The Association of Physical Activity and Health-Related Quality of Life in Adults with Type 2 Diabetes

by

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ABSTRACT

Physical activity is a key component of type 2 diabetes management, and is associated with numerous health benefits for individuals with type 2 diabetes. In the general adult population, physical activity participation is associated with better health-related quality of life. The primary objective of this project was to explore the relationship between physical activity and health-related quality of life (HRQL) in adults with type 2 diabetes. Two studies were conducted: the first study used a cross-sectional design to investigate this relationship in the Alberta's Caring for Diabetes cohort, and the second study used a longitudinal design to assess the relationship between physical activity and change in HRQL. Previous cross-sectional studies have shown positive relationships between physical activity and HRQL, but very few longitudinal studies have been performed. In our cross-sectional study, we saw positive associations between meeting recommendations for physical activity and HRQL and also demonstrated a positive association between higher levels of weekly physical activity and scores on the physical components of HRQL. In our longitudinal study, we demonstrated a significant positive association between meeting physical activity recommendations and HRQL scores on the physical functioning, vitality and general health dimensions. We also showed that participation in physical activity is associated with maintenance of HRQL over one year. The results from this project provide strong support for the current recommendations for physical activity for type 2 diabetes patients in Canada, and indicate that individuals with type 2 diabetes may experience better HRQL by participating in regular leisure-time physical activity.

PREFACE

The manuscripts presented in this thesis are the work of Danielle M. Thiel, in collaboration with her co-authors. D.M. Thiel was responsible for formulating the research questions, completing the data analyses, interpreting the results and writing the manuscripts. F. Al Sayah was responsible for data collection, and contributed to manuscript edits. J. Vallance and S.T. Johnson contributed to manuscript edits. J.A. Johnson was the supervisory author, and was involved with both concept and manuscript formation.

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LIST OF ABBREVIATIONS

ABCD	Alberta's Caring for Diabetes Project
BMI	Body Mass Index
CDA	Canadian Diabetes Association
CI	Confidence Interval
CID	Clinically Important Difference
GLTEQ	Godin Leisure-Time Physical Activity Questionnaire
HRQL	Health-Related Quality of Life
MCS	Mental Component Summary Score
MI	Multiple Imputation
MVPA	Moderate-Vigorous Physical Activity
OR	Odds Ratio
PA	Physical Activity
PCS	Physical Component Summary Score
SD	Standard Deviation
SE	Standard Error
WHO	World Health Organization

CHAPTER 1.

INTRODUCTION

1.1 BACKGROUND

Type 2 Diabetes

Over 2.4 million Canadians (7.6% of the population) currently suffer from diabetes mellitus (1). The prevalence of diabetes roughly doubled in Canada between 2000 and 2010, according to data from the Canadian Chronic Disease Surveillance System (1). Recent increases in the prevalence rate of diabetes have been linked to many factors including the aging population, rising obesity rates and increasingly sedentary lifestyles. In 2010, the cost of diabetes to the Canadian health care system was approximately $12.2 billion, and the direct cost of the disease accounted for 3.5% of health care spending (2). With the rising prevalence of diabetes in Canada, these costs are estimated to increase by an additional $4.7 billion by 2020 (2).

There are three types of diabetes mellitus: type 1 diabetes, type 2 diabetes and gestational diabetes, with type 2 diabetes constituting over 90% of cases. Type 2 diabetes is a metabolic disorder characterized by hyperglycaemia and insulin resistance. There are multiple factors associated with an elevated risk of developing type 2 diabetes, including older age, overweight or obesity, sedentary behaviour, high blood pressure, high cholesterol, cardiovascular disease, as well as genetic factors including ethnicity and family history (3). Type 2 diabetes is typically diagnosed in adults over 40 years of age, but prevalence rates in children and adolescents have risen in recent years (1,2). Individuals with type 2 diabetes have an increased risk of developing serious long-term complications, including kidney disease, cardiovascular disease, neuropathy and retinopathy (4). Furthermore, prevalence of mental health disorders, particularly depression, are significantly higher in individuals with type 2 diabetes than in the general population (5).

Physical Activity for Type 2 Diabetes

Physical activity is defined by the American College of Sports Medicine as “bodily movement produced by the contraction of skeletal muscle that substantially increases energy expenditure” (6). This definition recognizes that many types of physical movement can have a positive effect on physical fitness, morbidity and mortality (6). The current Canadian Physical Activity Guidelines for Adults encourage all Canadians aged 18-64 to accumulate at least 150 minutes of moderate- to vigorous-intensity aerobic physical activity per week, in bouts of 10 or more minutes, plus muscle and bone strengthening activities at least two days per week (7). Adults aged 65 years and older are also encouraged to meet these guidelines, in order to achieve health benefits and improve functional abilities (7). However, despite the widespread acceptance of physical activity as a component of a healthy lifestyle, only a small portion of the population adheres to published guidelines.

Both physical inactivity and sedentary lifestyles are associated with an increased risk of type 2 diabetes, and participation in physical activity is one of the key strategies for managing type 2 diabetes. The Canadian Diabetes Association (CDA) provides guidelines for physical activity for type 2 diabetes patients that mirror the guidelines for the general population. The CDA recommends that type 2 diabetes patients accumulate at least 150 minutes of moderate-vigorous physical activity (MVPA) over at least three days in a week, with no more than two consecutive days without exercise, in addition to two sessions of resistance exercise per week (8). Moderate-intensity physical activity is defined as activities such as biking, brisk walking, swimming or dancing, and vigorous-intensity physical activity consists of jogging, aerobics, hockey or brisk walking up an incline. Resistance exercise consists of activities of brief duration that involve the use of weights, machines or resistance bands to increase muscle strength and endurance (8).

In type 2 diabetes, physical activity is associated with improved glycemic control, insulin resistance and blood pressure (9). Physical activity also has a positive impact on blood lipids, cardiovascular risk factors and mortality (6,8,9). However, despite health promotion efforts to emphasize these benefits, less than 30% of adults with type 2 diabetes participate in physical activity that meets the recommendation of at least 150 minutes per week (10). Likewise, many adults do not participate in resistance training despite the recommendations from the CDA (11).

As diabetes prevalence rates continue to rise, emphasis on physical activity for preventing and managing type 2 diabetes is crucial in order to reduce the economic burden of the disease. Healthcare professionals must continue to find ways to increase uptake of physical activity recommendations among their patients. Emerging data has suggested an association between physical activity and patient-reported outcomes such as HRQL exists in the type 2 diabetes population. HRQL has become an important patient-reported outcome, as it represents the ultimate goal of all health interventions. Positive associations between physical activity and patient-reported outcomes such as HRQL could be valuable in order to motivate patients to increase their participation in physical activity.

Health-Related Quality of Life

In its 1948 constitution, the World Health Organization (WHO) defined health as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (12). This new perspective reflected a change from defining health in terms of death and disease, to an increased interest in quality of life, well-being and specifically, health-related quality of life. Health-related quality of life (HRQL) is a multidimensional construct that embraces the WHO definition of health by reflecting an individual's perception of his or her own physical, emotional, social and mental wellbeing (13,14). The concept of HRQL allows health-related outcomes to be evaluated with respect to the impact they have on an individual's quality of life. HRQL indicators typically consist of six fundamental dimensions: physical functioning, psychological functioning, social functioning, role activities, overall life satisfaction and perception of health status (15).

As a rising proportion of the population lives with chronic conditions, HRQL has become increasingly important in order to measure the impact of these conditions on a patients' quality of life (16). In type 2 diabetes, outcome assessment has traditionally relied on biomedical indicators (17), however, reliance on clinical outcomes does not reflect a patient's perception of his or her health or satisfaction with treatment (18). Complex treatment regimens requiring lifestyle changes can influence patients' daily functioning and well-being, and evidence suggests that the physical and emotional burden of diabetes can negatively impact HRQL (16,19). The psychological toll of diabetes can have a negative impact on self-care behaviour, which can then have a negative impact on glycemic control, the risk of developing complications, and quality of life (16). HRQL instruments should be used to assess patients' perspectives alongside traditional biomedical measures (20). By doing so, health care professionals can evaluate both new and existing treatments, as well as patients' satisfaction with their care.

Health-Related Quality of Life Measures

There are two major approaches to measuring HRQL: generic instruments that provide a summary of HRQL and disease-specific instruments that focus on issues or problems associated with a particular disease state, symptom or patient group (13). Generic HRQL instruments include both profile and utility instruments, and are useful in comparing HRQL across disease populations, as well as between people with no disease and those with a disease (13). While disease-specific instruments are not useful for comparison across populations, they are often better able to capture changes specific to unique conditions (17).

Utility measures are most commonly used in cost-utility analyses, using the quality-adjusted life year (QALY), which combines both duration and quality of life to assess the value of a treatment or intervention (13). These instruments relate health states to death based on population preferences, and typically summarize HRQL on a scale ranging from death (0.0) to full health (1.0). A single index score is generated and can be used to compare changes in HRQL after an intervention, or to contrast two treatments (13). A widely used utility measure in diabetes research is the EuroQOL five-dimensions questionnaire (EQ-5D) (21–23). It consists of five questions representing five dimensions of HRQL: mobility, self-care, usual activities, pain or discomfort and anxiety or depression. Three versions of the EQ-5D are available: one with three functional levels, one with five functional levels (no problems, mild problems, moderate problems, severe problems, extreme problems), and one tailored for use in children and adolescents. The use of the 5-level version increases the discriminative capacity of the EQ-5D, and improves its ability to detect small changes in health states (24,25). The EQ-5D is short, easy to administer, and generates a single index score, derived using scoring functions based on standard gamble or time-trade off preferences (24,26). The EQ-5D questionnaire also includes a Visual Analogue Scale (EQ-VAS), on which the respondent is asked to provide a self-assessment of their overall health ranging from 0 (worst imaginable health state) to 100 (best imaginable health state).

Health profiles, on the other hand, provide an array of scores representing different aspects or dimensions of health status. The most commonly used generic health profile instrument in diabetes research is the Medical Outcomes Study Short-Form General Health Survey (16,17), in either one of its more recent forms (i.e., SF-36, SF-12). In both of these forms, eight dimensions of HRQL are measured: physical functioning (PF), role limitations due to physical health problems (RP), bodily pain (BP), general health (GH), vitality (VT), limitations due to emotional problems (RE), social functioning, and mental health (MH). These dimensions are scored from 0 to 100, with higher scores representing better HRQL (27). Two summary scores are generated: a physical component score (PCS) and a mental component score (MCS), which are standardized to a normal distribution (mean=50 and standard deviation=10).

