prevention of complications will be hindered, which may precipitate increases in emergency department and specialist visits (Johnson et al., 2011b). This information demonstrates the increased burden on the healthcare system secondary to diabetes especially considering this same trend is most likely occurring in all provinces across Canada.

Nichols et al. (2007) retrospectively analyzed the 2003 US Medical Expenditures Survey and similarly found those with T2D are three times more likely to be hospitalized secondary to cardiovascular disease, 12 times more likely to be hospitalized due to end-stage renal failure, and 20 times more likely to be hospitalized for limb amputation than those without diabetes. Adults with T2D are reported to see family physicians twice as often and specialists up to three times as often compared to those without diabetes and stay longer in hospitals once admitted (Government of Canada, 2018). A US population-based study by Simon et al. (2005) utilizing survey and health record examination found that individuals with three or more diabetes-related complications incurred a two-fold increase in acute medical costs compared to diabetics without complications. Comorbid depression amongst adults with T2D results in higher healthcare utilization as these individuals seek out more medical services and treatments than the general population or those who have diabetes without depression (Gaitonde & Shaya, 2016).

Wielgosz et al. (2018) performed an analysis of the 2013-2014 hospital separations discharge abstract database (where ‘separation’ refers to the process by which care for an admitted patient ceases) in all Canadian jurisdictions, excluding Quebec, where diabetes was the primary diagnosis to determine the number and proportion of comorbid conditions in hospitalized Canadians. Findings demonstrated the increased prevalence and subsequent use of healthcare services by those with diabetes. Specifically, in 2013-2014 in Canada, there were 30,422 hospital separations where diabetes was the main diagnosis. Over this time period, those with diabetes incurred an average admission length of 9.9 days compared to 6.4 days for all hospitalizations excluding diabetes, and an average of 3.8 comorbid conditions were present for each diabetes hospital separation compared to 2.5 for hospitalizations without diabetes as the main diagnosis.

Individuals with diabetes face large out-of-pocket financial costs for diabetes management which are not covered by the public system in Canada. For example, people with diabetes can have medical costs up to three times higher than those without diabetes (Patel, Piette, Resnicow, Kowalski-Dobson, & Heisler, 2016). Proportionally, members of lower socioeconomic status bear the highest burden related to self-funding and often, in addition to other health determinants, they are unable to afford effective management strategies (Diabetes Canada, 2018) and are less likely to have third-party insurance to cover costs not included within the public healthcare system (Barnes & Anderson, 2015). As a result, these individuals tend to have poor glycemic control (Walker et al., 2014) which may increase costs to the healthcare system due to the increased occurrence of diabetic and comorbid complications; the increased complexity of diabetes management and the higher costs of care may have contributed to this trend (Walker et al., 2014).

As can be seen, those with T2D have increased healthcare utilization compared to the general population. The increasing costs associated with diabetes management and concomitant comorbid conditions contribute to this cost which, when coupled with an aging population that is living longer with this disease, accounts for this growth. Bilandzic and Rosella (2017) conducted a study designed to estimate the future direct health care costs in Canada over a 10-year period (2012-2022) related to diabetes. Results demonstrated that during this 10-year period 2.15 million new cases of diabetes will be diagnosed incurring $15.36 billion in health care costs. Acute hospitalization will account for $6.64 billion of the costs, followed by physician costs ($3.37 billion), and the costs of prescription medications and assistive devices ($2.60 billion). Outpatient services ($0.83 billion), long-term care ($1.05 billion), and other inpatient services ($0.88 billion) contribute to the remaining cost. If left unmanaged, it is not unreasonable to anticipate future cost growth and burden on the healthcare system secondary to T2D.

Healthcare Utilization and Activity Behaviours in Type 2 Diabetes

It is well known physical activity has many benefits to overall health and reduction in mortality and morbidity in people with T2D (Nguyen, 2007; Colberg et al., 2016). Additionally, the presence of a sedentary lifestyle may produce or exacerbate chronic health and comorbid conditions, preclude physical activity, and lead to obesity that impacts healthcare utilization (Li et al., 2015). Karl et al. (2018) conducted a large population-based cross-sectional study utilizing data from the German 2013-2014 KORA FF4 study to examine physical inactivity and direct healthcare costs using both self-report and accelerometer assessed measures of physical activity. Findings demonstrated that participants with very low device assessed MVPA incur higher healthcare costs compared to participants with higher levels of MVPA suggesting appropriate physical activity can be effective in reducing these costs. Li et al. (2015) found 150 min/week of MVPA significantly lowers the chance of admission to hospital and, if admitted, a shorter hospital stay suggesting that reducing sedentary time and increasing physical activity in adults with T2D may have significant health care cost savings. Additionally, Plotnikoff et al. (2008) discerned a link between meeting MVPA guidelines and reduced healthcare utilization, which suggests replacing sedentary time with MVPA may ameliorate the harmful effects of sedentary time and the potential associated increase in healthcare utilization.

Increasing physical activity and reducing sedentary time in this population may have significant cost savings to the Canadian healthcare system. In order to obtain these cost savings, changes to current diabetes primary care practices must occur. Li et al. (2010) conducted a review of 56 studies examining the cost-effectiveness of various interventions for the management of T2D and determined lifestyle interventions, or health promotion interventions, were achievable, beneficial, and cost-effective. Specifically, intensive lifestyle modification focusing on nutritional therapy and education for adults with T2D was found to be very cost-effective saving $84,700/quality adjusted life years (QALY). Nguyen et al. (2007) found that older adults with diabetes who engaged in community-based exercise programming had significantly fewer hospitalizations one year after study initiation compared to those who declined to participate (13.5% vs 20.9%, respectively). Healthcare costs for those who engaged in exercise programming were 37% lower than control subjects and 41% lower than those who did not use exercise programming.

A study by Johnson et al. (2015) utilized the Alberta based Healthy Eating and Active Living for Diabetes (HEALD) intervention, an exercise specialist-led pedometer program, to determine if increasing the number of steps per day in adults with T2D would reduce healthcare costs associated with this disease. The cost-effectiveness of this intervention was determined through exploration of the incremental cost, defined as the difference in average cost and average steps (incremental health effect) per participant between study groups. It was determined that utilizing an exercise specialist-led group program in a primary care setting incurred more cost than usual care (an incremental cost of $111/1000 steps) and was more effective than usual care and provided better health outcomes (measured in daily steps). Of note, it was determined an incremental cost of $111/1000 steps was well within the threshold for a cost-effective intervention suggesting if society was willing to pay for such interventions, the benefit to overall health of adults with T2D would be greater and, subsequently, health costs associated with this disease may decrease (Mayor, 2015).

