SELF- REFLECTIONS OF PHYSICAL ACTIVITY BEHAVIOUR: EXPLORING REAL-WORLD CONTEXTS

by

Blanca Gala

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The following individuals certify that they have read, and recommend to the College of Graduate Studies for acceptance, a thesis/dissertation entitled:

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submitted by Blanca Gala in partial fulfillment of the requirements of

the degree of Master of Science .

Dr. Mary Jung, School of Health and Exercise Sciences

Supervisor

Dr. Heather L. Gainforth, School of Health and Exercise Sciences

Supervisory Committee Member

Dr. Brodie Sakakibara, Faculty of Medicine

Supervisory Committee Member

Dr. Charlene Ronquillo, School of Nursing

University Examiner

Abstract

Type 2 diabetes (T2D) affects millions of individuals worldwide. Diabetes Prevention Programs (DPPs) targeting diet and physical activity (PA) have shown reduction in T2D incidence by up to 58%. However, few DPPs report how well participants adhere to PA recommendations. Small Steps for Big Changes (SSBC) is an evidence-based DPP which delivers brief dietary and PA counseling. SSBC aims to help adults living with prediabetes make sustainable modifications to their dietary and PA behaviour to reduce their risk of developing T2D. Participants were asked to use mHealth (i.e., mobile health applications) to self-monitor and self-reflect on their PA in the year following program completion.

Behaviour change require an understanding of the current and desired behaviour. Commonly, retrospective data from interviews or focus groups are interpreted, coded, and then analyzed within specific frameworks such as the Theoretical Domains Framework (TDF). Few studies collect data in real-time free-living environments to assess people's perceptions on their PA practices. Real-time data collection methods can provide unbiased information about people's experiences when engaging in PA. This thesis examined self-reported PA and real-time self-reflections reported in the year following completion of SSBC. The most common barriers and facilitators to PA were identified and categorized within the TDF. Finally, correlation was calculated to examine the relationship between PA and self-reflections.

On average, participants reported that they exercised 143 days and wrote 78 self-reflections during the year. Self-reflections most commonly included detailed information on their exercise (i.e., self-monitoring of exercise) (4,872 times during the year) and descriptions of facilitators to exercising (3,190). The most commonly identified domains were *Behavioural*

regulation (5,018) and *Environmental context and resources* (4,532). A positive and moderate correlation was found between self-reflections and days exercised ($r = 0.424, p = 0.01$).

These findings add to the literature on PA patterns among individuals at risk of T2D and suggest that elaborating on self-monitoring of PA is an acceptable way to self-reflect among SSBC participants. Future research could benefit from exploring how self-monitoring of PA influences internal processes to improve PA habits. mHealth technology may be an effective way to incorporate self-reflection in future interventions aiming to prevent T2D.

Lay Summary

Type 2 diabetes (T2D) affects millions of people in the world. Diabetes Prevention Programs (DPPs) focused on diet and physical activity (PA) have shown positive results in preventing and delaying T2D. However, little is known about how well participants follow PA recommendations during and after the completion of DPPs. Small Steps for Big Changes (SSBC) is a DPP that aims to empower individuals to make lasting dietary and PA behaviours that will reduce their risk of developing T2D. SSBC is delivered through 6 counseling sessions and 4 follow-up sessions. Participants are asked to keep record of their PA through a mobile application in the year following program completion.

Little is known about the consistent obstacles and enablers that participants face in their daily lives to being active when not being supervised or monitored in a study. This thesis examined short texts that SSBC alumni recorded through a mobile application during the 12-month follow-up period to understand what helps and prevents individuals to adhere to PA. Participants shared information about factors that helped them to be physically active and detailed information about the exercise that they completed. It was also shown a positive relationship between the number of times participants recorded small texts and the number of days that they exercised.

Preface

I declare that the composition of this dissertation is the result of my own work. This thesis is part of a larger project, *Small Steps for Big Changes (SSBC)*, developed and run by Dr. Mary Jung. Myself and Dr. Megan MacPherson were responsible for the conception of methods to identify the most frequent barriers and facilitators to physical activity and their categorization within the TDF domains utilizing SSBC alumni's self-reflections recorded during the SSBC Randomized Control Trial (RCT). I, Ms. Blanca Gala, was responsible for the literature review, data analyses, interpretation, and writing of this thesis. This study protocol analyzed in this work was approved by The University of British Columbia Okanagan Research Services Behavioural Research Ethics Board (H12-02268). Dr. Mary Jung was responsible for all primary data collection for the RCT and overseeing all aspects of the study including editing of the thesis.

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List of Abbreviations

App: mobile application

A1c: glycosylated hemoglobin

BCT: behaviour change techniques

BCW: Behaviour Change Wheel

BG: Blanca Gala

COM-B: Capability, Opportunity, Motivation – Behaviour

CRF: cardiorespiratory fitness

CVD: cardiovascular disease

DPP: Diabetes Prevention Program

EMA: Ecological Momentary Assessment

HIIT: high intensity interval training

IGT: impaired glucose tolerance

KB: Kyra Braaten

mHealth: mobile health

MICT: moderate-intensity continuous training

MM: Megan MacPherson

MVPA: of moderate to vigorous physical activity

PA: physical activity

PAR-Q+: Physical Activity Readiness Questionnaire-Plus

PMQOA: Participation Motivation Questionnaire of Older Adults in Physical Activity

PRE: perceived rate of exertion

RCT: Randomized Control Trial

SC: Sarah Craven

SCT: Social Cognitive Theory

SSBC: Small Steps for Big Changes

TDF: Theoretical Domains Framework

T2D: type 2 diabetes

WHO: World Health Organization

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Thank you to my fantastic lab, the Diabetes Prevention Research Group. The DPRG has been a family to me. I admire each one of my genius lab mates and feel grateful for having the opportunity to learn from them.

A special thank you to my lab mates Megan MacPherson for all your help and mentorship. Thank you to Kyra Braaten and Sarah Craven for all your help during the coding process for this thesis. It would not be possible without you.