Disease-specific instruments aim to capture specific problems related to a health condition or symptom. The primary advantage of disease-specific instruments is that they are usually more sensitive than generic instruments to small clinically important changes within the population in which they are employed. For example, a generic instrument may not address all aspects of life that patients with diabetes consider important, including hypoglycaemia, insulin injections, and monitoring of blood glucose (13,17). A variety of diabetes-specific instruments exist, and they generally include dimensions such as physical functioning, psychological functioning, social-role fulfillment, diabetes control, and treatment satisfaction (28,29). Diabetes-specific instruments include the Diabetes Quality of Life (DQOL) measure, the Diabetes-39 (D-39), and the Problem Areas in Diabetes Survey (PAID) (28,30,31).

Associations between Type 2 Diabetes and Health-Related Quality of Life

Type 2 diabetes patients typically report diminished HRQL in comparison with the general population, particularly on scales assessing physical functioning, role functioning and general health perceptions, but not on scales pertaining to social functioning and mental health (27,32). Quality of life in individuals with diabetes is generally better than in those with other chronic conditions, with the exception of hypertension (16), however the majority of studies comparing HRQL between diabetes and other chronic disease populations do not include subgroups of type 2 diabetes patients suffering from severe complications and comorbidities (16). Diminished HRQL in diabetes is most strongly linked to complications and comorbidities associated with the disease, where the presence of two or more diabetes-related complications or comorbidities is associated with worse HRQL (33,34). EQ-5D index scores are significantly lower in individuals with diabetes-related complications versus those without, with stroke, neuropathy and fear of hypoglycaemia having the greatest impact on HRQL (35). Other studies have also found large deficits in HRQL associated with stroke, depression, neuropathy and retinopathy (19,36,37).

The impact of diabetes on HRQL is also influenced by socio-demographic factors including age and sex (29). Older age in people with type 2 diabetes is associated with reduced physical functioning but better mental health (38,39), congruent with research in the general population (40). Sex also influences HRQL in patients with type 2 diabetes, where males tend to report better HRQL than females, consistent with the general population (16). Socioeconomic status (measured by income or level of education) is positively associated with HRQL in the general population (41–43), and in diabetes (19,34,39).

The association between treatment regimen and HRQL is unclear, but there is evidence that individuals who manage their diabetes with lifestyle modifications only (diet and exercise) have better HRQL. Evidence also suggests that HRQL declines as treatment progresses from lifestyle modification to oral agents, combination therapy or insulin (16). However, this treatment progression likely reflects increased disease severity and could be influenced by other factors associated with lower HRQL including age, obesity and number of complications and comorbidities (16). Regardless, this evidence suggests that a positive association between lifestyle modifications and HRQL exists, and those individuals who are able to manage their diabetes with lifestyle modifications should strive to do so.

Physical Activity, Type 2 Diabetes and Health-Related Quality of Life

It is well-established that a positive association between physical activity and overall well-being and HRQL exists in the general population (44). Higher levels of physical activity are consistently associated with better scores across various HRQL dimensions, particularly those relating to physical functioning and vitality (44). Additionally, existing evidence provides support for a dose-response relationship between physical activity and HRQL (45–47).

While the current evidence suggests a strong association between physical activity and HRQL in the general population, these associations may not be generalizable to chronic disease subgroups. These subgroups may have specific physical activity guidelines tailored to their disease, and often have unique HRQL profiles in comparison with the general population, due to the daily challenges associated with their conditions. In type 2 diabetes, the evidence surrounding the relationship between physical activity and HRQL is inconclusive. To date, the majority of research examining the effects of physical activity has focused on biomedical outcomes such as glycemic control, body mass and blood pressure.

Cross-sectional studies have indicated positive relationships between physical activity and HRQL in type 2 diabetes, particularly on dimensions related to physical health. Eckert (2012) reported significant decrements in HRQL with decreasing physical activity level on the PCS, MCS, physical functioning, vitality and psychological well-being dimensions of the SF-36 after adjustment for age, sex and BMI among a sample of 370 outpatients with type 2 diabetes (48). Chyun (2006) et al reported a significant association between achieving greater than three hours of exercise per week and the physical functioning and vitality dimensions of the SF-36, controlling for a number of relevant covariates (49). Imayama (2011) reported a significant association between physical activity and HRQL as measured by a single-item of self-rated health in a large population-based survey (50). A recent study reported negative correlations between physical activity and all sub-scales of the Diabetes-39 questionnaire, with the exception of diabetes control. Participants reporting high levels of physical activity had better scores than those reporting low levels of physical activity (51). While the evidence from cross-sectional studies appears to indicate that there are positive associations between physical activity and HRQL, the inherent limitations of cross-sectional research and the inability to draw inferences to causality must be considered.

In experimental studies, the evidence between physical activity and HRQL is less straightforward. A systematic review examining evidence from only experimental studies found inconclusive results with respect to this relationship (52). Studies that examined only the effect of aerobic exercise on HRQL showed no significant effects of aerobic training compared with usual care (53–56) or education (57) immediately post-intervention.

Results from studies examining the effects of resistance exercise on HRQL are mixed. Studies using the mental component scale of the SF-36 or SF-12 showed mixed results. Lincoln et al. found a significant positive effect compared with usual care (58), Reid et al. reported a positive effect favouring usual care in comparison with 6 months' training on exercise machines (59) and Plotnikoff et al. reported no significant effects in a home-based training regimen (60). On the physical component scale, two studies found no significant effects of resistance exercise (59,60), however Cheung et al found a significant positive effect of home-based exercise-band training in comparison with usual care on the general health subscale in the highest mean BMI group (61).

Five studies assessing the impact of combined training (aerobic and resistance exercise) on quality of life found no significant effects (54,55,62–64). However, Nicolucci et al. found positive effects of intensive combined training over 12 months on all subscales of the SF-36 in a large sample (n=606) (65). Aylin et al. found positive effects of resistance training combined with walking compared with usual care on the emotional role, mental health and vitality dimensions of the SF-36 (66), and Tsang et al. found significant correlations with the social functioning subscale, however these correlations were no longer significant after correction for body fat (67).

One limitation identified from experimental studies is that the majority of studies measured outcomes immediately post-intervention (52). The effect of physical activity on HRQL might be more pronounced over a longer period of time, as HRQL is shown to be adversely associated with diabetes-related complications, but not with short-term diabetes control (52,68). However, two studies who performed additional follow-up measurements after a year (54) and 6, 12 and 18 months (57) did not find any significant effects of aerobic exercise on HRQL. Continued efforts to investigate longer-term physical activity patterns are needed in order to accurately quantify the relationship with HRQL.

1.2 RESEARCH OBJECTIVES

The primary objective of this research was to explore the association between physical activity and HRQL in adults with type 2 diabetes using data from a large, prospective cohort study. In the first study, we used baseline data from the Alberta's Caring for Diabetes (ABCD) cohort to determine cross-sectional associations between meeting the CDA recommendations for physical activity (i.e. 150 minutes of moderate-vigorous physical activity per week) and HRQL. Additionally, we sought to investigate the association between higher levels of physical activity and HRQL. The second study focuses on the longitudinal relationship between physical activity and HRQL. We used follow up data from the ABCD cohort to determine how baseline level of physical activity impacts changes in HRQL over one year of follow-up.

This project will expand upon previous cross-sectional work that has explored the associations between physical activity and HRQL in type 2 diabetes. Additionally, the use of a longitudinal study design will help to fill a gap in the literature surrounding the association between physical activity and HRQL in type 2 diabetes. The findings from this thesis could be used to support the existing CDA guidelines for physical activity for adults with type 2 diabetes.

1.3 SUMMARY OF RESEARCH PROJECTS

Project 1: Association between Physical Activity and Health-Related Quality of Life in Adults with Type 2 Diabetes

Objective. The benefits of physical activity on clinical health outcomes in type 2 diabetes are well-established, however, the benefits in terms of health-related quality of life (HRQL) are less clear. The objective of this study was to examine associations between meeting physical activity recommendations and HRQL in adults with type 2 diabetes.

Methods. Data from the Alberta's Caring for Diabetes cohort were used. Self-report questionnaires were mailed to type 2 diabetes patients living in Alberta, Canada. Weekly moderate-vigorous PA (MVPA) was reported using the Godin-Shepherd Leisure Time Physical Activity Questionnaire, and HRQL using the Medical Outcomes Survey Short Form-12 items questionnaire (SF-12) version 2, and the 5-level EuroQol 5-dimensions questionnaire (EQ-5D-5L). Based on current guidelines for type 2 diabetes patients in Canada, participants were grouped according to whether they accrued 150 minutes of MVPA per week or not. Multivariable linear regression models were used to explore associations between physical activity and HRQL.

Results. Mean age of participants (N=1948) was 64.5 ± 10.8 and 45% were female. Participants reported a mean of 84.1 ± 172.4 min of MVPA/week, and 21% (N=416) met recommendations for physical activity. Those who met physical activity recommendations reported higher scores on physical functioning (b=9.58,p<0.001), role physical (b=8.87,p=0.001), bodily pain (b=5.12,p=0.001), general health (b=6.66,p<0.001), vitality (b=9.05,p<0.001), social functioning (b=3.32,p=0.040), and role emotional (b=3.08,p=0.010), physical component summary (b=3.31, p<0.001), mental component summary (b=1.43,p=0.001) and EQ-5D-5L index score (b=0.022,p=0.005) compared with those not meeting recommendations.

Conclusions. The majority of the sample did not meet recommendations for physical activity. Among those who did, a significant positive association was observed with HRQL, particularly physical health.

Project 2: Physical Activity and Health-Related Quality of Life in Adults with Type 2 Diabetes: Results from a Prospective Cohort Study

Objective. Many cross-sectional studies have showed a positive association between physical activity and health-related quality of life in individuals with type 2 diabetes, but

very little longitudinal evidence has been generated. The objective of this study was to investigate the longitudinal relationship between physical activity and health-related quality of life (HRQL) in adults with type 2 diabetes.

Methods. Data were from a prospective cohort of adults with type 2 diabetes living in Alberta, Canada. Weekly moderate-vigorous physical activity (MVPA) was reported using the Godin Leisure Time Physical Activity Questionnaire, and HRQL was measured using the SF-12 version 2, and the 5-level EQ-5D. Participants were categorized based on whether they met current recommendations for physical activity, or not. Multivariable linear regression was used to explore associations between weekly MVPA and HRQL, and multinomial logistic regression was used to explore associations with the direction of change in HRQL after one year of follow up.