These findings are consistent with longitudinal studies identifying physical inactivity as contributory to higher health-related costs (Peeters et al., 2014) suggesting inactivity is non-exclusive regarding its effects on health yet may be more detrimental when coupled with disease states, such as T2D. Rosenberg et al., (2015) determined older adults over age 65 who were overweight and obese that had diabetes or CVD in conjunction with poor self-rated health had increased sitting time (5.96 to 6.53 h/day) compared to healthy individuals; healthcare costs were found to increase approximately $126 (US)/additional hour of sitting. This information highlights sedentary time as an important health indicator in adults with T2D that can also be used to determine associated healthcare costs.

Increasing daily unstructured physical activity alone may be enough to help offset increased healthcare utilization (Katzmarzyk, 2010; Owen, Healy, Mathews, & Dunstan, 2010; Dunstan et al., 2012; Duvivier et al., 2013). Physical activity in adults with T2D improves overall health and physical and mental functioning, and can significantly reduce healthcare costs and utilization (Nguyen et al., 2007). Reducing the burden on the public health system by intervening before diabetes and its associated complications become overwhelming is paramount for successful T2D mitigation strategies (Hutchinson et al., 2015).

Summary

Type 2 diabetes is a preventable chronic disease with increasing prevalence in Canada secondary to an aging population, improved diabetes treatment options, insufficient physical activity levels, and high levels of sedentary time. Physical activity plays an important role in the management of T2D and, when recommended levels are met, ameliorates the harmful effects of this disease. However, despite the known benefits of physical activity, high levels of sedentary time in this population persist and thus contributes to poor health outcomes. As a result, adults with T2D often have increased healthcare costs and levels of utilization compared to those without T2D which results in significant economic consequence to society and healthcare systems. Most studies pertaining to healthcare utilization and T2D have only examined MVPA and have not considered sedentary time. As discussed, MVPA behaviour contributes to a very small proportion of daily behaviour in adults with T2D. In order to fully comprehend the impact of activity behaviours associated with T2D on healthcare utilization, it is important to examine both MVPA and sedentary behaviour together.

Primary Objective and Hypothesis

The primary objective of this study is to examine cross-sectional associations of device-measured physical activity (i.e., light, moderate, and vigorous physical activity, steps, and sedentary) time with healthcare utilization (i.e., number of physician claims, number of emergency department visits, number of ambulatory care visits, and number of hospitalizations) among a sample of adults with T2D in Alberta, Canada. It was hypothesized that compared to lower levels of physical activity and higher levels of sedentary time, higher levels of physical activity (steps and MVPA) and lower levels of sedentary time will result in lower levels of healthcare utilization.

Chapter 2. Methods and Procedures

Research Design and Data Source

This was a secondary analysis using a cross-sectional observational approach to examine the associations between daily physical activity (steps, MVPA, and sedentary time) and healthcare utilization in adults with T2D using year-three data from the Alberta Caring for Diabetes (ABCD) cohort study (Al Sayah et al., 2015) and accelerometer data from a subsequent sub-study (Mathe et al., 2017). In total, 1942 participants who completed year three assessments of the ABCD study were invited to participate in the sub-study, 1315 of which responded, 534 were accepted, and 237 participants were included in the study via quota sampling. Quota sampling was done according to the distribution of participants across the five health zones in Alberta: North, Edmonton, Central, Calgary, and South. Of these 237 participants, N=163 fulfilled the accelerometer study requirements and provide the accelerometer and healthcare utilization data used in this study.

Data Collection

The ABCD cohort study examined medical, behavioural, and psychosocial factors known or thought to contribute to, mediate, or compound living with T2D (Al Sayah et al., 2015). A survey incorporating previously validated measures and standardized scales was developed for use with this population. Data was collected through use of mailed, self-administered questionnaires with follow-up measurements occurring on an annual basis for the first three years and biannually thereafter. Additional important variables that characterized this population were identified after one year of data collection and adjustments to the survey and subsequent data collection occurred for year-three assessments (Al Sayah et al., 2015). Year three ABCD study participants who consented to participate in accelerometer assessment were mailed a study package, including an accelerometer and logbook to record non-wear time during the day (Mathe et al., 2017).

Alberta's Caring for Diabetes Cohort summary

Sociodemographic Characteristics. Sociodemographic information was obtained using questions based on the Public Health Agency of Canada – Survey on Living with Chronic Diseases in Canada (PHAC-SLCDC) (Al Sayah et al., 2015). The average age of participants for the ABCD cohort (N=2040) was 64.4 years (SD ± 10.7), 45% were female, 91% were Caucasian, 14% had less than high school education, 57% were unemployed/retired, and 29% were within the lowest income category (<$40,000/yr.). Additionally, 76% of participants were deemed physically inactive based on self-report measure and 10% actively smoked. One-third of participants reported diabetes duration ≥ 10 years with the average duration being 12.3 years (SD ± 10.0) (Al Sayah et al., 2015).

Medical Characteristics. Medical information was obtained using questions based on the PHAC-SLCDC survey and included diabetes duration, family history of diabetes, comorbidities, diabetes complications, and hypoglycemic episodes (Al Sayah et al., 2015). Additional medical information was obtained through use of personal health numbers to link healthcare utilization data through the Data Integration, Measurement and Reporting unit within Alberta Health Services. Of 16 potential comorbid conditions, the average number was 4 (SD=2.3) with 88% reporting having two or more chronic conditions in addition to diabetes, the most common of which were hyperlipidemia (68%), obesity (54%), and musculoskeletal or rheumatic disorders (50%) (Al Sayah et al., 2015).

Demographics. Key demographic variables included age, sex, marital status, education level, employment status, ethnicity, and total household income. Additionally, key disease-related variables included diabetes duration, family history of diabetes, comorbidities, diabetes complications, and hypoglycemic episodes. Both sets of variables were assessed using questions based on the PHAC-SLCDC survey.

Device-based Physical Activity and Sedentary Time. Device-based physical activity and sedentary time for participants of this sub-study (N=163) were assessed using the ActiGraph® GT3X+ accelerometer worn on the dominant hip over a period of seven consecutive days. The ActiGraph® GT3X+ provides precise measurements of activity counts, energy expenditure, activity intensity, MET's, and step counts (ActiGraph®, 2019). Participants were required to wear the device during waking hours except during interaction with water. Accelerometer data was processed utilizing 60-second epochs with sedentary time (<100 counts/min), LPA (100-1951 counts/min), and MVPA ($\geq$1952 counts/min) cut-offs distinguishing between daily activity behaviours (Freedson et al., 1998). A logbook provided to participants recorded non-wear time during the day. Non-wear time was defined as intervals of at least 60 minutes of zero counts. Participants were allowed two minutes of less than 50 counts/min within the non-wear interval. In order for a collection day to be valid, at least 600 minutes of device wear time with no excessive counts (>20,000/min) were required. Accelerometer data was used to indicate mean daily time spent in MVPA and prolonged periods (bouts) of sedentary time. Sedentary time was indicated by bouts of 20 or more consecutive minutes and MVPA time was indicated by bouts of 10 or more consecutive minutes following identified physical activity guidelines (Diabetes Canada, 2018).