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Chapter 1: Introduction

Globally 483 million people have T2D, half of whom are unaware that they have it (International Diabetes Federation, 2021). This statistic is anticipated to rise to 7,079 individuals per 100,000 by 2030 (Khan et al., 2020). T2D results from the body's inefficiency to use insulin produced by the pancreas (Chatterjee, 2017) and may result in severe health complications such as kidney disease, eye damage, heart disease and stroke (Diabetes Canada, 2021; Chatterjee et al., 2017; Zheng, 2017), especially among undiagnosed adults (Zheng et al., 2018). In 2021 alone, T2D was the main cause of approximately 6.7 million deaths worldwide among adults aged 20 to 79 years (International Diabetes Federation, 2021). This condition increases the risk of hospitalization threefold for cardiovascular diseases, 12 times for end-stage renal illness and approximately 20 times for a non-traumatic lower limb amputation (Diabetes Canada, 2020). In addition to physical health, T2D can also influence an individual's mental health with approximately 30% of all individuals with diabetes experiencing depressive symptoms (Diabetes Canada, 2020).

T2D places a large financial burden on the healthcare system. In 2021 the direct global health expenditure associated with diabetes was roughly USD $966 billion; this equates to 9% of the global health expenditure (International Diabetes Federation, 2021). In Canada, approximately 29% of the population live with diabetes (90% of whom have T2D) or prediabetes (Diabetes Canada, 2020; Diabetes Canada, 2022). Diabetes had a financial impact of almost $3.8 billion in healthcare costs in 2020, and this number is expected to increase to $4.9 billion by 2030 (Diabetes Canada, 2020).

While there are several reasons for the worldwide increase in incidence of this condition, physical activity (PA) and a healthy diet represent the most powerful path to prevent or delay

T2D onset (Magkos, et al., 2020; International Diabetes Federation, 2021). Early detection and prevention programs combining education, self-management and psychological support are urgently needed (Chatterjee et al., 2017).

According to the International Diabetes Federation (2021), 541 million adults are at risk of developing T2D. Prediabetes is the antecedent of T2D and is often characterized by fat accumulation and insulin resistance that leads to gradual increases in fasting and postprandial hyperglycaemia (Chatterjee et al., 2017). In prediabetes, a compensatory increase in pancreatic insulin secretion (known as hyperinsulinemia) results in blood glucose that is higher than normal but below T2D levels (Magkos et al., 2020), and it can be diagnosed as having a hemoglobin A1c (HbA1c) score between 5.7% to 6.4% (39–46 mmol/mol) (Edwards & Cusi, 2016; American Diabetes Association, 2021).

Regular PA is an essential behaviour for T2D risk reduction (Jadhav et al., 2017) and can result in improvements in insulin sensitivity, glucose regulation, and changes in visceral fat (Galaviz et al., 2015; Galaviz et al., 2018). Over half of all T2D cases can be prevented or delayed by making dietary and physical activity changes, including meeting PA guidelines (Smith et al., 2016; Zheng et al., 2018; Diabetes Canada, 2021). The World Health Organization Guidelines on physical activity and sedentary behaviour (2020) recommends that, to prevent chronic diseases such as T2D, adults should engage in 150 to 300 minutes of moderate intensity aerobic exercise or 75 to 150 minutes of vigorous intensity aerobic exercise per week (or an equivalent combination of moderate to vigorous PA). Similarly, the Canadian 24-Hour Movement Guidelines (Canadian Society for Exercise Physiology, 2021) and Diabetes Canada suggests at least 150 minutes of aerobic exercise per week as well as strength training at least twice a week **(**Sigal et al., 2018)**.** Despite the clear recommendations and widely known benefits

of engaging in regular PA, most individuals with prediabetes do not meet the recommended guidelines (Taylor et al., 2011; Steeves et al., 2015). In fact, only 54.7% of people with prediabetes in the USA tried to increase their PA over a one-year period of time (Taylor et al., 2011). Thus, there is an enormous opportunity for public health interventions to reduce the incidence of T2D by increasing PA in those at risk (Smith, et al., 2016).

1.1 Diabetes Prevention Programs (DPPs)

Several large-scale randomized trials within China, Finland, India, and America have highlighted that intensive lifestyle interventions targeting diet and PA can reduce T2D incidence by up to 58% (Vita, et al., 2016; Knowler, et al., 2002; Laaksonen et al, 2005; Patel et al., 2017).

The China Da Qing Diabetes prevention study, a 6-year cluster randomised trial implemented from 1986 to 1992, included 577 participants with impaired glucose tolerance (IGT) from 33 health care clinics in Da Qing city, China (Li et al., 2008). Participants were randomized to either a control group or to one of the three intervention groups: diet, exercise, or both diet and exercise (Pan et al, 1997). All intervention groups received ongoing individual and group counselling from their local physician. This counselling continued on a weekly basis for the first month, then reduced in frequency to monthly counselling for the next three months and then once every three months for the remainder of the 6-year study duration (Pan et al, 1997). Topics such as vegetables and sugar consumption and alcohol intake were addressed in the diet group, while the exercise group discussed ways to increment their leisure physical exercise and suggestions for winter activities were discussed. In the diet-plus-exercise group all those topics were covered (Pan et al, 1997). The control group only received general information regarding diabetes, IGT, diet, and PA (Pan et al, 1997).

The main evaluated outcomes were T2D incidence, cardiovascular disease (CVD) incidence and mortality, and all-cause mortality (Li et al., 2008). At the 6-year examination time point, the incidence of diabetes was significantly lower in the three intervention groups compared with the control group, and incidence rates did not significantly differ from one another, but significantly differed from the control group: the diet group reduced T2D incidence by 33%, the exercise group 47%, and the diet and exercise group 38%, compared with the control group (Pan et al, 1997). In a 20-year follow-up, including 98% of the original sample of participants, there was an overall reduction in diabetes incidence of 43% among all intervention groups combined vs the control group (Li et al., 2008).