Results. The mean age of participants (N=1948) was 64.5 ± 10.8 years and 45% were female. Participants reported a mean of 84.1 ± 172.4min of MVPA/week, and 21% (N=416) met recommendations for physical activity. Weekly MVPA was associated with differences in the physical functioning (b=5.42, $p<0.001$), general health (b=2.45, p=0.037) and vitality (b=2.83, p=0.016) dimensions of the SF-12. Participants who met weekly MVPA recommendations were less likely to report a decline (versus no change) in EQ-5D index score (OR=0.75, 95% CI [0.57,0.99]), and SF-12 physical component summary (OR=0.67, 95% CI [0.50,0.90]), compared with participants not meeting recommendations.

Conclusions. Adults with type 2 diabetes who met recommendations for weekly MVPA had better physical functioning and were more likely to maintain their physical health and overall HRQL over time.

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CHAPTER 2.

ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND HEALTH-RELATED QUALITY OF LIFE IN ADULTS WITH TYPE 2 DIABETES

2.1 INTRODUCTION

Over two million Canadians currently live with diabetes, and approximately 90% of cases are type 2 diabetes. Diabetes is the seventh leading cause of death in Canada and is a major driver of total health care costs (1). If current incidence and mortality trends continue, approximately 3.8 million Canadians will be living with type 2 diabetes by 2018 (1). As there is presently no cure for the disease, the focus of diabetes care is improving functioning and quality of life, while working to minimize health-care costs associated with the disease.

Health-related quality of life (HRQL) is an important outcome in type 2 diabetes research. HRQL is a multidimensional construct that incorporates physical, mental, emotional and social wellbeing. Research indicates that those with type 2 diabetes typically report diminished HRQL, in part due to the complications and comorbidities that often accompany the disease (2). Additionally, individuals with type 2 diabetes tend to be older and overweight or obese, both of which are associated with lower HRQL (3).

The Canadian Diabetes Association (CDA) recommends at least 150 minutes per week of moderate-vigorous aerobic exercise, such as brisk walking, jogging or biking plus at least two sessions per week of resistance exercise (4). Despite these recommendations, many

Canadians with type 2 diabetes are sedentary or insufficiently active (5). Previous research has demonstrated a positive relationship between physical activity and HRQL in the general adult population (6). Some studies suggest that this relationship holds in populations of type 2 diabetes patients, however some randomized control trials have indicated that participation in aerobic physical activity programs did not result in improved physical or mental health scores (3,7–9). Therefore, more research is required to better understand the relationship between physical activity and HRQL in this patient population.

The aim of this study was to examine the differences in HRQL between type 2 diabetes patients who meet the CDA recommendations for physical activity, compared with those who do not. We hypothesized that people who meet PA recommendations will have better HRQL than those who do not. Additionally, we sought to investigate whether exceeding the base recommendations (≥300 MVPA minutes per week) was associated with better HRQL in type 2 diabetes compared to meeting base recommendations.

2.2 METHODS

Data Source

This study used baseline data from the Alberta Caring for Diabetes (ABCD) cohort study, which has been described elsewhere (10). Briefly, English speaking individuals with type 2 diabetes who were living in Alberta and over the age of 18 were eligible to participate. Participants were recruited over a two-year period (December 2011 to December 2013) through primary care networks and diabetes clinics as well as public advertisements. Those who agreed to participate were mailed self-administered surveys, which contained various items and measures which have been developed, validated and used in previous diabetes population studies. Surveys included information about disease management, health and lifestyle, health-related quality of life, emotional and psychosocial well-being and socio-demographics. The sample was considered to be generally representative of the adult type 2 diabetes population in Alberta (10).

Physical Activity

Physical activity was assessed using the Godin Leisure Time Physical Activity Questionnaire (GLTEQ) (11). Participants were asked to report the frequency and duration of light-intensity (easy walking, yoga, golf), moderate-intensity (brisk walking, easy bicycling, tennis) and vigorous-intensity (aerobics, jogging, swimming laps) leisure-time physical activity performed in a typical week. The number of weekly minutes was calculated by multiplying the frequency of physical activity by the duration in minutes. The sum of the un-weighted weekly minutes of moderate and vigorous physical activity gave the total MVPA minutes per week.

Health-Related Quality of Life

Health-related quality of life was assessed using both the Medical Outcomes Study (MOS) 12-Item Short-Form Health Survey version 2 (SF-12) and the 5 level EuroQol 5-Dimensions (EQ-5D-5L) questionnaire. The SF-12 is a condensed 12-item version of the SF-36, a commonly used generic health-status tool. An eight-dimension profile (physical functioning, role limitations due to physical problems, bodily pain, general health, vitality, limitations due to emotional problems, social functioning and mental health) is created from which physical (PCS) and mental (MCS) component summary scores are derived. This study used scoring coefficients from oblique factor analysis (12). SF-12 summary scores follow a T-distribution with a mean of 50 and a standard deviation of 10, which is normalized for the general US population. Scores range from zero to 100 and lower scores on the MCS and PCS indicate greater disability (13). For domain and summary scores, a minimal important difference (MID) is in the range of 3-5 points (14).

The EQ-5D-5L is a preference-based health status measure consisting of 5 dimensions (mobility, self-care, usual activities, pain or discomfort and anxiety or depression), each with five levels (no problems, mild problems, moderate problems, severe problems, extreme problems), which yields a single index score (15). The index score was calculated using a scoring function derived from Canadian preferences (16). Each described health state has a unique score, anchored at 0.0 for “dead” and 1.0 for “full health”, with higher scores indicating better HRQL. A MID on this scale is 0.03 points (17).

Other Measures

Data on age, sex, ethnicity (white; Aboriginal; other), annual household income in Canadian dollars (<$80,000; ≥$80,000), level of education (less than high school, high school; more than high school), employment status (employed; not employed), family history of diabetes (yes; no), smoking status, diabetes duration, number of comorbidities (out of 16 common diabetes comorbidities), and depressive symptoms (using the Patient Health Questionnaire-8 items “PHQ-8”) were also collected (18).

Statistical Analyses

CDA guidelines were used to categorize participants based on their physical activity into two levels:

- Those who did not meet recommendations: <150 MVPA min/week
- Those who met recommendations: ≥150 MVPA min/week

A secondary analysis included three levels:

- Those who did not meet recommendations: <150 MVPA min/week
- Those who met the base recommendations: 150-299.9 MVPA min/week
- Those who exceeded the base recommendations: ≥300 MVPA min/week

Descriptive statistics were computed for all variables in the overall sample and by physical activity level. Differences were tested using t-test or chi-square test, as appropriate. Univariable analyses were performed to determine associations between physical activity and HRQL indicators. The association of possible covariates was tested using simple linear regression, and variables were included in the final model if significant in univariable analysis, or if they have been shown to be clinically relevant in other studies. In this study, these included the categorical variables income, number of comorbidities (0, 1 or ≥2), depressive symptoms, and smoking status as well as age and duration of diabetes as continuous variables. Multivariable linear regression was used to examine differences between groups on each HRQL indicator. Unstandardized beta coefficients were interpreted by both statistical significance and clinical importance. All final model assumptions were checked. Statistical inferences were based on a significance level of $p<0.05$ (two-sided). The data was analyzed using Stata 13.1 for Mac (Stata Corp, College Station, TX, USA).

2.3 RESULTS

General Characteristics of Participants

The cohort consisted of 2040 individuals (Table 2-1), however 92 individuals received a survey with a different version of the HRQL measures, and therefore were excluded from the analysis. The final number of participants was 1948, and the average age of participants was 64.5 ±10.8, 45% were female and 91% were white. The majority of participants had at least a high school education and a household income less than $80,000. On average, participants had lived with diabetes for 12.6 ±10 years and had an average of 4.2 ± 2.3 comorbidities in addition to diabetes. HRQL was slightly lower than average when compared to the general population, with a mean EQ-5D index score of 0.79 ± 0.17, mean PCS of 44.2 ± 10.8 and mean MCS of 48.9 ± 9.8 (Table 2-1).

The majority (N=1532; 78.6%) of participants did not meet physical activity recommendations, with a mean duration of 84.1 ± 172.4 min of MVPA per week. Participants who did not meet recommendations were more likely to have less education, be smokers, have more comorbidities and report more depressive symptoms (Table 2-1). Participants who exceeded the base recommendations for physical activity (≥ 300 MVPA min per week) (N=167) were more likely to be male, earn more than $80,000, have more than a high school education, have fewer comorbidities, and were less likely to be depressed (Table 2-1).

Physical Activity and HRQL Indicators

After adjustment for age, sex, income, smoking status, number of comorbidities, diabetes duration and depressive symptoms, multivariable regression analyses revealed differences in HRQL between those who met the CDA recommendations and those who did not (Table 2-2). Those who met recommendations reported higher HRQL scores on the physical functioning ($b=9.58$, $p<0.001$), role physical ($b=8.87$, $p=0.001$), bodily pain ($b=5.12$, $p=0.001$), general health ($b=6.66$, $p<0.001$), vitality ($b=9.05$, $p<0.001$), social functioning ($b=3.32$, $p=0.040$), and role emotional ($b=3.08$, $p=0.010$) domains when compared with those who did not meet recommendations. The PCS score ($b=3.31$, $p<0.001$), MCS score ($b=1.43$, $p=0.001$) and EQ-5D-5L index score ($b=0.022$, $p=0.005$) were also strongly associated with physical activity when the meeting recommendations group is compared to the not meeting recommendations group.

Those who exceeded the recommended amount of physical activity (≥300 MPVA min per week) reported higher HRQL scores than those who did not achieve physical activity recommendations (Table 2-3). Differences on the physical functioning ($b=14.68$, $p<0.001$), role-physical ($b=12.13$, $p<0.001$), bodily pain ($b=5.66$, $p=0.018$), general health ($b=9.62$, $p<0.001$) and vitality ($b=12.13$, $p<0.001$) dimensions were statistically significant, as were differences on the PCS ($b=4.64$, $p<0.001$), MCS ($b=1.76$, $p=0.006$) and EQ-5D index score ($b=0.035$, $p=0.003$). When comparing those who exceeded recommendations (≥300 MPVA min per week) to those who met the base recommendation (150-299.9 MVPA min per week), no significant differences in any HRQL parameter were found (Table 2-3).

2.4 DISCUSSION

The aim of this study was to examine the association between meeting CDA recommendations for physical activity and HRQL among adults with type 2 diabetes living in Alberta. Overall, the results confirmed our hypothesis that meeting the CDA recommendations for physical activity would be associated with better HRQL when compared with not meeting recommendations. These associations persisted after adjustment for relevant demographic and clinical variables. Specifically, meeting recommendations was associated with higher scores on the physical functioning, role physical, bodily pain, general health, vitality, social functioning and mental health dimensions. Moreover, the observed differences were meaningful based on guidelines for minimal important differences. A 3-5 point difference is considered clinically important on the SF-12 domains, and the difference between the group who met recommendations and the group who did not exceeded this difference in the dimensions related to physical health (i.e., PF, RP, BP, GH and VT). When considering mental health or overall HRQL, the relationship is not as strong, and differences were not considered clinically important.