Healthcare Utilization. Eligible participants provided written consent and their personal health number (PHN) which was used to link survey data with healthcare utilization data from Alberta Health Services (Al Sayah et al., 2015). Data for the ABCD cohort study was initially obtained via annual self-administered questionnaires over a three-year period (2012-2015) and biannually thereafter. Accelerometer data utilized in the sub-study by Mathe et al. (2017) utilized year three (2015) data from the ABCD cohort study. This information included number of physician claims (i.e. frequency of billing performed by a physician), type of physician service (i.e. family doctor or physician specialities), number of emergency department visits, number of outpatient visits (non-hospital related outpatient services, i.e. physiotherapy, massage, etc.), and the number of hospitalizations (i.e. the number of admissions to a hospital facility) (Al Sayah et al., 2015) and demonstrated the frequency of service use by each consenting participant to determine healthcare utilization practices.

Data Analysis. Descriptive statistics were used to provide information on sociodemographic and medical characteristics of participants, healthcare utilization, as well as device-based activity behaviours. First, a series of independent samples t-tests were performed comparing participant sociodemographic information of the Mathe et al. (2017) sub-study and the ABCD cohort study (2015) to assess for participant representativeness. To determine associations between healthcare utilization (i.e., number of hospitalizations, physician claims, outpatient visits, and emergency department (ED) visits) and device-measured physical activity (divided into MVPA and steps) and sedentary time, a series of unadjusted analysis of variance (ANOVA) models were performed with activity/accelerometer variables as the dependent variables and healthcare utilization variables as the independent variables. To determine if there were any significant differences between the means of healthcare utilization groups, all healthcare variables were dichotomized according to their respective median (i.e., admissions was dichotomized as '0' = no admissions and '1' = 1 or more; physician claims was ‘0’ = 4 or less and ‘1’ = 5 or more; outpatient visits was ‘0’ = 1 or less and ‘1’ = 2 or more; and ED visits was '0' = 4 or less visits and '1' = 5 or more). Pairwise comparison procedures were conducted on all significant ANOVA statistics.

Unadjusted binomial logistic regression analyses were also used to determine the independent effects of MVPA, sedentary time, and steps on healthcare utilization variables. In the first step, a series of unadjusted logistic regression models were constructed to examine the independent association between the accelerometer variable (MVPA, sedentary time, and steps) and the healthcare utilization variables. Regression models were developed with each model containing one of the healthcare utilization variables and an accelerometer variable. Each model included accelerometer weartime as a covariate. For healthcare utilization variables, the same median split protocol was used to dichotomize variables into the aforementioned groups reflecting higher and lower healthcare use. This format was found to be the most logical approach to organizing the data for interpretation as it allowed for a roughly equal sample size between groups; it should be noted ‘admissions’ had a high frequency of zero counts creating unequal group sizes, a limitation which is discussed later. Additionally, MVPA was dichotomized into two groups (meeting or not meeting 150min/week of MVPA) and then analyzed via logistic regression using aforementioned dichotomized healthcare utilization variables. This was done to understand MVPA data in respect to current activity recommendations and determine potential associations each group might have with healthcare utilization.

These ANOVA and logistic regression analyses were then adjusted with key sociodemographic and clinical characteristics demonstrated to be clinically relevant in other studies [age, sex, comorbidities (dichotomized using a median split protocol into ‘less than two’ or ‘more than two’), and income (less than $60,000 or more than $60,000] in addition to wear time. These variables, in addition to depression, pain, and diabetes duration, were first analyzed for interactions through multiple regression and tests for multicollinearity. No evidence of confounding was noted through multiple regression analyses. Additionally, multicollinearity analyses demonstrated variance inflation factors (VIF) below two suggesting limited correlation between predictor variables and thus no effect on model interpretation (Laerd Statistics, 2015). All analyses were performed using SPSS v.25.

Chapter 3. Results

Participant Characteristics

Five health zones of Alberta (North, Edmonton, Central, Calgary, and South) were targeted for an approximate 1% recruitment of Alberta's T2D population over a two-year period (December 2011 to December 2013). Distribution of participants was as follows: Edmonton zone (37%), Calgary zone (32%), Central zone (21%), North zone (7%), and South zone (3%). To determine representativeness of the population sample in this study, comparison to participants of the Survey for Living with Chronic Diseases in Canada (SLCDC) occurred (Statistics Canada, 2011). Findings demonstrated similar population characteristics but participants in the ABCD cohort were more likely to be white and less educated. In comparison to 380 patients with diabetes identified in the Heath Quality Council of Alberta (HQCA) survey (Health Quality Council of Alberta, 2013), ABCD cohort participants were more likely be older, Caucasian, and have similar income, however, the ABCD cohort was more representative across education levels. In comparison to the Alberta Diabetes Atlas (Johnson & Balko, 2011a), similar age and gender dominance (male) was identified.

Information pertaining to sub-study participant demographic characteristics and past medical history are presented in Table 1 and Table 2, respectively. Of the 163 participants that wore an accelerometer, the mean age was 56.3 (SD ± 9), the majority were male (n=88, 54%), Caucasian (n=145, 88.9%), and the average BMI was 33.9 (SD ±7.2). Further, n=128 (78.5%) were married/common-law, the majority were not employed (n=91), and n=81 (49.7%) had post-secondary education. Income was more distributed with n=33 (20.2%) making less than $40,000/year, n=50 (30.6%) making between $40,000 - $80,000, and n=54 (33.1%) making more than $80,000; n=26 (15.9%) refused to respond to this question. The mean age of diagnosis was

52.3 (SD ± 10.2), n=95 (58%) had a history of smoking with n=84 (51.5%) having at least two medical comorbidities. Hyperlipidemia (n=104, 63.8%), hypertension (n=88, 54%), obesity (n=87, 53.4%), and joint problems (n=81, 50.3%) were the main comorbid conditions among participants.