The Finnish Diabetes prevention study was a 4-year randomised controlled trial started in 1993 which included 522 participants with overweight and IGT treated in five different health centers located in Helsinki, Kuopio, Oulu, Tampere and Turku (Eriksson et al., 1999). Participants were randomized to an intensive lifestyle intervention including diet and exercise or to a control group (Lindström et al., 212;2013; Uusitupa et al., 2019). Participants in the intervention group received ongoing individualized counselling for approximately 4 years (range 1–6 years) (Lindström et al., 212;2013). During the first year they had seven sessions with a nutritionist and every three months thereafter, where topics related to weight loss (e.g., fiber intake, reduce saturated fat consumption), as well as PA, were addressed (Eriksson et al., 1999). At the beginning of the study, the control group received guidance from a nutritionist, verbal and written, to adopt a diet reduced in fat, reduce alcohol intake, and stop smoking, in addition to general information on advantages of recreational PA (Eriksson et al., 1999). During the trial, T2D risk was reduced by 58% in the intervention compared to the control group, and 13-years after baseline there remained a 38% relative risk reduction (Uusitupa et al., 2019).

The American DPP started in 1996 and had 3234 adults at high risk to develop T2D from 27 health centers countrywide randomized to placebo (n = 1082), metformin (n = 1073), or intensive lifestyle group (n = 1079) (Knowler et al., 2002). Participants in the lifestyle group completed a 24-week intensive core curriculum in which they learned about diet and exercise with a goal to reduce 5-7% of initial body weight and engage in at least 150 minutes of moderate to vigorous PA (MVPA) per week. This intensive core curriculum was followed by an ongoing maintenance intervention consisting of monthly in-person and telephone follow-ups with their case managers until program completion (ranging from 1.8 – 4.6 years) (Knowler et al., 2002). The placebo and the metformin groups received standard advice on diet and exercise plus the placebo or the treatment, respectively (Knowler et al., 2002).

T2D incidence was 58% lower in the intensive lifestyle group, and 31% lower in the metformin group compared to the control group (Knowler et al., 2002). At 10 and 15-years following baseline, T2D incidence was still reduced by 34% in the lifestyle group, and 18% in the metformin group when compared to the placebo group (Knowler et al., 2002; Uusitupa et al., 2019).

The Indian DPP-1 was a 30-month randomised, controlled clinical trial. It had 531 participants with IGT assigned into four groups: 133 followed lifestyle modification, 133 were given metformin; 129 were given lifestyle modification plus metformin, and 136 were part of the control group (Ramachandran et al., 2006). The two groups which included lifestyle modification received individualized advice on regular PA and a healthy diet (targeting calorie intake reduction and inclusion of foods high in fiber). The guidance was provided at the time of randomisation and after two weeks by phone calls, continued by monthly phone calls. Personal sessions were provided every six months. The control group was treated with standard health

care advice (Ramachandran et al., 2006). After 30 months of follow-up, compared to the control group, there were significant lower cumulative incidence rates of T2D in the three intervention groups: 28.5% reduction the lifestyle modification group, 28.2% in the lifestyle modification plus metformin group, and 26.4% in the metformin group (Ramachandran et al., 2006; Uusitupa et al., 2019).

A second version of this study, the Indian DPP-2, was carried out while the Indian DPP-1 was still in progress (Ramachandran et al., 2009). It was a three-year placebo-controlled prospective study including 407 participants with IGT. Participants were assigned into two groups, one included lifestyle modification plus pioglitazone, an oral administered drug used for the treatment of T2D (Gillies & Dunn, 2000), and the other one included lifestyle modification plus placebo. At the end of the study, the incidence of diabetes was 29.8% in the group receiving pioglitazone and 31.6% in the placebo group, with no significant difference between them (Ramachandran et al., 2009). The effectiveness reported in both groups were similar to those reported from the lifestyle group in the Indian DPP-1, providing some evidence that the lifestyle intervention is what is driving the reduction in T2D incidence, not the added medication (Ramachandran et al., 2012).

1.2 Adherence to PA Recommendations

Many of the large-scale DPPs highlight that PA is a key interventional piece to reducing T2D incidence (Eaglehouse, et al., 2015); however, few provide information on how well participants are adhering to PA recommendations during and following these intensive programs, and those that do demonstrate that there is room for improvement.

For example, during the 4-year follow-up period of the Finnish Diabetes Prevention Study (Laaksonen et al., 2005) MVPA increased in the intervention group by approximately 36

minutes per week compared to baseline levels of PA; however, 38% of participants in the intensive lifestyle intervention group were still not meeting PA recommendations. Similarly, the Sydney DPP resulted in a mean weight loss of 2 kg and an estimated 30% diabetes risk reduction (Vita, et al., 2016). However, there was only a slight change of 17 ± 160.8 minutes of MVPA per week at the 12-month follow-up, and less than 11% of participants achieved the weekly goal of 210 minutes of MVPA a week (Vita, et al., 2016).

It is clear DPPs have demonstrated success in preventing and delaying the development of T2D, but that long-term PA behaviour change maintenance poses a challenge (Ozemek, et al., 2019; Vita, et al., 2016). One way to improve long-term PA adherence following participation in a DPP is to understand what barriers and facilitators to continued PA engagement exist. Individualised and targeted strategies could help to have a better understanding of people's PA behaviour following completion of a DPP, and in consequence, lead to better sustainment of changes made in the DPP to their PA patterns.

1.3 Barrier and Facilitator Identification

Understanding the main cognitive, affective, social, and environmental determinants of any particular behaviour is essential to implement strategies to improve long-term behavioural maintenance. Barriers and facilitators to PA have been defined as perceived influencers enhancing (positive) or hampering (negative) exercise behaviour (Garne-Dalgaard et al., 2019). In order to improve existing DPPs' long-term effects on PA levels, it is imperative to understand the barriers and facilitators facing individuals living at risk of T2D.

Based on the tools outlined, the barriers and facilitators reported to engaging in exercise in the literature appear diverse and multifaceted. Aspects like social norms and values, structural and socioeconomical factors, guidance from experts, as well as individual capabilities (e.g., time

management skills) play an important role to engaging in PA (Patel et al., 2017; Gary-Webb, et al., 2018; Spiteri, et al., 2019). For example, prioritizing work over exercise, cultural norms, and feeling exposed when exercising in the gym represent common obstacles (Patel et al., 2017). Similarly, social status, gender expectations, and available fitness facilities have been identified as barriers preventing underrepresented and underserved populations from taking part of in the U.S.A National DPP (Gary-Webb, et al., 2018).