The results from this study are generally consistent with previous research, which indicates positive associations between physical activity and HRQL. In healthy adults, those who attain recommended levels of physical activity have previously reported higher scores on the PF, GH, VT dimensions, as well as the PCS (19,20). In diabetes-specific populations, HRQL has been found to decrease with decreasing levels of physical activity in other cross-sectional studies (8,9). The results from this study contribute to this body of knowledge by providing evidence from a large population-based cohort of type 2 diabetes patients. Additionally, this study used current clinical practice guidelines to categorize participants into physical activity groups to assess the difference in HRQL between those who were meeting the guidelines and those who were not.

In general, these study results also confirm previous research that indicates that the physical aspects of HRQL are more closely associated with physical activity than the mental aspects (21–23). Vitality is classified as a mental health dimension but seeks to measure the level of energy, pep or tiredness experienced, and is moderately correlated with both mental and physical health functioning (13). Participation in physical activity is typically associated with physical benefits, including better fitness and a reduced risk for developing adverse health conditions and complications. Additionally, physical activity has been shown to be associated with better mental health, including improved self-esteem and increased social interactions. Most likely, a bidirectional relationship between physical activity and HRQL exists, whereby those individuals who perceive themselves as having better physical and mental health are more likely to participate in in physical activity. Due to the cross-sectional nature of this study, we are unable to draw a conclusion on the direction of this relationship.

Despite evidence that participation in physical activity is associated with better HRQL, nearly two-thirds of participants did not meet current recommendations. Low levels of physical activity are typically reported among diabetes patients, particularly among females (5). Despite the existence of clinical guidelines that seek to educate diabetes patients on the importance of physical activity, it is challenging to motivate individuals to make lifestyle modifications and maintain new habits (9). The results of this study provide more evidence that there are significant associations between meeting the current clinical practice guidelines for physical activity and better HRQL in this patient population.

The United States Department of Health and Human Services (USDHHS) suggests that additional health benefits can be accrued by achieving at least 300 minutes per week of moderate-vigorous PA (24). We sought to investigate whether there was an association between a higher level of physical activity and HRQL in individuals with type 2 diabetes. Those individuals who exceeded the base recommendations (≥300 MPVA min per week) reported higher HRQL scores across all dimensions compared with those who did not meet the base recommendations (<150 MVPA min per week). The differences in HRQL between those who exceeded recommendations and those who did not meet recommendations were larger than the differences between those who met base recommendations and those who did not in the physical health dimensions, but not in the mental health dimensions. Our results suggest that those individuals with type 2 diabetes who are able to accrue more than 300 minutes of MVPA per week may experience improvements in physical health. Differences between those who met base recommendations and those who exceeded base recommendations were not statistically significant, however this may have been due to a lack of statistical power to detect differences. Previous studies in both the general population, and in community-dwelling older adults have demonstrated similar associations between higher levels of physical activity and HRQL, however there is little evidence to date on this relationship in type 2 diabetes (6,25–27).

The strengths of this study include the use of a large, population-based cohort which is representative of the type 2 diabetes population in Alberta, based on estimates from the Alberta Diabetes Surveillance System, as well as the use of validated questionnaires and multiple indicators of HRQL (10). Nonetheless, the results should be interpreted in light of a few limitations. First, the use of cross-sectional data precludes us from establishing temporality or causality. We found a positive association between physical activity and HRQL, however we are unable to confirm the direction of this association. Second, data were collected using self-report questionnaires. In particular, the use of the GLTEQ for self-reported physical activity could have lead to overestimates (28). Accelerometer data has been collected in a subset of this cohort and could be used in a future study to assess the validity of the self-report questionnaire in this population. Additionally, the GLTEQ only assesses leisure-time physical activity, so physical activity associated with work is not captured in this study. Third, we did not have a measure dedicated to resistance exercise and therefore it is impossible to know whether those who meeting recommendations for aerobic exercise were also meeting recommendations for resistance exercise, and whether this would impact HRQL. Finally, although we adjusted for several variables that might be associated with physical activity and HRQL, we cannot rule out that there could be other factors (including physical injury, access to facilities, medications and other habits related to health) that might have impacted this relationship.

In summary, the findings in this study indicate that individuals with type 2 diabetes who meet recommendations for physical activity report better HRQL compared with those who do not. Meeting recommendations for physical activity is more strongly related to improvements in physical health than mental health. Our findings also suggested that the improvements in physical health were even greater in those individuals who accrued higher weekly levels of physical activity. This suggests that individuals with type 2 diabetes who are capable of exceeding the recommended amount of physical activity may experience better HRQL than those who simply meet the base recommendations. To better assess this relationship, both longitudinal and experimental studies are needed to determine whether changes in PA are associated with changes in HRQL. Additionally, only 21.5% of the sample reported physical activity levels that were congruent with the recommendations set forth by the CDA, indicating that public health efforts to promote physical activity and decrease sedentary lifestyle habits must be continued in order to improve care and health outcomes for type 2 diabetes patients.

Table 2-1. Characteristics of Participants

Characteristic	Overall (N=1948) mean ± SD or N(%)	Met PA Recommendations Yes (N=416) mean ± SD or N(%)	No (N=1532) mean ± SD or N(%)	P-Value
Female sex	875 (45.2)	158 (38.0)	717 (46.8)	0.001
Age (years)	64.5 ± 10.8	63.4 ± 10.3	64.9 ± 10.9	0.013
Annual household income (Canadian dollars)				0.012
<$80,000	1122 (57.6)	228 (54.8)	894 (58.4)	
≥$80,000	454 (23.3)	119 (28.6)	335 (21.9)	
Education				<0.001
Less than high school	275 (14.1)	37 (8.9)	238 (15.5)	
Completed high school	780 (40.0)	139 (33.4)	641 (41.8)	
More than high school	881 (45.2)	250 (57.7)	641 (41.8)	
Employment status - Unemployed/retired	1127 (58.8)	238 (57.9)	889 (59.0)	0.682
Ethnicity				0.448
White	1765 (90.6)	379 (91.1)	1386 (90.5)	
Aboriginal	46 (2.4)	8 (1.9)	38 (2.5)	
Others	106 (5.4)	27 (6.5)	79 (5.2)	
Current smoker	199 (10.2)	28 (6.7)	171 (11.2)	0.008
Diabetes duration (years)	12.6 ± 10.0	12.0 ± 9.5	12.8 ± 10.2	0.262
Number of comorbidities	4.2 ± 2.3	3.5 ± 2.1	4.4 ± 2.3	<0.001
Depressive symptoms	5.2 ± 5.4	3.7 ± 4.7	5.6 ± 5.5	<0.001
No (PHQ-8 <10)	1532 (78.6)	366 (88.0)	1166 (76.1)	
Yes (PHQ-8 ≥10)	416 (21.4)	50 (12.0)	366 (23.9)	
HRQL indicators				
EQ-5D-5L				
Mobility	1030 (52.9)	151 (36.4)	879 (58.0)	<0.001
Self-Care	223 (11.5)	26 (6.3)	197 (12.9)	<0.001
Usual Activities	928 (47.6)	123 (29.6)	805 (52.6)	<0.001
Pain/Discomfort	1431 (73.5)	269 (64.7)	1162 (75.9)	<0.001
Anxiety/Depression	905 (46.5)	169 (40.6)	736 (48.0)	0.004
Index score	0.79 ± 0.17	0.84 ± 0.13	0.78 ± 0.18	<0.001
SF-12				
Physical functioning	66.3 ± 34.8	80.7 ± 29.1	62.3 ± 35.2	<0.001
Role physical	65.8 ± 30.2	78.7 ± 25.7	62.3 ± 30.4	<0.001
Bodily pain	67.5 ± 30.7	76.5 ± 27.3	65.1 ± 31.1	<0.001
General health	60.9 ± 24.0	70.2 ± 19.7	58.4 ± 24.4	<0.001
Vitality	53.0 ± 24.8	63.7 ± 23.0	50.1 ± 24.4	<0.001
Role emotional	77.9 ± 25.5	84.8 ± 21.5	76.0 ± 26.1	<0.001
Social functioning	76.1 ± 28.2	84.0 ± 24.9	73.9 ± 28.6	<0.001
Mental health	71.1 ± 20.6	74.6 ± 20.0	70.1 ± 20.7	<0.001
PCS	44.2 ± 10.8	49.1 ± 9.0	42.9 ± 10.9	<0.001
MCS	48.9 ± 9.8	50.7 ± 9.3	47.1 ± 9.8	<0.001

Note: Data is presented as mean (SD) for continuous variables and frequency (%) for categorical variables. Numbers may not add up to 1948 due to missing data.

Abbreviations: PA physical activity, HRQL health-related quality of life, PCS physical component summary score, MCS mental component summary score, SD standard deviation

Table 2-2. Results of adjusted multivariable linear regression models of the relationship between meeting guidelines for PA (two categories) and HRQL

HRQL indicator	Met PA Recommendations Yes (N=416) mean ± SE	No (N=1532) mean ± SE	b	SE	*p*-value
SF-12					
Physical functioning	73.92 ± 1.45	64.33 ± 0.75	9.58	1.64	<0.001
Role physical	72.85 ± 1.24	63.98 ± 0.64	8.87	1.41	<0.001
Bodily pain	71.56 ± 1.39	66.44 ± 0.71	5.12	1.57	0.001
General health	66.36 ± 1.03	59.69 ± 0.53	6.66	1.17	<0.001
Vitality	60.23 ± 1.07	51.18 ± 0.56	9.05	1.22	<0.001
Role emotional	80.41 ± 1.05	77.33 ± 0.55	3.08	1.20	0.010
Social functioning	78.65 ± 1.14	75.32 ± 0.59	3.32	1.29	0.010
Mental health	71.97 ± 0.88	70.90 ± 0.45	1.06	0.99	0.284
PCS	46.81 ± 0.42	43.50 ± 0.22	3.31	0.48	<0.001
MCS	48.97± 0.38	47.54 ± 0.20	1.43	0.43	0.001
EQ-5D-5L					
Index score	0.81 ± 0.007	0.79 ± 0.003	0.022	0.007	0.005

Abbreviations: PA physical activity, HRQL health-related quality of life, PCS physical component summary score, MCS mental component summary score SD standard deviation, SE standard error, b beta coefficient

Reference: not meeting recommendations group (<150 min of MVPA per week)

Table 2-3. Results of adjusted multivariable linear regression models of the relationship between meeting guidelines for PA (three categories) and HRQL