Healthcare Utilization

Descriptive statistics for healthcare utilization variables are presented in Table 3. In total, participants had an average hospital admission prevalence of 0.2 days (SD ± 0.6), 5.1 (SD ± 4.0) physician claims, 1.7 (SD ± 3.2) outpatient visits (i.e. physiotherapy, ambulatory care clinics), and 5.3 (SD ± 4.0) emergency department visits. Additionally, visits to general practitioners/family doctors accounted for 85.3% of total physician visits. Internal medicine physicians accounted for 6.1%, ophthalmologists for 4.3%, and emergency, optometrist, and podiatrist physicians each accounted for 1.2%. Finally, general surgeon's account for 0.6% of physician visits.

Physical Activity

Descriptive statistics for physical activity (accelerometer variable) characteristics are presented in Table 4. Participants had an average of 6.8 (SD ± 1.3) valid wear days with an average of 840.5 (SD ± 81.1) minutes of wear time/valid day. Participants had an average of 6019 (SD ± 2973.3) daily steps, spent 274.3 (SD ± 90.3) minutes in light intensity activity, 22.1 (SD ± 19.6) minutes in moderate intensity activity, 0.2 (SD ± 0.8) (12 seconds ± 45 seconds) minutes in vigorous intensity activity, and 22.3 (SD ± 19.7) minutes in MVPA intensity activity during a valid wear day. Participants were sedentary for 544 (SD ± 88.1) minutes per day with 249.7 (SD ± 99.8) minutes spend in prolonged bouts of sedentary time (>30minutes).

MVPA. ANOVA and logistic regression results for activity behaviours can be found in tables five through nine respectively. Unadjusted ANOVA models for MVPA and health care utilization suggested no significant findings between MVPA and dependent health care utilization variables: hospital admissions [no admission vs one or more admissions (M_{diff} = 7.1, 95% CI: -3.4 – 17.6, p = 0.185)], physician claims [four or less vs five or more (M_{diff} = -0.3, 95% CI: -6.4 – 5.9, p = 0.934)], outpatient visits [one or less vs two or more (M_{diff} = -0.8, 95% CI: -7.4 – 5.8, p = 0.806)], and ED visits [four or less vs five or more (M_{diff} = 0, 95% CI: -6.0 – 6.1, p = 0.995)]. Adjusted ANOVA models for MVPA and health care utilization variables suggested no significant findings between MVPA and health care utilization: hospital admissions [no admission vs one or more admissions (M_{diff} = 4.5, 95% CI: -5.2 – 14.3, p = 0.363)], physician claims [four or less vs five or more (M_{diff} = 2.8, 95% CI: -2.8 – 8.5, p = 0.327)], outpatient visits [one or less vs two or more (M_{diff} = -0.5, 95% CI: -6.5 – 5.5, p = 0.864)], and ED visits [four or less vs five or more (M_{diff} = 4.5, 95% CI: -5.2 – 14.3, p = 0.363)].

Logistic regression suggested meeting or not meeting 150 min/week of MPVA did not produce significant associations in unadjusted models: hospital admissions (OR = 1.18, 95% CI: 0.26 - 5.40, p = 0.827), physician claims (OR = 0.79, 95% CI: 0.41 - 1.55, p = 0.495), outpatient visits (OR = 0.77, 95% CI: 0.39 - 1.63, p = 0.531), and ED visits (OR = 0.85, 95% CI: 0.43 - 1.65, p = 0.624). Similarly, no significant findings were observed in adjusted models: hospital admissions (OR = 1.10, 95% CI: 0.23 - 5.34, 0.912), physician claims (OR = 0.92, 95% CI: 0.46 - 1.86, p = 0.918), outpatient visits (OR = 0.71, 95% CI: 0.34 - 1.51, p = 0.395), and ED visits (OR = 0.98, 95% CI: 0.49 - 1.96, p = 0.930).

Sedentary Time. Unadjusted ANOVA models for sedentary time and health care utilization suggested no significant findings were present between sedentary time and dependent health care utilization variables: hospital admissions [no admission vs one or more admissions (M_{diff} = -7.5, 95% CI: -54.7 – 39.8, p = 0.754)], physician claims [four or less vs five or more (M_{diff} = -23.4, 95% CI: -50.6 – 3.7, p = 0.091)], outpatient visits [one or less vs two or more (M_{diff} = -5.6, 95% CI: -35.1 – 23.8, p = 0.705)], and ED visits [four or less vs five or more (M_{diff} = -24.2, 95% CI: -51.3 – 2.9, p = 0.079)]. Adjusted ANOVA models for sedentary time and health care utilization variables suggested no significant findings between sedentary time and healthcare utilization: hospital admissions [no admission vs one or more admissions (M_{diff} = -7.6, 95% CI: -52.5 – 37.1, p = 0.736)], outpatient visits [one or less vs two or more (M_{diff} = -3.8, 95% CI: -31.4 – 23.8, p = 0.785)], and ED visits [four or less vs five or more (M_{diff} = -23.8, 95% CI: -49.3 – 1.8, p = 0.068)]. However, for physician claims (four or less vs five or more), significance was approached (M_{diff} = -24.9, 95% CI: -50.6 – 0.87, p = 0.058).

Steps. Unadjusted ANOVA models for steps and health care utilization suggested no significant findings between steps and dependent health care utilization variables: hospital admissions [no admission vs one or more admissions (M_{diff} = 1255.5, 95% CI: -328.5 – 2839.5, p = 0.119)], physician claims [four or less vs five or more (M_{diff} = 251.8, 95% CI: -673.0 – 1176.6, p = 0.592)], outpatient visits [one or less vs two or more (M_{diff} = -195.1, 95% CI: -1189.6 – 799.4, p = 0.699)], and ED visits [four or less vs five or more (M_{diff} = 371.4, 95% CI: -549.9 – 1292.7, p = 0.427)]. Adjusted ANOVA models for steps and health care utilization suggested no significant findings were observed between steps and hospital admissions [no admission vs one or more admissions (M_{diff} = 590.8, 95% CI: -792.2 – 1973.8, p = 0.400)] or outpatient visits [one or less vs two or more (M_{diff} = 24.5, 95% CI: -829.1 – 878.1, p = 0.955)]. However, for physician claims, a significant difference was observed between participants with four or less claims compared to those with five or more in a year (M_{diff} = 782.9, 95% CI: -13.0 – 1578.7, p = 0.054).

Similarly, significant differences were observed for ED visits in that those with four or less visits in a year had significantly higher levels of steps compared to those with five or more ED visits in a year (M_{diff} = 822.0, 95% CI: 34.5 – 1609.5, $p = 0.041$).