In contrast, concern about weight, the desire to be healthy, awareness when diagnosed with T2D, and safe exercising environments have been reported to act as positive influences on staying physically active in ethnically diverse populations (Patel et al., 2017). Other common motivators are the wish to be role models for family members, having effective weight and stress management strategies, using time purposefully (especially among the retired population), and seeing PA as an opportunity to socialize (Spiteri, et al., 2019). Finally, positive sensations and enjoyment when exercising also constitute enablers for PA (Kanning et al., 2015).

Health behaviour change is a process that requires understanding of the context and influences of current behaviours (Atkins et al., 2017). Barriers and facilitators to engaging in a given behaviour are commonly identified through interviews, focus groups, or questionnaires (Spiteri et al., 2019; Baert, et al., 2011; Nikolajsen et al., 2021). Specifically, within the context of PA, the following scales developed using theoretical frameworks are often used: the Barrier to PA Practice Questionnaire (Hirayama, 2006 as cited in Gobbi et al., 2012, cited in Spiteri et al., 2019), the Perceived Barrier to Exercise Scale (Salmon, Owen, Crawford, Bauman, & Sallis, 2003, cited in Spiteri et al., 2019), the Barriers to Health Promoting Activities for Disabled People (Becker, Stuifberge, & Sands, 1991 in Spiteri et al., 2019), and the Participation

Motivation Questionnaire for Older Adults (Kirkby, Kolt, Habel, & Adams, 1999 in Spiteri et al., 2019).

There are advantages to using interviews and questionnaires constructed on theoretical frameworks. Theory-based questionnaires represent a potentially useful tool to address the full range of possible factors relevant to the target behaviour (Michie et al., 2011). Individuals can be asked about specific aspects known to influence PA through valid and reliable tools. For example, a study looking for motivational sources in older adults' adherence to PA in community-dwelling Iranians (Derakhshanrad et al., 2020) used the Participation Motivation Questionnaire of Older Adults in Physical Activity (PMQOA) based on the Social–Ecological model. This is a 35-item self-administered and self-reported questionnaire that has a three-factor structure to measure participants' intrapersonal, interpersonal, and community motivation to engage in PA (Derakhshanrad et al., 2020).

With the intention to assess intrapersonal, interpersonal and environmental determinants to PA, participants' responses to items such *as "I enjoy doing physical activity."*, *"My sport coaches encourage me to do physical activity."* and *"The existence of safe places around us encourages me to take part in physical activity."* were ranked on a 5-point Likert scale from "complete agreement" to "complete disagreement" (Derakhshanrad et al., 2020). Higher scores for each category indicated higher influence on PA. Different from conventional questionnaires, self-administered and self-reported questionnaires allowed participants to respond to the questions at their preferred time and under no researchers' supervision. However, the intrapersonal, interpersonal, and community motivation classification was already established, preventing them to add any different aspect relevant to their PA behaviour.

1.4 Self-monitoring and self-reflection

Commonly, retrospective data from interviews and focus groups is interpreted, coded and then analyzed within specific frameworks such as the Theoretical Domains Framework (TDF) (Penn et al., 2014; James et al., 2021; Crutzen et al., 2021). Collected data is usually taken from participants' recall on their past behaviours/emotions, thus their responses are based on their memories (Shiffman et al., 2008). Few studies use real-time momentary assessment questionnaires to assess people's PA practices through hands-on tools such as smartphones (Murphy et al., 2020; Kanning et al., 2015) or with online facilities (Willmott et al., 2021).

Feelings of well-being vary over context and time (de Vries et al., 2021). Real-time self-monitoring and self-reflection through smartphones, such as e-diaries, have been widely used to capture different factors that change over time (Bolger et al, 2003). Reliable tools such as smartphones provide the opportunity to examine individuals' ongoing experiences, and consequently, feelings, thoughts, goals, and behaviors (Bolger et al, 2003).

Compared to traditional research methods, in-the-moment self-report of events and experiences in natural and spontaneous scenarios has unique advantages. It provides the opportunity to capture additional details and reducing the likelihood of retrospection, minimizing the time between the moment an experience happened and the account of it (Bolger et al, 2003). Similarly, smartphones offer the opportunity of collecting data in a practical way through flexible designs (de Vries et al., 2021).

For these reasons, and in order to have a better understanding of participants' PA-related reflections, the present thesis project seeks to examine real-time reported barriers and facilitators to PA from Small Steps for Big Changes alumni.

1.5 Theoretical Domains Framework (TDF)

Behaviour change interventions require a wide understanding of the specific current and desired behaviour, including its determinants (Atkins et al., 2017). The TDF is an integrative framework that helps us understand the context of a particular behaviour and the factors that influence the engagement in it (Atkins et al., 2017). It is often used to guide interviews, focus groups, and structured observation (Michie et al., 2014; Atkins et al., 2017) and has been used to understand determinants such as barriers and facilitators related to diverse behaviours, such as improving hand hygiene, reducing calorie intake, and increasing PA (Michie et al., 2011; Penn et al., 2014; James et al., 2021; Crutzen et al., 2021).

The TDF comprises 14 domains synthesised from 128 theoretical constructs from 33 theories, recognized as determinants of behaviour change (Atkins et al., 2017). For a list of all domains. Such domains provide a theoretical perspective through which to observe the cognitive, affective, social, and environmental factors influencing a particular behaviour (Atkins et al., 2017).

As depicted before, the domains of the TDF are distinctly related to the Capability, Opportunity, Motivation – Behaviour (COM-B) model of behaviour used within the Behaviour Change Wheel (BCW), which broadly explains the three overarching influencers of behaviour as capability (which can be further delineated into psychological and physical), opportunity (which could be social or physical) and motivation (which may refer to automatic or reflective). Through the identification of relevant domains within the TDF, the BCW can be used to identify targeted behaviour change techniques (BCTs) to be implemented as possible intervention strategies (Michie et al., 2014). BCTs, defined as “observable, replicable, and irreducible components of an intervention designed to alter or redirect causal processes that regulate

behavior" (Michie et al., 2013), have been studied in contexts such as PA with the intention to develop effective interventions (Michie et al., 2013).