HRQL Indicator	Adjusted score mean ± SE	b	SE	*p*-value
SF-12				
Physical functioning				
Not meeting recommendations (Ref)	63.73 ± 0.81			
Meeting recommendations	74.47 ± 2.00	10.74	2.16	<0.001
Exceeding recommendations	78.42 ± 2.41	14.68	2.56	<0.001
Role-physical				
Not meeting recommendations (Ref)	63.52 ± 0.68			
Meeting recommendations	73.71 ± 1.69	10.19	1.83	<0.001
Exceeding recommendations	75.65 ± 2.96	12.13	2.18	<0.001
Bodily pain				
Not meeting recommendations (Ref)	66.08 ± 0.74			
Meeting recommendations	73.69 ± 1.84	7.61	1.99	<0.001
Exceeding recommendations	71.74 ± 2.25	5.66	2.39	0.018
General health				
Not meeting recommendations (Ref)	59.40 ± 0.56			
Meeting recommendations	66.36 ± 1.38	6.96	1.50	<0.001
Exceeding recommendations	69.02 ± 1.68	9.62	1.78	<0.001
Vitality				
Not meeting recommendations (Ref)	50.88 ± 0.58			
Meeting recommendations	60.16 ± 1.42	9.28	1.54	<0.001
Exceeding recommendations	63.01 ± 1.74	12.13	1.84	<0.001
Role-emotional				
Not meeting recommendations (Ref)	77.14 ± 0.55			
Meeting recommendations	81.66 ± 1.37	4.52	1.48	0.002
Exceeding recommendations	80.29 ± 1.67	3.15	1.76	0.074
Social functioning				
Not meeting recommendations (Ref)	75.10 ± 0.60			
Meeting recommendations	81.52 ± 1.48	6.52	1.60	<0.001
Exceeding recommendations	76.41 ± 1.81	1.31	1.91	0.495
Mental health				
Not meeting recommendations (Ref)	70.72 ± 0.46			
Meeting recommendations	72.59 ± 1.13	1.83	1.22	0.135
Exceeding recommendations	72.29 ± 1.38	1.53	1.46	0.295
PCS				
Not meeting recommendations (Ref)	43.32 ± 0.24			
Meeting recommendations	47.10 ± 0.59	3.77	0.64	<0.001
Exceeding recommendations	47.96 ± 0.71	4.64	0.75	<0.001
MCS				
Not meeting recommendations (Ref)	47.45 ± 0.20			
Meeting recommendations	49.35 ± 0.50	1.90	0.54	<0.001
Exceeding recommendations	40.20 ± 0.61	1.76	0.64	0.006
EQ-5D-5L Index Score				
Not meeting recommendations (Ref)	0.78 ± 0.004			
Meeting recommendations	0.82 ± 0.009	0.032	0.0010	0.001
Exceeding recommendations	0.82 ± 0.011	0.035	0.012	0.003

Note: not meeting recommendations (<150 min of MVPA per week), meeting recommendations (150 – 299.9 min of MVPA per week), exceeding recommendations (≥300 min of MVPA per week).

Abbreviations: PA physical activity, HRQL health-related quality of life, PCS physical component summary score, MCS mental component summary score SD standard deviation, SE standard error, b beta coefficient

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CHAPTER 3.

PHYSICAL ACTIVITY AND HEALTH-RELATED QUALITY OF LIFE IN ADULTS WITH TYPE 2 DIABETES: RESULTS FROM A PROSPECTIVE COHORT STUDY

3.1 INTRODUCTION

Type 2 diabetes mellitus is a universal health problem, with a rising prevalence worldwide. An estimated 422 million adults live with diabetes globally, and the prevalence in adults has nearly doubled since 1980, rising from 4.7% to 8.5% (1). Type 2 diabetes is commonly associated with many debilitating complications including vision loss, kidney damage and neuropathy. The burden of diabetes, including the necessity to make lifestyle changes in order to manage complications and comorbidities can have a negative impact on health-related quality of life (HRQL) in this population (2). HRQL is a multidimensional construct that represents an individual's perception of his or her own physical, emotional, social and mental wellbeing. Type 2 diabetes patients typically report diminished HRQL in comparison with the general population, particularly on scales assessing physical functioning, role functioning and general health perceptions, but not on scales pertaining to social functioning and mental health (3,4). HRQL has become increasingly important in diabetes-related research, and is often used as an outcome in studies to evaluate the effectiveness of interventions or management strategies, alongside other important health outcomes.

The Canadian Diabetes Association (CDA) provides guidelines for the management of type 2 diabetes that include various strategies for self-management including physical activity and diet. The CDA currently recommends that type 2 diabetes patients participate in at least 150 minutes of moderate-vigorous aerobic physical activity per week spread over at least three days, with no more than two consecutive days without physical activity, in addition to two sessions of resistance exercise per week (5). Physical activity is one of the cornerstones of type 2 diabetes management, and has been shown to be effective for improving outcomes such as glycemic control, insulin resistance, and blood pressure (6).

Studies in the general population, and in older community dwelling adults indicate positive associations between physical activity and HRQL, particularly in dimensions related to physical health (7–9). In the type 2 diabetes population, evidence from cross-sectional studies generally indicates positive associations (10–12), however evidence from experimental and longitudinal studies has not been conclusive. One recent systematic review of experimental studies suggested there was no association between aerobic exercise and HRQL (13) and few longitudinal studies have been conducted to date. Therefore, the objective of our study was to investigate the association between physical activity and HRQL over one year in a population-based sample of adults with type 2 diabetes.

3.2 METHODS

Data Source

We used baseline and one year follow up data from the Alberta Caring for Diabetes (ABCD) cohort study (14). English speaking individuals with type 2 diabetes who were living in Alberta at the time of the study and over the age of 18 were eligible to participate in the cohort. Participants were recruited over a two-year period (December 2011 to December 2013) through primary care networks and diabetes clinics as well as public advertisements. Participants were mailed self-administered surveys containing various measures of disease management, health and lifestyle, HRQL, emotional and psychosocial well-being and socio-demographics (13). The sample was considered to be representative of the adult type 2 diabetes population in Alberta (14). All participants were mailed a follow up survey one year after their enrolment.

Measures

Physical activity was assessed using the Godin Leisure Time Physical Activity Questionnaire (GLTEQ) (15). Participants were asked to report the frequency and duration of light, moderate, and vigorous intensity leisure-time physical activity that lasted at least 10 minutes over a typical week during the past month. The number of weekly minutes for each intensity level was calculated by multiplying the frequency of activity by the duration in minutes. The sum of weekly minutes of moderate and vigorous physical activity gave the total MVPA minutes per week. Two groups were defined at baseline as: those who were meeting the CDA recommendations of at least 150 minutes of MVPA per week, and those who were not meeting the CDA recommendations (i.e., reporting less than 150 minutes of MVPA per week) (5).

HRQL was assessed using the 5-level EQ-5D questionnaire and the Medical Outcomes Study 12-Item Short-Form Health Survey version 2 (SF-12). The EQ-5D is a generic preference-based (utility) measure of HRQL, consisting of five dimensions (mobility, self-care, usual activities, pain or discomfort and anxiety or depression), each with five levels (no problems, mild problems, moderate problems, severe problems, extreme problems), which yields a single index score (16). The index score is derived using a scoring function based on Canadian preferences from time-trade off interviews (17). A clinically important difference (CID) on the index score is 0.03 points (18).

The SF-12 is a condensed version of the SF-36, a generic health profile measure. It consists of 12 items, from which an eight-dimension profile (physical functioning, role limitations due to physical problems, bodily pain, general health, vitality, limitations due to emotional problems, social functioning and mental health) is created. Physical (PCS) and mental (MCS) component summary scores are derived from dimension scores, using scoring coefficients from oblique factor analysis (19). The PCS and MCS follow a T-distribution with a mean of 50 and standard deviation of 10, normalized for the general US population. Lower scores on both dimension and summary scores indicate greater disability (3), and a CID is in the range of 3-5 points for these scores (20).

Data were also collected on other variables including age, sex, ethnicity (white, Aboriginal or other), annual household income (<80,000 or ≥$80,000), level of education (less than high school, high school or more than high school), employment status (employed or unemployed/ retired), family history of diabetes (yes or no), diabetes duration, number of comorbidities, smoking status and depressive symptoms (using the Patient Health Questionnaire-8 items (PHQ-8) (21)

Statistical Analysis

Descriptive statistics at baseline were calculated for the overall sample, and by physical activity level. Differences were tested using t-test or chi-square test, as appropriate. Differences in the presence of problems in each of the EQ-5D dimensions (response ≥ level 2) and in the means of the EQ-5D index score, PCS, MCS and each of the SF-12 dimension scores by physical activity level at baseline were also examined using t-test or chi-square test.

The attrition rate in the cohort from baseline to year one follow up was 23.6%. Participants who did not complete surveys at follow up were younger, less educated, less likely to be white, more likely to be physically inactive, living with diabetes for a shorter duration, more likely to have depressive symptoms and to report worse HRQL than those who completed follow up surveys (Table 3-1). These differences are presumably related to health status, and therefore we cannot assume the data to be missing completely at random. As such, a complete case analysis excluding those participants who did not return year one surveys would likely introduce bias. Therefore, to account for missing data, a multiple imputation (MI), with 10 imputations, was performed using the MI/ICE suite in Stata 13.0. Variables were included in the imputation models based upon pairwise correlations of all variables in the dataset, and missing indicators for each variable.

Using these MI datasets, linear regression was employed to explore the independent association of weekly MVPA with each HRQL indicator at follow up, adjusting for significant covariates including age, sex, education, income, diabetes duration, smoking status, depressive symptoms, and number of comorbidities. The baseline value for each HRQL indicator was included as a covariate in order to reduce the residual standard error and account for regression to the mean. We subsequently stratified the regression analyses by sex and age (<50, 50-65, and >65 years).

Additionally, we created categorical variables for change in each HRQL indicator using the CID for each indicator (18,20) as follows:

<u>EQ-5D: 0.03 points</u>

No change: between -0.03 and 0.03

Improvement: ≥ + 0.03

Decline: ≤ -0.03

<u>SF-12 Dimensions and PCS/MCS: 5 points</u>

No change: between -5 and 5

Improvement: ≥ +5

Decline: ≤ -5

Adjusted multinomial logistic regression models were then used to examine the association of baseline weekly MVPA with the direction of change in HRQL (no change, improved, or declined) for each of the PCS, MCS, and EQ-5D index score. All data management and analysis was performed using Stata 13.0.