Chapter 4. Discussion

The primary objective of this study was to examine cross-sectional associations of device-measured physical activity and sedentary time with healthcare utilization among a sample of adults with T2D in Alberta, Canada. ANOVA and logistic regression were used to determine associations between physical activity behaviours and healthcare utilization by participants for the purpose of understanding potential associations as they may exist in the larger T2D population. Study findings revealed MVPA and sedentary time were not associated with healthcare utilization, but daily step count was associated suggesting those individuals with higher step counts utilized healthcare services less than those with lower step counts.

Healthcare Utilization and MVPA

In this study, participants had an average of 22.3 minutes (SD $\pm$ 19.7) per day of MVPA, or 156.4 minutes (SD $\pm$ 19.7) per week, with n=98 not meeting recommended MVPA and n=65 meeting recommended MVPA criteria of 150min/week (Diabetes Canada, 2018). These results demonstrated that adults with T2D have low levels of MVPA and the majority do not meet recommended MVPA criteria; this may be linked to poor health outcomes and thus higher levels of healthcare utilization. The results of this study are similar to other studies using accelerometers to determine MVPA in adults with T2D where recommended MVPA levels were not achieved. De Greef et al. (2011) and Cichosz et al. (2013) assessed MVPA levels in adults with T2D using accelerometers and found, on average, participants engaged in MVPA for only 14 minutes per day (98 min/week). Our results are clinically important as they demonstrate the tendency of this population to have low levels of MVPA, findings consistent with previous research. As previously described, Karl et al. (2018) found study participants with very low device-assessed MVPA incur higher healthcare costs compared to participants with higher levels of MVPA. Li et al. (2015) found 150 min/week of MVPA significantly lowers the chance of admission to hospital and, if admitted, shorter hospital stays. Similarly, Plotnikoff et al. (2008) found adults with T2D who met physical activity guidelines had fewer hospital visits, physician claims, and general practitioner visits than those who did not meet physical activity guidelines. The challenge with comparing MVPA results of this study is that a majority of research thus far has utilized self-report MVPA, which as discussed earlier, has limitations (Sallis & Saelens, 2000; Shephard, 2003; Hidding, Altenburg, Mokkin, Terwee, & Chinapaw, 2017) which makes it difficult to associate findings to other studies due to the difference in methods.

Sedentary Time and Healthcare Utilization

In this study, participants had 544 minutes (SD ± 88.1) of sedentary time per day and 249.7 minutes (SD ± 99.8) of prolonged sedentary time (30+ min bouts). The sedentary time prevalence in this study is similar to findings from previously described research that also found increased levels of sedentary time in adults with T2D (Healy et al., 2008b; Bankoski et al., 2011; Yates et al., 2015; Falconer et al., 2015; Balducci et al., 2017). Using accelerometers, Cichosz et al. (2013) found that adults with T2D had a mean sedentary time of 926 minutes (SD ± 44) per day (16hr) over a testing period of 608 days compared to the control group. Similarly, Hamer et al. (2014) used accelerometers to assess activity level in adults with T2D and found that of 878 minutes of wear time, participants were sedentary for 660 minutes, slightly more than what was observed in this study but on par with findings and clearly establishes a concerning trend.

Our study found sedentary time was not associated with healthcare utilization, although it should be noted significance was approached with the ANCOVA model comparing participants with four or less physician claims to five or more suggesting participants with lower levels of sedentary time may have fewer physician claims; this is an area that should be further explored with a larger sample size. Additionally, study findings may be of clinical significance because elevated levels of sedentary time, irrespective of MVPA time, have been associated with poor health outcomes and increased healthcare utilization in this population suggesting that adults with T2D should at a minimum decrease time spent sedentary if recommended levels of MVPA cannot be achieved (Katzmarzyk et al., 2009; Cooper et al., 2014). On review of the literature, a majority of studies have used accelerometers to assess the effect of sedentary time on various health indicators (i.e. glycemic index, cardiometabolic markers) in adults with T2D (Healy et al., 2008a; Healy et al., 2008b; Fritschi et al., 2016; Gintz et al., 2018) but few have linked this activity behaviour to higher levels of healthcare utilization using accelerometers. Recently, Dohrn et al. (2019) positively associated increased levels of sedentary time with higher levels of hospitalization and length of stay in a group of 1,220 men and women who had a main diagnosis of either cardiovascular disease, cancer, type-2 diabetes, dementia, obesity, or depression. Findings demonstrated higher levels of physical activity were inversely associated with hospital visits while higher levels of sedentary time doubled the risk of increased hospital days during an admission. While this study was not specific just to adults with T2D, results can be extrapolated to this population and results demonstrate the impact physical activity habits may have on healthcare costs. No further research was identified on review of the literature associating healthcare utilization to sedentary time using accelerometers in adults with T2D, which suggests there is a significant research gap in this area making it difficult to compare findings of this study in a reliable manner.

Steps and Healthcare Utilization

Participants had an average 6,019 (SD±2,973) steps per day, and steps were associated with healthcare utilization. Higher step counts were associated with lower physician claims and emergency department visits; both had significantly reduced levels after adjusting for covariates indicating that increased step count per day is beneficial for reducing these aspects of healthcare utilization. To date, there are no other studies that have studied step counts and healthcare utilizations. However, research does strongly suggest walking can potentially have significant positive effects on mortality in this population. A recent observational study by Saint-Maurice et al. (2020) identified higher number of daily steps was associated with lower all-cause mortality, cardiovascular disease mortality, and cancer mortality. Comparatively, participants in their study (n=4,840) had a higher mean number of daily steps (n=9,124) with a similar number of hours per day of wear time (approximately 14 hours/day). When examined in the context of this study, lower levels of steps per day were beneficial for healthcare utilization while higher levels of steps per day had the added benefit of improved health outcomes. Lee et al. (2019) identified that an average of 4,400 steps per day may still produce significantly lower mortality rates up to a value of approximately 7,500 steps per day, but no information regarding the effect on healthcare utilization at these lower levels can be discerned. While their study focused on older woman, the results are significant, may be extrapolated to both genders, and corroborate findings from studies focusing on T2D. Hansen et al. (2020) identified similar findings and concluded all-cause mortality was reduced by half when comparing least active participants against the next quartile, a difference equivalent of approximately 2,200 steps per day.