Some common BCTs used in behaviour change interventions targeting PA include self-monitoring and self-reflection. Self-monitoring consists of a "method for the person to monitor and record their behaviour(s)" (Michie et al., 2011) which has been shown to improve PA and dietary behaviours (Michie et al., 2009). Self-monitoring enables individuals to be aware of their target behaviour, allowing them to implement strategies when they realize they have not been fully engaged in it (Carels et al., 2005). This BCT has also been demonstrated to be successfully implemented within complex interventions to increase PA and healthy eating (Michie et al., 2014; Howlett et al., 2019; Murphy et al., 2020).

Self-reflection is one of the main capabilities framed within the Social Cognitive Theory (SCT) (Michie et al., 2014). SCT states that behaviour, the environment, and personal factors all interrelate to impact each other. In accordance with Michie (et al., 2014), self-reflection is a BCT that refers to people's ability to analyze their experiences, thoughts and knowledge to produce general knowledge and guide their actions. Perceived self-efficacy, defined as people's perceptions of their ability to perform under any circumstances is a specific example of a self-reflective thought (Michie et al., 2014). This represents the most influential thought on people's actions and vice versa (Michie et al., 2014). Prompting self-reflection can be done in several ways, such as through questionaries, journaling, or by writing in e-diaries (Kanning et al., 2015; Holmberg et al., 2018; Poppe et al., 2021). In the context of behaviour change interventions targeting PA, self-reflection results in positive user experience, specifically when mHealth tools are implemented (Griauzde et al., 2019).

Regular PA requires constant effort and dedication, which can be influenced by factors including how individuals feel about their environment and how they interact with it (Poppe et al., 2021). Mental and somatic stressors, such as negative affect and fatigue, respectively, determine the way how people react to those factors (Kanning & Schoebi, 2016 in Poppe et al., 2021). Given that individuals with T2D are more vulnerable to experiencing mental and somatic stressors (Darwish et al., 2018 & Heidari et al., 2019 in Poppe et al., 2021), it is imperative to understand their subjective experiences to address barriers and enable ways to adopt healthier behaviours, including increasing PA.

Self-monitoring and self-reflection together could provide an alternative to having an integral understanding of people's PA paths. As such, this thesis aimed to identify, through self-reflections from Small Steps for Big Changes past participants, barriers and facilitators that they experienced to engaging in PA in a naturalistic environment. Further, these barriers and facilitators were mapped onto the TDF to help guide future PA intervention development.

1.6 Small Steps for Big Changes

Small Steps for Big Changes is an evidence-based diabetes prevention program delivered through brief counselling sessions at a local fitness facility at no cost to participants (Bean et al., 2020). Its main purpose is to empower individuals living with prediabetes to make, and sustain, dietary and PA behaviours to prevent their risk of developing T2D.

A two-arm parallel group randomized trial was conducted, the full details of which and primary results were published elsewhere (Jung et al., 2020). Briefly, the randomized trial consisted of 10 supervised sessions over a 2-week period in which 99 adults between 30 and 65 years of age, considered to be low active (i.e., engaged in less than 2 bouts of moderate or vigorous aerobic exercise per week in the last 6 months), had a body mass index (BMI) between

25 and 40 kg/m^2, and were cleared to engage in exercise using the Physical Activity Readiness Questionnaire-Plus (PAR-Q+) were randomized to one of two groups: high intensity interval training (HIIT) or moderate-intensity continuous training (MICT) (Jung et al., 2020). HIIT exercise progressed from 4 to 10 intervals of 1-min high intensity intervals at ~ 80–90% VO_{2peak} interspersed with 1-min rest periods at ~ 40% VO_{2peak} and 5 minutes of warm up and cool down over the 10 sessions (Jung et al., 2020). Exercise in MICT progressed from 20 to 50 minutes of continuous moderate-intensity exercise at ~ 45–55% VO_{2peak} (Jung et al., 2020). In addition to the exercise sessions, participants also received brief counseling in 7 of the 10 sessions to bolster self-efficacy to perform physical activity on their own. Brief counseling was identical for both groups and delivered by trained coaches.

The primary aims of the randomized trial were to observe changes and potential differences in cardiorespiratory fitness (CRF) and accelerometer-measured purposeful free-living PA between participants performing HIIT and MICT 6- and 12-months after the 2-week intervention (Jung et al., 2020). Changes in CRF were assessed using a maximal VO_{2peak} test on a cycle ergometer at baseline, 6- and 12-months post intervention. Free-living PA adherence was measured by calculating daily minutes spent in moderate-to-vigorous physical activity in bouts of 10 minutes or more (MVPA10+) using a triaxial accelerometer (GT3X-BT) worn on the right hip for 7 consecutive days at baseline, 6-, and 12-months post-intervention. Results from the randomized trial showed that participants in both groups (HIIT and MICT) improved their CRF and MVPA10+ 12-months post-intervention compared to baseline, the last one with greater results in MICT (Jung et al., 2020).

Of relevance to this secondary analysis, participants were asked to self-report their daily exercise behaviour in a mobile application (app) for 365 days following the 2-week supervised

intervention. They also had the option to write brief reflections about their exercise in an open box heading “Reflection”. See Table 1.1 for more information on demographics of participants who participated in the randomised trial.

1.7 Objective:

The primary objective of this thesis was to identify the barriers and facilitators to engaging in PA among Small Steps for Big Changes participants who have completed the program and categorise those barriers and facilitators within the TDF. This research resulted in a systematic analysis and identification of relevant domains and associated list of plausible BCTs to target in future interventions aimed at increasing real-world PA behaviour in individuals living at risk of T2D.

1.8 Research question:

a) What were the most frequent self-reported barriers and facilitators to engaging in regular PA for participants who completed the Small Steps for Big Changes program?
    a. What domains within the Theoretical Domains Framework do these barriers and facilitators map onto?
    b. Based on the domains identified, what BCT strategies could be implemented to help Small Steps for Big Changes participants maintain and/or increase PA behaviour?