3.3 RESULTS

The cohort consisted of 1948 individuals (Table 3-2); the average age was 64.5 ± 10.8 years, 45% were female and 91% were white. The majority of participants had at least a high school education and a household income of less than $80,000. On average, participants had lived with diabetes for 12.6 ±10 years and had an average of 4.2 ± 2.3 comorbidities. One-fifth (21%) met recommendations for weekly MVPA. The average PHQ-8 score was 5.2 ± 5.4, and 21% of participants screened positive for depressive symptoms (PHQ-8 ≥10).

The mean EQ-5D index score reported by participants was 0.79 ± 0.17, the mean PCS was 44.2 ± 10.8 and the mean MCS was 48.9 ± 9.8 (Table 3-2). Participants who were meeting recommendations reported significantly higher HRQL scores at baseline across all dimensions of the SF-12 and the EQ-5D index score than participants who were not meeting recommendations. These differences are considered clinically important, based on the suggested thresholds. Furthermore, participants who were not meeting recommendations were more likely to report having problems (≥ level 2) on all dimensions of the EQ-5D than those who were (Table 3-2).

Based on MI for missing values at baseline and year one, participants reported small declines on each of the HRQL indicators (Table 3-3). Participants who were meeting recommendations at baseline reported larger declines in EQ-5D index score, PCS, MCS and all dimensions of the SF-12, except mental health, in comparison with those who were not. However, the distributions of raw (i.e., unadjusted) change in HRQL appeared to be different, with greater proportions of participants who were not meeting recommendations at baseline reporting both clinically important improvements and declines in PCS, MCS and EQ-5D (Table 3-3).

In adjusted analyses using MI data, baseline weekly MVPA was not associated with the EQ-5D index ($b=0.070$, $p=0.298$), PCS ($b=0.66$, $p=0.076$) or MCS ($b=0.50$, $p=0.234$) scores at one year of follow up; however, it was associated with the physical functioning ($b=5.42$, $p<0.001$), general health ($b=2.44$, $p=0.038$) and vitality ($b=2.79$, $p=0.018$) dimensions of the SF-12 (Table 3-4). Based on a CID of 3-5 points, only the difference in physical functioning between those meeting recommendations and those who were not reached the threshold for clinical importance. We did not find any meaningful differences when stratified by sex, nor across stratified age groups (data not shown).

Participants who were meeting recommendations at baseline were less likely to report a decline (versus no change) in EQ-5D index score (OR=0.75, 95% CI [0.57,0.99]), and PCS (OR=0.67, 95% CI [0.50,0.90]) in comparison with those who were not meeting recommendations (Table 3-5). There were no differences between groups with regards to reporting an improvement (versus no change) on the PCS, MCS or EQ-5D index scores (Table 3-5). Again, there were no important differences when stratified by sex or age group.

3.4 DISCUSSION

We investigated associations between weekly MVPA and HRQL over one year. We found participants reported a small decline in all dimensions of HRQL, regardless of weekly MVPA at baseline. After adjustment for significant socio-demographic and clinical characteristics, we observed that those individuals who were meeting the CDA recommendations for weekly MVPA had improvements in physical functioning, general health and vitality, compared to those not meeting CDA recommendations for physical activity. The magnitude of difference was small on the general health and vitality domains, but was considered clinically important on the physical functioning dimension. Furthermore, those participants who were meeting weekly MVPA recommendations at baseline were less likely to decline in both PCS and EQ-5D index score, in comparison with those participants who were not meeting recommendations.

We did not find any associations between weekly MVPA and the MCS. The only dimension of the SF-12 related to mental health that was associated with weekly MVPA was vitality, which is known to be positively correlated with both the MCS and the PCS (22,23). Previous research, including both cross-sectional and experimental studies report similar results, where physical activity is more closely associated with physical components of HRQL. A single cross-sectional study reported a positive association between aerobic physical activity and the MCS (10), but other research has not confirmed this association (11,24,25). Therefore, the relationship between physical activity and mental components of HRQL are not entirely clear. Given the prevalence of mental disorders in people with diabetes (2), there are likely to be many factors other than physical activity that influence this relationship in type 2 diabetes.

It has been previously established that physical activity improves functional performance in the general population and among older adults (26,27). The perception of better physical functioning in our sample of adults with diabetes could reflect better functional performance in those who are meeting weekly MVPA recommendations. Additionally, our results reveal that weekly MVPA is associated with maintenance of physical health (as represented by the PCS) over time, suggesting that by meeting physical activity recommendations set forth by the CDA, individuals with type 2 diabetes may be better able to maintain their functional status and physical health as they age. This is particularly important in this patient population, as diminished physical functioning could impact the ability to perform the necessary self-care needed to manage type 2 diabetes.

Many experimental studies have failed to show an association between aerobic physical activity and HRQL, however this could be partially attributed to the fact that HRQL is typically measured immediately post-intervention (13). The benefits of physical activity on HRQL might occur more so in the long-term and therefore experimental studies employing longer follow up are important (13). It should be noted that despite efforts to promote the importance of physical activity, compliance to recommendations remains a concern. In our sample, only 21% of participants were meeting recommendations for physical activity, consistent with similar studies (28). Our results, which indicate physical activity is associated with maintaining physical health and HRQL, could help motivate individuals with type 2 diabetes to remain physically active and continue to meet the recommendations set forth by the CDA as they age.

While the longitudinal nature and large sample size are strengths of this study, the results should be interpreted in light of a few limitations. Firstly, the use of self-reported physical activity could have lead to bias, as participants are more likely to over-report their physical activity due to social desirability (29). This could lead to misclassification into the “meeting recommendations” group, and bias in our results. Additionally, the use of the GLTEQ assesses only leisure-time physical activity, and thus other daily activities such as sleep, light intensity activity and sedentary time, are not captured. Future research should consider additional behaviours occurring throughout the day when considering HRQL. Also, our cohort consisted of mostly white, English-speaking individuals, so generalizability to other populations may be limited. Finally, we initially observed larger declines over one year of follow up in the group who was meeting recommendations in comparison with the group who was not. This could be attributable, in part, to regression towards the mean, as those respondents meeting recommendations reported significantly higher scores at baseline, and therefore it is not unexpected to see scores at follow up that are closer to the overall mean of the sample. Once these baseline differences in HRQL were accounted for in the multivariable analyses, the observed differences in unadjusted changes between groups were reversed.

Among this population-based sample of adults with type 2 diabetes, higher weekly MVPA at baseline was independently associated with better physical functioning, general health, and vitality scores after one year of follow up. Furthermore, higher weekly MVPA was also associated with a greater likelihood of maintaining health status. These results provide further support for the current recommendations for physical activity in type 2 diabetes, by demonstrating that meeting these recommendations is associated with better HRQL.

Table 3-1. Baseline characteristics of the study sample, overall, and by follow up completion

Characteristic	Overall (N=2040)*	Completers (N=1558)	Non-Completers (N=482)	P-Value
Female sex	917 (45.0)	716 (46.0)	201 (42.3)	0.219
Age	64.4 +/- 10.7	65.0 (10.4)	62.3 (11.7)	<0.001
Household income				0.08
< $40,000	583 (28.6)	426 (27.3)	157 (32.6)	
$40,000-$80,000	596 (29.2)	468 (30.0)	128 (26.6)	
> $80,000	485 (23.8)	373 (23.9)	112 (23.2)	
Education				0.002
Less than high school	276 (13.5)	209 (13.4)	67 (13.9)	
Completed high school	813 (39.9)	594 (38.1)	219 (45.4)	
More than high school	939 (46.0)	752 (48.3)	187 (38.8)	
Unemployed/retired	1167 (57.2)	909 (58.3)	258 (53.5)	0.131
Ethnicity				0.021
White	1852 (90.8)	1435 (92.1)	417 (86.5)	
Aboriginal	48 (2.4)	38 (2.3)	10 (2.1)	
Others	109 (5.3)	72 (4.6)	37 (7.7)	
Current smoker	213 (10.4)	1401 (89.9)	411 (85.3)	0.004
Physical inactivity	1602 (78.5)	1209 (77.5)	394 (81.7)	0.049
Diabetes duration	12.3 (10.0)	12.5 (10.0)	9.3 (9.2)	<0.001
Number of comorbidities	4.1 (2.3)	4.1 (2.3)	4.2 (2.4)	0.449
Depressive symptoms (PHQ-8 score)	5.2 (5.4)	4.8 (5.1)	6.5 (6.0)	<0.001
No (0-5)	1162 (57.0)	936 (60.1)	226 (46.9)	
Mild (6-9)	458 (22.5)	349 (22.3)	109 (22.6)	
Moderate (10-14)	204 (10.0)	142 (9.1)	62 (12.9)	
Moderate-severe (15-19)	113 (5.5)	63 (4.0)	50 (10.4)	
Severe (>=20)	55 (2.7)	37 (2.4)	19 (3.7)	
HRQL indicators				
EQ-5D index score	0.79 (0.17)	0.80 (0.16)	0.77 (0.19)	<0.001
PCS	44.4 (10.8)	45.1 (10.6)	41.9 (11.1)	<0.001
MCS	49.1 (9.9)	48.8 (9.7)	45.9 (10.2)	<0.001
Physical functioning	66.7 (34.5)	68.7 (33.8)	59.8 (36.0)	<0.001
Role physical	63.6 (31.2)	65.9 (30.3)	56.3 (33.0)	<0.001
Bodily pain	68.1 (30.5)	70.0 (29.7)	62.1 (32.3)	<0.001
General health	61.3 (23.8)	62.0 (23.1)	59.2 (25.7)	0.028
Vitality	53.2 (25.0)	54.4 (24.6)	49.1 (26.4)	<0.001
Role emotional	75.3 (27.7)	77.6 (26.4)	67.6 (30.3)	<0.001
Social functioning	76.6 (28.0)	78.7 (26.9)	69.8 (30.4)	<0.001
Mental health	71.5 (20.9)	73.0 (20.5)	67.2 (22.2)	<0.001

Note: 92 individuals received a different version of the survey in year 1, using different measures of HRQL (SF-12 version 1 instead of version 2), and were therefore excluded from the current analysis.