These findings corroborate the importance of increasing daily steps in those who are least active for improving health and thus reducing healthcare utilization. Sari (2009) identified physical inactivity as a significant contributor to increased healthcare utilization amongst those with chronic diseases in Canada, of which T2D was a significant contributor. In total, it was determined a physically inactive person will spend 38% more days in hospital, have 5.5% more family physician visits, and 13% more specialist visits when compared to active individuals. A study by Hardy et al. (2011) identified increased healthcare costs in those who self-reported difficult or inability in walking ¼ mile. Specifically, total annual healthcare costs were $2,773 higher in those with difficulty and $3,919 higher in those who were unable to walk ¼ mile compared to those who reported no difficulty. Further, for every 100 persons, older adults who reported difficulty walking ¼ mile at baseline were found to have, on average, an additional 14 hospitalizations and those were unable to walk ¼ mile had on average an additional 22 hospitalizations when compared to those who reported no difficulty. As described previously, a study by Johnson et al. (2015) determined that walking is a cost-effective intervention that is more effective than traditional care and incurs better health outcomes in adults with T2D. These improved health outcomes associated with walking translate to a potential decrease in health costs associated with this disease (Mayor, 2015).

Depression, Pain, and Diabetes Duration

Depression has been shown to have a strong association with T2D and levels of physical activity (Cardenas et al., 2017), is more prevalent in those with diabetes than in the general population (Nouwen et al., 2010; Darwish et al., 2018), and has been associated with increased morbidity, mortality, and healthcare utilization (Hussain et al., 2018; Huang et al., 2019) in this population. Similarly, pain (i.e. neuropathies) may negatively affect capacity for physical activity and increase healthcare utilization in this population (Kuznetsov et al., 2013) while diabetes duration, as a potential indicator of disease severity, may precipitate the development of potential comorbid conditions further impacting these variables (Maddigan et al., 2003).

Depression, pain, and diabetes duration were recognized as potential confounders in this study based on previous research and clinical significance. Using hierarchical regression, no confounding was noted with inclusion of these variables. Additionally, after initial adjusted ANOVA and logistic regression testing was completed, the models were run again with depression, pain, and diabetes duration included to assess for any changes to the model results, and again, no changes were observed and model interpretations remained the same. Due to the risk of unnecessary adjustment and model over-specification, the models presented in this study did not include these variables.

The disagreement between findings of this study and those of prior research (Maddigan et al., 2003; Kuznetsov et al., 2013; Cardenas et al., 2017; Hussain et al., 2018; Huang et al., 2019) may be related to the potential bias present in this study. Participants in this study volunteered to participate suggesting they may have lower levels of depression so are more likely to exercise or, conversely, they exercise more so are less depressed where both alternatives may result in reduced healthcare utilization. Similarly, if participants had lower levels of pain, physical activity engagement may not be impacted and thus healthcare utilization may be lower. Finally, if study participants were more likely to engage in physical activity because of lower levels of depression and pain, the effects of diabetes duration and the resultant impact on comorbid conditions and disease severity may be reduced further lowering prevalence of healthcare utilization.

In conclusion, this present study identified that increased activity in the form of walking may lower some aspects of healthcare utilization, and thus healthcare costs, and, when examined in the context of reviewed literature, improve overall health and lower all-cause mortality in adults with T2D.

Strengths and Limitations

A key strength of this study is the examination of both sedentary time and physical activity on healthcare utilization. Most previous research has examined MVPA only and did not assess for sedentary time, which has been shown to be predominant in this population (Healy et al. 2008b; Bankoski et al., 2011; Cooper et al., 2012; Falconer et al., 2015; Healy et al., 2015; Yates et al., 2015; Berg et al., 2016; Balducci et al., 2017; Mathe et al., 2017). The use of accelerometer data is also a strength as it allows for increased precision and accuracy of data collected (Shephard, 2017). Examining different categories of healthcare utilization also serves to provide an accurate representation of the different areas that may have increased rates of utilization by this population allowing for more targeted management strategies in future intervention-type research.

A key limitation exists regarding the period during which data used in this study was collected. Healthcare utilization data was obtained over a two-year period while accelerometer data was obtained from year three of the ABCD study (i.e., outside of the two-year window of healthcare utilization. There is a lack of consistency between the timeframe of data collection for key variables used in this study. This discrepancy may make it difficult to accurately determine potential associations between physical activity variables and healthcare utilization variables due to the relatively large difference in time during which information was obtained. Prevalence of healthcare utilization that occurred earlier in the two-year time period may not be the same as the prevalence that occurred during the time period during which accelerometer data was obtained.

It can be difficult to distinguish the effects of medical management, such as medications, from health behaviours, such as physical activity. A person who is not physically active but has an appropriate medication regime may have a similar outcome to an individual who is more active and less dependent on medications (Brown et al., 2016). In this study, accelerometers were worn at the waist so distinguishing between sitting and standing was not possible and may affect results of the sedentary time assessment. Recent research has also indicated that when adults with T2D are provided with an accelerometer or pedometer, they are more likely to increase their daily step count/physical activity level suggesting that levels of activity presented in this study may be elevated above what would be normal for these participants (Baskerville, Ricci-Cabello, Roberts, & Farmer, 2017).

Risk of selection bias can also occur presenting a disadvantage of this research design (Supino & Borer, 2012). An under-representation of non-white minorities and aboriginal populations occurred throughout the recruitment process for the ABCD study mitigating representation of these demographics that have a high propensity for T2D development. Additionally, an over-representation of ABCD study participants from the Central health zone of Alberta may have occurred affecting generalizability and representativeness of this study (Al Sayah et al., 2015). The sample size in this sub-study was quite small compared to the sample size of the ABCD cohort study which may reduce its power and effect external validity (Carlson & Morrison, 2009). A series of t-tests were performed comparing participant sociodemographic information of the Mathe et al. (2017) study and the ABCD cohort study (2015) to assess for participant representativeness. All sociodemographic variables (see Table 1) between the two studies were significantly different ($p < .001$) suggesting participants of this study were not representative of the larger ABCD cohort study and thus potentially not representative of the larger population, which may affect external validity and generalizability of study findings.

Additionally, participants who agreed to participate in the accelerometer study may have been predisposed to higher levels of physical activity than those who declined to participate biasing the results and potentially undermining internal validity of the study; activity levels may have been overestimated and sedentary time underestimated which would influence the results of this study. Not all participants in the ABCD study agreed to have their information linked to the

AHS database suggesting those who did may be healthier than those who declined further biasing the results and affecting internal validity; healthcare utilization by these individuals may not have been as frequent as those who declined to have their information linked. These limitations may affect the representativeness and generalizability of this study's findings.

Limitations may also exist around the significant step findings. It is unclear whether the number of steps per day and the intensity of stepping are associated with lower healthcare utilization. This study did not look at intensity of stepping, just volume, so it could be that lower volume with higher intensity may have the same effect as results found in this study. However, Saint-Maurice et al. (2020) found that intensity did not have an effect on all-cause mortality and volume was more significant in this regard, so this is an area that needs further exploration. Additionally, results of this study may have been biased if participants had higher levels of steps in a day than they would have if they had not had an accelerometer. Qiu et al. (2014) suggest that adults with T2D who are provided with an accelerometer or pedometer will have increased daily step count due to the motivational factor associated with use of these devices. Their study determined an increase of approximately 1,822 steps when participants were provided with an accelerometer, which lends support to the potential for bias in this study but also provides insight regarding a potential method to increase physical activity in this population.