Chapter 2: Manuscript

2.1 Overview

There are 483 million people in the world who live with type 2 diabetes (T2D) and half of them are unaware they have this condition (International Diabetes Federation, 2021). In Canada, 90% of diabetes cases correspond to T2D and 10% of Canadians are living with prediabetes (Diabetes Canada, 2022). T2D is a condition that causes the body to not to produce enough insulin or use it appropriately, resulting in high levels of blood sugar (T2D; Diabetes Canada, 2022). Prediabetes occurs when blood sugar levels are higher than normal but not significant enough to be diagnosed as T2D (Diabetes Canada, 2022). Glycosylated hemoglobin (A1c), an indicator that measures blood sugar levels over the last three months, is within normal levels at 5.7% or lower. Prediabetic levels of blood sugar are between 5.7 and 6.4%, and T2D is indicated at 6.5% or higher (American Diabetes Association, 2021).

Health behaviour changes integrating a healthy diet and physical activity (PA) play an important role in preventing or delaying prediabetes and T2D (Smith et al., 2016; Zheng et al., 2018; Diabetes Canada, 2021). PA has shown clinical positive effects such as insulin sensitivity improvement and reduced A1c levels (Amanat et al., 2020). The World Health Organization (WHO) has recommended between 150 to 300 minutes of moderate intensity aerobic exercise or 75 to 150 minutes of vigorous intensity aerobic exercise weekly in its Guidelines on physical activity and sedentary behaviour (2020). In Canada, the Canadian Society for Exercise Physiology (2021) recommends 150 minutes of aerobic exercise per week and strength training at least twice a week in the Canadian 24-Hour Movement Guidelines.

Despite the recommendations and well know benefits of doing regular PA, this modifiable behaviour factor continues to be a risk of developing T2D. In Canada, 46.2% adults

and 57.1% of young people are physically inactive (Diabetes Canada, 2022). Public health interventions to address physical inactivity and reduce the incidence of T2D in those at risk have been developed and tested (Smith, et al., 2016). Diabetes Prevention Programs (DPPs) provide powerful strategies to promote healthy eating and PA behaviours. DPPs within China, Finland, India, and America have emphasised that intensive lifestyle interventions targeting a healthy diet and PA can reduce T2D incidence by up to 58% (Vita, et al., 2016; Knowler, et al., 2002; Laaksonen et al, 2005; Patel et al., 2017).

In the ***China Da Qing Diabetes prevention study***, a 6-year cluster randomised trial started in 1986, 577 participants with impaired glucose tolerance (IGT) were randomized to either a control group or to one of three intervention groups: diet, exercise, or both diet and exercise (Pan et al, 1997). At the 6-year follow-up, the diet group reduced T2D incidence by 33%, the exercise group by 47%, and the diet and exercise group by 38%, compared with the control group (Pan et al, 1997). In a 20-year follow-up, 98% of the original sample of participants was examined resulting in a lower diabetes incidence of 43% among all intervention groups combined compared to the control group (Li et al., 2008).

In the ***Finnish Diabetes prevention study***, a 4-year randomised controlled trial started in 1993, 522 participants with overweight and IGT were randomized into either an intensive lifestyle intervention group targeting diet and exercise or a control group (Lindström et al., 212;2013; Uusitupa et al., 2019). During this study, T2D risk decreased by 58% in the intervention group vs the control group and 13 years after baseline, 38% remained at reduced risk (Uusitupa et al., 2019).

The ***Indian DPP-1*** was a 30-month randomised trial in which 531 participants with IGT were randomised to one of four groups: lifestyle modification, metformin, lifestyle modification

plus metformin, or control group (Ramachandran et al., 2006). At the 30-month follow-up there was a lower incidence of T2D of 28.5% in the lifestyle modification group, 28.2% in the lifestyle modification plus metformin group, and 26.4% in the metformin group, compared to the control group (Ramachandran et al., 2006; Uusitupa et al., 2019).

There was a second edition of this study, the ***Indian DPP-2***, started while the Indian DPP-1 was still in progress (Ramachandran et al., 2009). It consisted of a three-year placebo-controlled prospective study in which 407 participants were assigned into two groups, one included lifestyle modification plus pioglitazone (an oral administered drug used for the treatment of T2D; Gillies & Dunn, 2000), and the other included lifestyle modification plus a placebo (Ramachandran et al., 2009). At the end of the trial there was a diabetes incidence reduction of 29.8% in the group receiving pioglitazone and a 31.6% reduction in the placebo group (Ramachandran et al., 2009).

The ***American DPP*** started in 1996 and included 3234 adults at high risk of T2D randomised to one of three groups; placebo, metformin, or intensive lifestyle group (Knowler et al., 2002). T2D incidence decreased by 58% in the intensive lifestyle group and by 31% in the metformin group, compared to the placebo group (Knowler et al., 2002). At the 10 and 15-year follow-ups, T2D incidence maintained a reduction of 34% in the lifestyle group, and 18% in the metformin group, compared to the placebo (Knowler et al., 2002; Uusitupa et al., 2019).

Despite past DPP success, little is known about how well participants adhere to PA recommendations during and following these programs (Steeves et al., 2015). Limited studies examine PA adherence measures post-program. Some examples include the 4-year follow-up period of the Finnish Diabetes Prevention Study (Laaksonen et al., 2005) and the Sydney DPP (Vita, et al., 2016). The Finnish Diabetes Prevention Study showed that 38% of participants in

the intensive lifestyle intervention group were not meeting the PA recommendations (Laaksonen et al., 2005). Similarly, the 12-month follow up of the Sydney DPP showed that no more than 11% of participants were achieving the weekly exercise goal (Vita, et al., 2016).