Table 3-2. Baseline characteristics of study sample, overall and by physical activity group

Characteristic	Overall (N=1948) mean ± SD or N(%)	Meeting Weekly MVPA Recommendations Yes (N=416) mean ± SD or N(%)	No (N=1532) mean ± SD or N(%)	p-value*
Female sex	875 (45.2)	158 (38.0)	717 (46.8)	0.001
Age (years)	64.5 ± 10.8	63.4 ± 10.3	64.9 ± 10.9	0.013
Annual household income (Canadian dollars)				0.012
<$80,000	1122 (57.6)	228 (54.8)	894 (58.4)	
≥$80,000	454 (23.3)	119 (28.6)	335 (21.9)	
Education				<0.001
Less than high school	275 (14.1)	37 (8.9)	238 (15.5)	
Completed high school	780 (40.0)	139 (33.4)	641 (41.8)	
More than high school	881 (45.2)	250 (57.7)	641 (41.8)	
Employment status - Unemployed/retired	1127 (58.8)	238 (57.9)	889 (59.0)	0.682
Ethnicity				0.448
White	1765 (90.6)	379 (91.1)	1386 (90.5)	
Aboriginal	46 (2.4)	8 (1.9)	38 (2.5)	
Others	106 (5.4)	27 (6.5)	79 (5.2)	
Current smoker	199 (10.2)	28 (6.7)	171 (11.2)	0.008
Diabetes duration (years)	12.6 ± 10.0	12.0 ± 9.5	12.8 ± 10.2	0.262
Number of comorbidities	4.2 ± 2.3	3.5 ± 2.1	4.4 ± 2.3	<0.001
Depressive symptoms	5.2 ± 5.4	3.7 ± 4.7	5.6 ± 5.5	<0.001
Absent (PHQ-8 <10)	1532 (78.6)	366 (88.0)	1166 (76.1)	
Present (PHQ-8 ≥10)	416 (21.4)	50 (12.0)	366 (23.9)	
HRQL indicators				
EQ-5D (problems: ≥ level 2)				
Mobility	1030 (52.9)	151 (36.4)	879 (58.0)	<0.001
Self-Care	223 (11.5)	26 (6.3)	197 (12.9)	<0.001
Usual Activities	928 (47.6)	123 (29.6)	805 (52.6)	<0.001
Pain/Discomfort	1431 (73.5)	269 (64.7)	1162 (75.9)	<0.001
Anxiety/Depression	905 (46.5)	169 (40.6)	736 (48.0)	0.004
EQ-5D index score	0.79 ± 0.17	0.84 ± 0.13	0.78 ± 0.18	<0.001
SF-12				
Physical functioning	66.3 ± 34.8	80.7 ± 29.1	62.3 ± 35.2	<0.001
Role physical	65.8 ± 30.2	78.7 ± 25.7	62.3 ± 30.4	<0.001
Bodily pain	67.5 ± 30.7	76.5 ± 27.3	65.1 ± 31.1	<0.001
General health	60.9 ± 24.0	70.2 ± 19.7	58.4 ± 24.4	<0.001
Vitality	53.0 ± 24.8	63.7 ± 23.0	50.1 ± 24.4	<0.001
Role emotional	77.9 ± 25.5	84.8 ± 21.5	76.0 ± 26.1	<0.001
Social functioning	76.1 ± 28.2	84.0 ± 24.9	73.9 ± 28.6	<0.001
Mental health	71.1 ± 20.6	74.6 ± 20.0	70.1 ± 20.7	<0.001
PCS	44.2 ± 10.8	49.1 ± 9.0	42.9 ± 10.9	<0.001
MCS	48.9 ± 9.8	50.7 ± 9.3	47.1 ± 9.8	<0.001

Note: Data is presented as mean (SD) for continuous variables and frequency (%) for categorical variables. Numbers may not add up to 1948 due to missing data.
* p-value comparing meeting recommendations group to not meeting recommendations group

Abbreviations: HRQL health-related quality of life, PCS physical component summary score, MCS mental component summary score, SD standard deviation

Table 3-3. Unadjusted changes in each HRQL indicator over one year; overall, and by physical activity group

HRQL Indicator	Change in HRQL after one year of follow up Overall Sample	Meeting Recommendations for PA	Not Meeting Recommendations for PA	p-value
EQ-5D Index score	-0.016 ± 0.12	-0.018 ± 0.10	-0.015 ± 0.12	0.128
PCS	-1.05 ± 7.00	-1.67 ± 6.14	-0.88 ± 8.21	0.033
MCS	-1.20 ± 7.86	-1.51 ± 7.54	-1.12 ± 7.95	0.231
Physical functioning	-2.85 ± 26.25	-3.00 ± 22.69	-2.81 ± 27.14	0.951
Role physical	-2.55 ± 22.96	-4.88 ± 20.70	-1.92 ± 23.49	0.016
Bodily pain	-1.88 ± 26.13	-2.55 ± 22.90	-1.70 ± 26.94	0.180
General health	-1.88 ± 20.24	-3.09 ± 17.90	-1.56 ± 20.82	0.100
Vitality	-2.03 ± 22.35	-4.14 ± 20.35	-1.46 ± 22.83	0.011
Role emotional	-3.47 ± 23.32	-4.59 ± 20.91	-3.16 ± 23.93	0.441
Social functioning	-1.42 ± 24.94	-2.64 ± 23.39	-1.09 ± 25.34	0.132
Mental health	-2.38 ± 19.21	-2.26 ± 18.77	-2.41 ± 19.33	0.926
EQ-5D Index score				
No change	599 (30.8)	161 (38.7)	438 (28.6)	<0.001
Improved	575 (29.5)	107 (25.7)	468 (30.6)	
Declined	774 (39.7)	148 (35.6)	626 (40.9)	
PCS				
No change	1156 (59.3)	281(67.4)	875 (57.1)	<0.001
Improved	316 (16.2)	39 (9.5)	277 (18.1)	
Declined	476 (24.5)	96(23.1)	380 (24.8)	
MCS				
No change	1061 (54.5)	246 (59.1)	815 (53.2)	0.065
Improved	362 (18.6)	64 (15.4)	298 (19.5)	
Declined	525 (27.0)	106 (25.5)	419 (27.4)	

Abbreviations: HRQL health-related quality of life, PA physical activity, PCS physical component summary score, MCS mental component summary score, SD standard deviation

Table 3-4. Associations of meeting weekly MVPA recommendations with HRQL over one year of follow up

HRQL indicator (year 2 score)	beta	SE	p-value
EQ-5D Index Score	0.007	0.007	0.298
PCS	0.66	0.37	0.076
MCS	0.50	0.42	0.234
SF-12 Dimensions			
Physical functioning	5.42	1.37	<0.001
Role physical	1.92	1.18	0.104
Bodily pain	2.11	1.38	0.128
General health	2.44	1.16	0.038
Vitality	2.79	1.17	0.018
Role emotional	0.87	1.17	0.455
Social functioning	1.76	1.25	0.159
Mental health	1.16	0.97	0.232

Adjusted for: age, sex, education, income, diabetes duration, smoking status, presence of depressive symptoms, and number of comorbidities

Abbreviations: HRQL health-related quality of life, PCS physical component summary score, MCS mental component summary score, SE standard error

Reference: not meeting recommendations group (<150 min of MVPA per week)

Table 3-5. Associations of meeting weekly MVPA recommendations with the direction of changes in HRQL over one year of follow up

Direction of change in HRQL indicator	OR [95% CI]	p-value
EQ-5D Index Score (ref: no change)		
Declined	0.76 [0.57,0.99]	0.049
Improved	0.85 [0.61,1.17]	0.316
SF-12: PCS (ref: no change)		
Declined	0.67 [0.51,0.91]	0.010
Improved	0.76 [0.50,1.16]	0.200
SF-12: MCS (ref: no change)		
Declined	0.82 [0.61,1.09]	0.164
Improved	0.93 [0.64,1.34]	0.694

Adjusted for: age, sex, education, income, diabetes duration, smoking status, presence of depressive symptoms, and number of comorbidities

Abbreviations: HRQL health-related quality of life, PCS physical component summary score, MCS mental component summary score, OR odds ratio

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CHAPTER 4.

DISCUSSION & CONCLUSIONS

4.1 SUMMARY OF FINDINGS

This thesis consists of two research studies exploring the relationship between physical activity and health-related quality of life in adults with type 2 diabetes. Understanding the association of physical activity with HRQL is important for the self-management of people living with type 2 diabetes. Physical activity is a key component for preventing and managing type 2 diabetes and provides numerous health benefits, including weight management, improved glycemic control, decreased blood pressure and decreased risk of developing complications and comorbidities.

The results presented in this thesis indicate that significant associations exist between meeting the CDA recommendations for physical activity (i.e., at least 150 minutes of MVPA per week) and HRQL in type 2 diabetes. In particular, we demonstrate that meeting recommendations for weekly MVPA was associated with better physical functioning, vitality and general health. This is an important finding within this population, as physical functioning, vitality and general health could all be associated with better functional status, as research has indicated in both the general population and older adults (1,2). Further research, including a longer follow-up time or an experimental design is needed to confirm the relationship between HRQL and functional status in adults with type 2 diabetes.

Additionally, weekly MVPA was associated with maintenance of physical health (as represented by the PCS) over one year of follow up. Participants who reported meeting recommendations for weekly MVPA at baseline were less likely to report declines in their physical health status than those individuals who were not meeting recommendations. Participants who reported meeting recommendations at baseline were also less likely to report improvements in physical health status. This finding, while seemingly contradictory, can most likely be explained by the phenomenon of regression to the mean. Those participants who were not meeting recommendations for physical activity reported lower HRQL scores at baseline, and are therefore more likely to report scores closer to the mean at follow up. The group with higher baseline physical activity levels reported higher HRQL scores at baseline, and therefore are more likely to report lower scores at follow up. Considering this, our results imply that by meeting physical activity recommendations, individuals with type 2 diabetes can maintain their physical health and functional status as they age. This is critical, as diminished physical functioning could impact the ability to live independently or to perform the necessary self-care needed to manage type 2 diabetes.

In our longitudinal analysis, we did not find any significant associations between weekly MVPA and mental health. Previous research, including both cross-sectional and experimental studies, report that physical activity is more closely associated with the physical components of HRQL than the mental components (3,4). A single cross-sectional study reported a positive association between aerobic physical activity and the MCS (5), but other research has not confirmed this association (6–8). Many other demographic and lifestyle factors may influence an individual's perception of his or her mental health. Personal enjoyment of physical activity could influence an individual's perception of his or her HRQL, and those individuals who participate in physical activity out of obligation versus enjoyment may not derive the same benefits, with respect to mental health and overall HRQL (9,10).

In our cross-sectional study, we demonstrated an association between higher levels of MVPA (i.e. more than 300 minutes of MVPA per week) and better HRQL on dimensions related to physical health. This provides support for the existence of a dose-response relationship between these variables. Health care providers should encourage patients with type 2 diabetes who are currently meeting recommendations for physical activity to achieve higher levels if possible to accrue additional health benefits related to HRQL and other important clinical outcomes (11).