Additionally, for some of the healthcare utilization variables, there was a limited range of values which could affect the distribution of the data and impact results: 147 participants had no admissions vs 16 who had one or more, and 112 participants had one or less outpatient visits vs 51 who had two or more. A significant limitation of this study is that levels of healthcare utilization identified may not be specific to T2D. There was no way for us to determine whether or not a participant was admitted to hospital, seeing a physician, utilizing outpatient services, or presenting to an emergency department for diabetes related concerns versus other medical conditions or concerns. This lack of specificity makes it challenging to fully understand the frequency of healthcare utilization as it pertains specifically to T2D. Finally, as this study was cross-sectional in design, the exposures and outcomes are assessed simultaneously so causation cannot be identified, only associations; results may have been different if another time period had been chosen (Carlson & Morrison, 2009). Additionally, observed relationships may be reciprocal, i.e. those participants who tend to have less healthcare utilization (they are healthier) tend to do more steps, making results more challenging to interpret.

Conclusions and Future Directions

This is one of the first studies to examine rates of healthcare utilization among adults with T2D in Alberta by examining MVPA, sedentary time, and steps concurrently using accelerometers. Physical activity is an important part of T2D management and has been found to improve overall health in this population. It stands to reason that adults with T2D who engage in more activity, even low intensity walking, will have improved health and thus lower levels of healthcare utilization. This study was able to demonstrate that increased number of daily steps/walking may reduce some aspects of healthcare utilization in this population. A review of the literature demonstrated that this population faces many barriers to engaging in and meeting MVPA criteria and that higher, more intense levels of physical activity may not be consistently achievable. Consequently, health benefits may still be achieved through increased walking, an activity that has been found to be both effective and manageable by this population.

With an aging population and increasing incidence of T2D in the adult population, research targeted specifically to T2D is needed in order to mitigate the effects of this disease on healthcare services. Research using larger samples sizes and accelerometers to assess physical activity using stronger methodology (i.e. prospective studies) is required in order to understand physical activity tendencies of this population. Using a prospective methodology will also help provide information of incidence over a given time period allowing more information regarding causation to be determined.

A majority of research has identified MVPA as necessary for this population to obtain health benefits, however, this population consistently does not meet MVPA criteria and has increased levels of sedentary time. It would be beneficial to examine changes in psychosocial characteristics of this population (i.e. quality of life, depression) in the context of physical activity behaviours to understand the interdependent relationship that may exist between them. Concurrently assessing participants for additional conditions (i.e. depression, pain) will help identify barriers to physical activity and guide future, more holistic, treatment strategies. Additionally, it would be interesting to understand what types of activities this population is more likely to participate in and explore alternative forms of activity that may yield similar beneficial results on health. Aquatic-based activities and resistance training have been shown to have positive effects on overall fitness in this population making it prudent to explore these activities in addition to other forms of low impact exercise (i.e. yoga, tai-chi). This will allow for the recognition of individual activity preference and thus development of individualized activity programming. Exploration of the efficacy and safety of alternative activities is warranted and necessary for expanding potential intervention strategies used with this population. These activity alternatives must be evidence-based and will require the scientific community to expand the type of research done with this population. Cooperation from policy makers and governmental organizations will be required for successful transition of mainstream research.

Additionally, assessment of how various activity levels (i.e. LPA, MVPA, steps, and sedentary time) affect specific diabetes related healthcare variables, such as prescriptions, should be explored. It has been well documented that adults with T2D typically present with associated comorbid conditions related to the presence of diabetes. Assessing individuals with comorbid conditions both before, during, and after an exercise intervention could provide valuable information on activity habits, and how various levels of physical activity may help control and/or reduce the negative impact of comorbid conditions by assessing the need for prescription medication. Factors such as prescription use and dosage changes while engaging in various activity levels could provide valuable insights into possible effects of physical activity on diabetes specific aspects of healthcare. Future intervention studies should examine the large percentage of adults with T2D who do not meet MVPA recommendations and explore methods to replace sedentary time with physical activity that is sustainable, such as walking. It may be worthwhile developing an MVPA sliding scale that takes into account age and diabetes duration and how these variables may limit capacity for MVPA as individuals with T2D age and spend more time with this disease. Using alternative measures for assessing MVPA, such as target heart rate, may be beneficial as this is an objective measure that can be used by individuals with T2D in the absence of more expensive and potentially cumbersome accelerometers. Such methods would also allow for assessment of activity intensity in activities where accelerometers cannot be used, i.e. aquatic-based and/or static hip movement activities, and may be more useful long term for assessment of interventional activities. Overall, this study and previous research demonstrates the need for implementation of large-scale interventions in diabetes care to support adults with T2D in initiating and maintaining increased physical activity in order to realize improved health outcomes and decreased healthcare utilization.

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Appendix A

Table 1

Participant Characteristics (N=163)

Characteristic	*N* or mean (%) or ± SD
Age (years)	56.3 ± 9.9
Age at diabetes diagnosis (years)	52.3 ± 10.2
Gender	
Male	88 (54.0)
Female	75 (46.0)
Marital status	
Never married	6 (3.7)
Married/common law	128 (78.5)
Other (separated, divorced, widowed)	29 (17.8)
Highest level of education	
High school and less	82 (50.3)
College and Higher	81 (49.7)
Current Employment Status	
Part-, full-time, self-employed	67 (41.1)
Unemployed	1 (0.6)
Other (retired, homemaker, and other)	91 (55.8)
Ethnicity	
Caucasian	145 (88.9)
Non-Caucasian	18 (11.1)
Annual Household Income (Canadian dollars)	
<$40,000	33 (20.2)
$40,000 - $80,000	50 (30.6)
>$80,000	54 (33.1)
No answer	26 (15.9)
Smoking	
Non-smoker	68 (41.7)
Current Smoker	9 (5.5)
Ex-smoker	86 (52.8)
Body mass index (kg/m^2)[a]	33.9 ± 7.2

*PA = physical activity

[a]Normal: < 25 $kg.m^{-2}$; Overweight: 25 $kg.m^{-2}$ – 29.9; Obese ≥ 30 $kg.m^{-2}$

Appendix B

Table 2

Participant Past Medical History (N=163)