2.1.1. Barriers and facilitators to PA

In order to improve long-term PA maintenance after participating in a DPP it is essential to understand what barriers and facilitators people face. Different aspects such as cognitive, affective, social, and environmental factors can influence PA adherence (Atkins et al., 2017) There are diverse and multidimensional barriers and facilitators to regular PA among populations at risk of T2D. The main drawbacks are prioritizing work over exercise, cultural norms, feeling exposed when exercising in the gym, social status, gender expectations, and available fitness facilities (Patel et al., 2017; Gary-Webb, et al., 2018; Spiteri, et al., 2019). Common enablers include concern about weight, the desire to be healthy, safe exercising environments, the motivation of being seen as a role model by family members, having effective weight and stress management strategies, using time purposefully (especially among the retired population), seeing PA as an opportunity to socialize, and enjoyment (Patel et al., 2017; Spiteri, et al., 2019; Kanning et al., 2015).

2.1.2. Theoretical Domains Framework (TDF) and Barriers & facilitators to PA

Health behaviour change is a complex process that requires comprehension of the circumstances and influences of a particular behaviour (Atkins et al., 2017). The Theoretical Domains Framework (TDF) helps to comprehend the key cognitive, affective, social, and environmental factors of PA behaviour. The TDF is an integrative framework comprised of 14 domains that are synthesised from 128 theoretical constructs and 33 theories and are recognized as determinants of behaviour change (Atkins et al., 2017).

The Behaviour Change Wheel (BCW) is an integrative framework widely used to design behaviour change interventions (Michie et al., 2011). The BCW synthesises common features from 19 frameworks and links them the Capability- Opportunity- Motivation Behaviour (COM-B) model. Such components of the COM-B model, capability (psychological and physical), opportunity (social or physical), and motivation (automatic or reflective) influence behaviour (Michie et al., 2014). The COM-B model helps identify targeted behaviour change techniques (BCTs). The TDF builds off of the COM-B model subdividing its components.

BCTs are "observable, replicable, and irreducible components of an intervention designed to alter or redirect causal processes that regulate behavior" (Michie et al., 2013). Self-monitoring and self-reflection are two common BCTs that have been examined in PA interventions (French et al., 2014; Larsen et al., 2020) to develop effective strategies for enhancing the daily amount of PA. (Michie et al., 2009; Michie et al., 2011). Self-monitoring is the process of recording one's own behaviour(s), allowing awareness and realization of how that target behaviour is evolving (Michie et al., 2011; Carels et al., 2005). Self-monitoring has proven to be effective in interventions targeting PA and healthy eating (Michie et al., 2014; Howlett et al., 2019; Murphy et al., 2020). Similarly, self-reflection is a competence framed within the Social Cognitive Theory (SCT). It is defined as people's ability to analyze their experiences, thoughts, and knowledge to produce more knowledge and guide their behaviour (Michie et al., 2014). People's perceptions of their capacity to perform under any conditions, their perceived self-efficacy, is an example of a self-reflective thought (Michie et al., 2014).

2.1.3. In-the moment self-monitoring and self-reflection

Usually, retrospective data from interviews and focus groups is interpreted, coded and then analysed within specific frameworks such as the TDF. Collected data from questionaries,

interviews or focus groups is usually taken from participants' recall on their past behaviours and emotions, thus their responses are based on their memories (Atkins et al., 2017). Few studies use real-time momentary assessment questionnaires to assess people's PA practices through in-the-moment tools such as smartphones. Data that is not reported while under the direct supervision from researchers allows for participants to report freely without following any specific guidelines and offers the opportunity to learn from real-world environments, where the specific behaviour happens. In-the-moment data enables participants to reflect on actual circumstances and permits exploration of particular behaviour through a variety of contexts of their daily life (Zapata et al., 2020).

Real-time self-reflections and self-monitoring may offer the advantage of providing unbiased, accurate and honest information about people's experiences when engaging in a specific behaviour such as PA (Liao et al., 2016). Practicing self-reflection and self-monitoring can be done in different ways, such as through questionaries, journaling, or using e-diaries or mobile apps (Kanning et al., 2015; Holmberg et al., 2018; Poppe et al., 2021). Self-report through mobile health (mHealth) technology has shown positive results (Zapata, et al., 2020; de Vries et al., 2021). In the last 10 years, interventions targeting PA behaviour change have widely implemented mHealth technology, mostly due to its sophistication and the emergence of new devices such as smartphones with capabilities to monitor lifestyle behaviours (Zapata, et al., 2020). One of the biggest benefits of this is to examine participants' daily natural contexts to study essential influences of PA minimizing retrospection (de Vries et al., 2021).

2.1.4. Small Steps for Big Changes (SSBC)

SSBC is an evidence-based diabetes prevention program delivered through brief counseling and exercise sessions at local fitness facilities at no cost to participants. The SSBC

program aims to help people aged 18 and older, living with prediabetes, learn how to make sustainable and lasting dietary and PA changes to prevent their risk of developing T2D (Jung et al., 2020). A Randomized Control Trial (RCT) was conducted as the first phase of SSBC before implementation within the community. The SSBC RCT studied changes in cardiorespiratory fitness (CRF) and accelerometer-measured purposeful PA (by calculating minutes per day of MVPA in bouts of 10 minutes, MVPA 10+) (Jung et al., 2020). The RCT studied 12 months of free-living high intensity interval training (HIIT) compared to moderate-intensity continuous training (MICT) in 99 individuals with overweight or obesity. Results showed improvements in CRF and MVPA10+ at the end of the study compared to baseline.

2.1.5. Objective

The primary objective of this thesis was to identify the most frequent barriers and facilitators to engaging in PA among past Small Steps for Big Changes participants during the RCT and categorise them within the TDF. A systematic analysis and identification of relevant domains was conducted and an associated list of plausible BCTs to target in future interventions aimed at increasing real-world PA behaviour in individuals living at risk of T2D was developed. This analysis also examined the correlation existing between self-reflections and self-report of PA of participants during the SSBC RCT.

2.2 Methods

2.2.1. Study design

Data from the SSBC RCT (Jung et al., 2020) was used in this secondary analysis. For one year following the two-week intervention, participants were asked to self-report their daily exercise behaviours in a mobile application (app) for 365 days. Participants were prompted to answer the following question within the app: “Did you exercise?”. The three possible responses

to this question were 1=”Yes”; 2=”No”; and 3 = “Day Off”. If they answered “Yes”, they were asked if they did HIIT or MICT, the duration of the exercise, number of intervals and perceived rate of exertion (PRE). Participants were also provided with a “Reflection” option, where they had the opportunity to write short descriptions of their feelings and thoughts on their exercise for each day. These self-reflections were entirely voluntary.