Light-intensity physical activity and resistance exercise could both be important in the relationship between MVPA and HRQL. In a series of sensitivity analyses, we included light-intensity physical activity alongside MVPA in our regression models, and found no change in the association with HRQL in those meeting recommendations or exceeding recommendations. Additionally, we investigated the independent association of light-intensity physical activity on HRQL in our sample, and found no significant results. These results provide evidence that MVPA has stronger effects on HRQL than light-intensity physical activity, particularly in a sample of relatively healthy type 2 diabetes patients. Nonetheless, those individuals who are older, or those who have severe complications and comorbidities might experience improved HRQL from participation in light-intensity physical activity, particularly if there are barriers to participation in MVPA. We did not measure resistance exercise within our sample, however previous studies have indicated that resistance exercise is associated with HRQL in type 2 diabetes patients (12), as well as in older, community dwelling adults (13). In future work, measures of both resistance and aerobic exercise should be incorporated to provide support for the existing literature.

In our cross-sectional analysis, we recognized the possibility of reverse causality or bi-directionality in the relationship between physical activity and HRQL. It is possible that if participants experienced a decline in their HRQL, they would subsequently reduce the amount of time spent participating in physical activity, and this would occur more readily in those with problems related to mobility, pain or fatigue. The use of a longitudinal design in our second study allowed us to better investigate the direction of causality, and we demonstrated that meeting physical activity recommendations at baseline was independently associated with better HRQL at one year of follow up.

While our longitudinal analysis strengthens the argument for a causal relationship, allowing for an assessment of the temporal relationship between baseline physical activity and changes in HRQL, we recognize that there still may be a bi-directional relationship. That is, baseline level of HRQL could affect changes in physical activity over time. As such, we conducted a sensitivity analysis, which revealed that there were no significant effects of baseline HRQL on changes in physical activity over one year of follow up (see Appendix). The cohort participants were dichotomized into two groups based on level of baseline HRQL (above or below the median score) for each of the PCS, MCS and EQ-5D index score. Multivariable linear regression, adjusting for age, sex, education, income, smoking status, diabetes duration, number of comorbidities and presence of depressive symptoms was used to explore the association between baseline HRQL and change in weekly MVPA minutes over one year of follow up. Among participants, there were no statistically significant differences in the amount of change in weekly MVPA over one year of follow up between those who had PCS (B=10.09, p=0.258), MCS (B=-1.24, p=0.892) or EQ-5D (B=14.78, p=0.118) scores above the median at baseline compared with those who reported scores below the median. While this finding provided corroborating evidence regarding the direction of causality (i.e., baseline physical activity improving or preserving physical-related HRQL), a longer follow up time might be useful to investigate longer-term patterns of physical activity with changing HRQL, particularly as it relates to aging within this population.

4.2 IMPLICATIONS OF RESEARCH

Currently, the physical activity guidelines published by the CDA describe the benefits of physical activity on cardiorespiratory fitness, glycemic control, insulin resistance, blood pressure and weight loss, however there is no mention of the benefits related to HRQL or overall well-being (14). Given the recent importance of patient-reported outcomes, the evidence surrounding the positive association between physical activity and HRQL should be incorporated within these guidelines, to provide additional support for the existing recommendations for physical activity. The results from our study, along with previous cross-sectional research, could be cited as evidence to support the existing recommendation for aerobic physical activity and the beneficial effect on HRQL in addition to biomedical outcomes. This evidence could be further strengthened in the future using an experimental study design, however the use of a longitudinal study design within a population-based cohort provides strong support.

By incorporating the evidence supporting the association between physical activity and HRQL into the guidelines, health care professionals might become better educated on this relationship and could become better able to convey this information to patients. Patients who are not currently active might be more likely to engage in weekly MVPA if they receive a meaningful benefit such as improved physical functioning, general health or vitality. Additionally, educating patients on the relationship between physical activity and maintenance of HRQL over time might motivate patients to engage in physical activity in order to maintain physical functioning, independence and ability to perform important self-management tasks. Maintenance of HRQL over time is a realistic goal that health care professionals can strive to work towards for patients with type 2 diabetes.

The low rates of adherence to physical activity guidelines attest to the need to find new means of increasing participation rates in weekly physical activity. As more evidence is generated, researchers and health care professionals can continue to develop effective programs and interventions that serve to improve HRQL alongside clinical outcomes for the type 2 diabetes population. Ideally, this would help lead to better health within this clinical population, and reduced burden of the disease on patients, as well as associated long-term health care costs in Canada.

4.3 STRENGTHS AND LIMITATIONS

One of the major strengths of this thesis involves the use of a large population-based cohort. In general, the cohort was fairly representative of the type 2 diabetes population in Alberta, Canada, with regards to age, sex and other socio-demographic factors (15). The use of data from a prospective cohort of this nature is unique, as the majority of Canadian epidemiological studies use population data available through administrative health records, which lack important covariates and are often incomplete (15). The ABCD cohort survey included various measures and questionnaires used to assess a variety of factors associated with health in type 2 diabetes. Measures that were selected for inclusion into the cohort survey have previously been validated for use in type 2 diabetes. Subsequently, a wide variety of covariates were available for use in statistical modelling.

Secondly, two well-known, generic measures of HRQL were selected as outcomes for this study. Both the EQ-5D and SF-12 are commonly used in type 2 diabetes research, and allow for comparisons between studies. Further, because generic measures were chosen, comparison of these results with studies in both the general population and other chronic disease groups are possible.

The third major strength of this thesis research is the longitudinal design of the second project. The majority of previous research investigating the relationship between physical activity and HRQL in type 2 diabetes has been cross-sectional in nature. The use of a longitudinal design allows us to better investigate the direction of causality. Further, we undertook a sensitivity analysis in order to investigate the possibility of a bi-directional relationship, and the results of this sensitivity analysis provided additional support for our hypothesis.

The fourth major strength of this project is the use of multiple imputation for missing data at follow up after one year. Multiple imputation for missing data was used as we observed systematic differences between those participants who completed follow-up and those who did not, and excluding those who did not complete surveys at follow up would have introduced bias into our study. The use of multiple imputation over simple imputation techniques helps to reduce the risk of bias in our estimates and allows statistical power to be preserved by using all available data.

Finally, a fifth strength of this project was the relevance to the current clinical practice guidelines for type 2 diabetes patients in Canada. This project used recommendations from the current guidelines in order to categorize participants into physical activity groups, and the evidence that is generated can be used in support of the guidelines. Evidence included within the current guidelines focuses on specific clinical outcomes, whereas our results focus on patient-reported HRQL. Focusing on the relevance of the current physical activity recommendations to patient-reported outcomes such as HRQL might provide more motivation for patients to participate in physical activity.

In spite of these strengths, there are some limitations that must be considered. While the cohort was generally representative of the type 2 diabetes population in Alberta with regards to socio-demographic factors, it under-represented non-white minorities, particularly immigrant and Aboriginal populations. This is an important limitation to recognize, as the prevalence of type 2 diabetes and burden of complications are usually high in these groups (16–18), thereby reducing the generalizability of the results.

Second, the Godin Leisure Time Physical Activity Questionnaire (GLTEQ) was used to assess self-reported physical activity in the cohort study. While the use of self-reported physical activity is common in large cohort studies, there are inherent limitations to this approach. Participants are more likely to over-report their physical activity due to social desirability (19), which could lead to misclassification into the meeting recommendations group, subsequently biasing our findings towards the null. Additionally, the GLTEQ assesses only leisure-time physical activity, and hence other forms of physical activity that may provide health benefits to type 2 diabetes patients are not considered. Such forms of physical activity could include occupational or household physical activity. Nevertheless, the GLTEQ has been widely used and is considered a reliable and valid measure of exercise behaviour in adults (20,21).

Third, despite the variety of data we collected from cohort participants, it is possible we missed important covariates in our models, leading to the possibility of residual confounding. In particular, our survey lacked a measure of body mass index (BMI) at baseline and at year one follow up. Current evidence indicates that negative associations exist between BMI and physical activity (22), where those individuals who have higher BMIs typically engage in lower levels of physical activity. Further, high BMIs, particularly those associated with obesity, are associated with severely diminished HRQL (23,24). Therefore, BMI is a potential confounder in the relationship between physical activity and HRQL, but was not included in our regression models. Additionally, other lifestyle behaviours such as sleep, diet and sedentary behaviour could impact the association between physical activity and HRQL, and these factors were not considered in this study. Additional information was collected on these variables in subsequent follow up years, and future work could make use of this data.

Also, we must recognize the issue of the healthy volunteer bias within the ABCD cohort, which impacts the generalizability of our results. Those individuals who volunteered to participate in the cohort study are likely to be more health conscious, have better health-related behaviours and have better HRQL in comparison to those who chose not to participate. At baseline, participants reported relatively high HRQL scores on both the SF-12 and the EQ-5D, in comparison to Canadian population norms. Other authors who have investigated the relationship between physical activity and HRQL in adults with type 2 diabetes have also addressed the issue of the healthy volunteer bias (25,26). Most likely, our sample under-represents type 2 diabetes patients who are living with severe complications or comorbidities, both of which are known to be associated with severely diminished HRQL (27–29). The healthy volunteer bias could have biased our results towards the null, and made it difficult to ascertain differences in HRQL between the group who met the recommendations for physical activity and the group who did not meet the recommendations.

Finally, due to availability of data, we were only able to assess change in HRQL after one year of follow up, and therefore we were not able to look at long term physical activity patterns or long term changes in HRQL. The positive impact of physical activity on HRQL might be more pronounced over a longer time period (30). Data collection for the ABCD cohort has continued for three years after baseline, and therefore further exploration of these relationships should be undertaken with the newly collected data in the future.

4.4 CONCLUSIONS

The results from this thesis provide stronger support of the existing CDA guidelines for physical activity. We have demonstrated positive associations between physical activity and HRQL in type 2 diabetes using both cross-sectional and longitudinal study designs. By showing a clear link between physical activity and HRQL, particularly physical health, we may be better able to motivate patients with type 2 diabetes to increase their physical activity levels, in order to achieve improvements in overall quality of life. Incorporating evidence surrounding the benefits of physical activity on HRQL into the CDA guidelines will allow patients and clinicians alike to become better informed of this relationship. Efforts to promote physical activity should emphasize the benefits on clinical outcomes as well as benefits associated with HRQL and general well-being. As the prevalence of diabetes continues to rise worldwide, promotion of physical activity and other healthy lifestyle behaviours for managing type 2 diabetes is increasingly important in order to reduce the burden on the health care system.

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APPENDIX

Table A-1. Adjusted multivariable linear regression results of the association of baseline HRQL with change in physical activity over one year of follow up

HRQL Indicator*	beta	SE	p-value
EQ-5D Index Score	14.78	9.36	0.118
PCS	10.09	8.88	0.258
MCS	-1.24	9.08	0.892

Adjusted for: age, sex, education, income, diabetes duration, smoking status, presence of depressive symptoms, and number of comorbidities

* Comparing those who were above the median HRQL score at baseline to those who were below