Characteristic	*N* (%)
Hyperlipidemia	104 (63.8)
Obesity	87 (53.4)
Respiratory (Asthma, COPD, emphysema)	34 (20.9)
Joint problems (arthritis, gout)	81 (50.3)
Thyroid problems	43 (26.4)
Cancer	23 (14.1)
Mental health problems	29 (17.8)
Retinopathy	8 (4.9)
Blindness (partial or complete)	5 (3.1)
Cataracts	54 (33.1)
Glaucoma	9 (5.5)
Proteinuria	25 (15.3)
Renal failure	9 (5.5)
Urinary tract infections	35 (21.5)
Cardiac issues (angina, MI, CHF)	27 (16.6)
Heart surgery/Angioplasty	19 (11.7)
Hypertension	88 (54.0)
Cerebrovascular accident	9 (5.5)
Nerve damage/neuropathy	38 (23.3)
Poor Circulation	43 (26.4)

Foot or leg ulcer/infection	7 (4.3)
Gangrene/Amputation	3 (1.8)
Dental problems	24 (14.7)
Erectile dysfunction (males only)	52 (31.9)
Family history of diabetes	
Mother and/or Father	83 (50.9)
Sibling(s)	59 (36.2)
Grandparents	44 (27.0)
None	34 (20.9)
Not sure	9 (5.5)

Appendix C

Table 3

Healthcare Utilization Variables

Variable	Mean ± SD
Number of admissions	0.2 ± 0.6
Number of physician claims	5.1 ± 4.0
Number of ambulatory visits	1.7 ± 3.2
Number of ED visits	5.3 ± 4.0

Note: ED = emergency department

Appendix D

Table 4

Accelerometer Variables

Variable	Mean ± SD
Valid days of physical activity*	6.8 ± 1.3
Average wear time/valid day**	840.5 ± 81.1
Total daily counts	226655.2 ± 110231.6
Total daily steps	6019 ± 2973
Physical activity (minutes)	
Light intensity (100 to <1952 cpm[a])	274.3 ± 90.3
Moderate intensity (1952 to <5725 cpm)	22.1 ± 19.6
Vigorous intensity (5725+ cpm)	0.2 ± 0.8
Moderate or vigorous intensity (1952+ cpm)	22.3 ± 19.7
Sedentary activity (<100 cpm)	
Sedentary time	544 ± 88.1
Minutes prolonged[b]	249.7 ± 99.8
Number of 30 min+ bouts	7.0 ± 2.4

Note: all activity levels measured in minutes, vertical, and average/valid day
* 10+ hours of wear
** at least 600 minutes of device wear time, no excessive counts (>20,000/min)
[a] counts per minute
[b] accrued in 30 minute+ bouts

Appendix E

Table 5

Activity Behaviours and Admissions

Activity behaviour	No Admissions (n=147)		≥1 Admissions (n=16)		Difference†		p	95% CI
	M	SE	M	SE	M	SE		
Sedentary time	543.3	7.3	550.8	22.8	-7.6	22.7	0.736	-52.5; 37.1
MVPA	23.0	1.6	15.9	5.1	4.5	4.9	0.363	-5.2; 14.3
Steps	6134.6	243.3	4879.1	764.3	590.8	700.1	0.400	-792.2; 1973.8

Note: Data are presented as the mean (M), and SE (standard error)
CI=confidence interval
†Difference scores represent adjusted differences.
Models adjusted for wear time, age, gender, income, and number of comorbidities

Appendix F

Table 6

Activity Behaviours and Physician Claims

Activity behaviour	≤ 4 physician claims (n=88)		≥ 5 physician claims (n=75)		Difference†		p	95% CI
	M	SE	M	SE	M	SE		
Sedentary time	533.2	9.3	556.6	10.1	-24.9	13.0	0.058	-50.6; 0.87
MVPA	22.2	2.1	22.4	2.3	2.8	2.9	0.327	-2.8; 8.5
Steps	6134.9	317.7	5883.1	344.1	782.9	402.8	0.054	-13.0; 1578.7

Note: Data are presented as the mean (M), and SE (standard error)
CI = confidence interval
†Difference scores represent adjusted differences.
Models adjusted for wear time, age, gender, income, and number of comorbidities

Appendix G

Table 7

Activity Behaviours and Outpatient Visits

Activity behaviour	≤ 1 outpatient visits (n=112)		≥ 2 outpatient visits (n=51)		Difference†		p	95% CI
	M	SE	M	SE	M	SE		
Sedentary time	542.2	8.3	547.8	12.4	-3.8	14.0	0.785	-31.4; 23.8
MVPA	22.0	1.9	22.9	2.8	-0.5	3.0	0.864	-6.5; 5.5
Steps	5958.0	281.7	6153.1	417.4	24.5	432.1	0.955	-829.1; 878.1

Note: Data are presented as the mean (M), and SE (standard error)
CI = confidence interval
†Difference scores represent adjusted differences.
Models adjusted for wear time, age, gender, income, and number of comorbidities

Appendix H

Table 8

Activity Behaviours and Emergency Department (ED) Visits

Activity behaviour	≤ 4 ED visits (n=84)		≥ 5 ED visits (n=79)		Difference[†]		p	95% CI
	M	SE	M	SE	M	SE		
Sedentary time	147 (532.3)	9.5	16 (556.5)	9.8	-23.8	12.9	0.068	-49.3; 1.8
MVPA	22.3	2.2	22.3	2.2	2.7	2.8	0.341	-2.9; 8.3
Steps	6199.0	324.8	5827.6	334.9	822.0	398.7	0.041	34.5; 1609.5

Note: Data are presented as the mean (M), and SE (standard error)
CI = confidence interval
[†]Difference scores represent adjusted differences.
Models adjusted for wear time, age, gender, income, and number of comorbidities

Appendix I

Table 9

Logistic Regression Results

	Unadjusted*			Adjusted**		
Variable	**OR**	**P-value**	**95% CI**	**OR**	**P-value**	**95% CI**
MVPA guidelines met/not met*						
Hospitalizations	1.18	0.827	0.26; 5.40	1.10	0.912	0.23; 5.34
Physician Claims	0.79	0.495	0.41; 1.55	0.92	0.918	0.46; 1.86
Outpatient visits	0.77	0.531	0.39; 1.63	0.71	0.395	0.34; 1.51
Emergency visits	0.85	0.624	0.43; 1.65	0.98	0.930	0.49; 1.96

Note: OR = odds ratio, CI = confidence interval, MVPA = moderate vigorous physical activity
* unadjusted models included wear time
** models adjusted for wear time, age, gender, income, and number of comorbidities
[a] MVPA criteria met/not met based on 150min/week of MVPA