2.2.2. Participants

Individuals who participated in the RCT were adults aging between 30 and 65, low active (meaning they engaged in less than 2 bouts of moderate or vigorous aerobic exercise per week in the last 6 months), had a body mass index (BMI) between 25 and 40 kg/m^2, and were cleared to engage in exercise using the Physical Activity Readiness Questionnaire-Plus (PAR-Q+) (Jung et al., 2020). Ninety-nine participants were randomised into the RCT, however data from 86 retained participants was analysed in this secondary study. From the RCT, 86 individuals provided either self-monitoring and/or sporadic self-reflections, which were included in this analysis; only 3 participants did not use the self-reflection app feature at all. Not all participants reported on their PA or recorded self-reflections every day. There was a total of 6,680 self-reflections that were recorded in the year following the two-week intervention. Self-reflections were examined considering participants’ reports on PA (Did you exercise? (1=Y; 2=N; 3 = Day Off) to identify barriers and facilitators, and then classified within the TDF constructs.

2.2.3. Procedure

The 6,680 self-reflections were independently coded by four people divided into three teams, to identify barriers and facilitators to engaging in exercise. To identify relevant codes for this dataset, two reviewers (BG and MM) double coded one hundred self-reflections. Following this, a consensus took place, and the codes below were identified (see Table 2.1). Each self-

reflection would be coded as: self-monitoring (in the case where participants added details of the PA they did on a particular day, instead of their thoughts or feelings); barrier and exercised (if they noted a barrier but self-reported that they exercised); barrier and did not exercise (noted a barrier and self-reported “no” or a “day off”); facilitator and exercised; facilitator and did not exercise; both a barrier and facilitator and exercised; and both a barrier and facilitator and did not exercise. There was also a code denominated N/A for cases were there was text imputed by participants, but none of the above codes were applicable (e.g., texts like “none”).

As part of the initial consensus made by BG and MM, it was agreed that all identified barriers and facilitators would be further categorized within the Theoretical Domains Framework (TDF). Every domain of the TDF was used as a code and can be seen in Table 2.2.

Dr. Mary Jung would issue a third opinion in the case of any disagreement that could not be resolved in a consensus meeting between the two coders. The TDF was chosen as it has been previously used to identify appropriate indicators to represent the key drivers of behaviour which can be expected to influence it (Atkins et al., 2017; Willmott et al., 2021; Howlett et al., 2019).

2.2.4. Coding process

Once codes for barriers, facilitators and TDF domains were agreed on between BG and MM, two more persons were included to participate in the analysis, Kyra Braaten and Sarah Craven (KB and SC). Both of them were trained to be coders during a one-hour meeting. Codes were explained to KB and SC and a description of how the coding would be conducted was provided. It was explained that as a facilitator would be coded any factor that enabled individuals to engage in PA (e.g. access to a gym facility, a fitness program like Pilates or yoga, or exercise equipment available, etc.), while as a barrier would be considered any factor that prevented participants to do exercise on a particular day (e.g., busy schedule, not feeling well, or having

any injuries, etc.). It was also explained that self-reflections were going to be analysed together with the self-monitoring of PA to determine if barriers were overcome or not, or if a facilitator enabled participants to exercise or not. The aforementioned by considering the responses to the question “Did you exercise?” (1=”Yes”, 2=”No”, and 3=”Day off”).

For example, *Facilitator exercised*, *Barrier overcome*, *Both exercised* and *Self-monitoring* would be used in case participants recorded 1 (“Yes”) as an answer for the question “Did you exercise?”. *Facilitator didn’t exercise*, *Barrier not overcome*, and *Both didn’t* exercise would be used in case participants recorded 2 or 3 (“No” or “Day off”, respectively) as an answer for the question “Did you exercise?”, or recorded no response at all.

After all coders were trained, three teams of two reviewers each participated in the process of coding. Team 1 (BG and KB) independently coded the first half of the self-reflections provided by participants 1 to 43 in the original dataset (3,769). The second team (MM and SC) independently coded the self-reflections provided by participants 44 to 59 (1,364). Team 3 (BG and SC) coded self-reflections provided by participants 60 to 86 in the original dataset, equal to 1,547. The independent coding process took place from June to August 2022. Weekly meetings occurred every Monday to discuss common described situations through the self-reflections, and agreements were made on general contexts. Agreements made during the weekly meetings are detailed in Appendix A.

After the independent coding, a screening of the codes provided by the reviewers was conducted in order to identify all the disagreements in each team. Once the disagreements were identified, virtual consensus meetings took place between the reviewers of each of the three teams to agree on a final code or identify if a third opinion was needed by Dr. Mary Jung. All disagreements reached consensus in the virtual meetings, so a third opinion was not necessary.

2.2.5. Interrater reliability (IRR)

In order to ensure consistency and accuracy (Belur et al., 2018;2021) in the coding process, Interrater Reliability (IRR), was calculated between the coders of each team Kappa and PABAK were calculated for 35% of the self-reflections provided by the 86 participants (2,310 self-reflections) corresponding to the first quarter of the 365 days post-intervention.

Analysis

Once the consensus meetings were finalized and all codes were compiled in an Excel sheet, they were analysed in two phases. The dataset analyses consisted of a matrix containing the participants ID, the days of the year (from 1 to 365), the codes for barriers and facilitators and codes for domains. Several cases had more than one code for barriers and facilitators and for TDF domains, and were separated by commas in the Excel file.

Phase 1

Phase 1 of the analysis was conducted using RStudio version 2022.02.0+443, "readr", "stringr", "dplyr", and "writexl" packages were downloaded and used to analyse the dataset. The main purpose of this phase was to obtain the frequencies of each one of the codes for barriers and facilitators and TDF domains for the 6,680 self-reflections. The frequencies of the responses to the question “Did you exercise?” with the possible responses “yes” (1), “no” (2), “day off” (3) or no response (0) were also obtained. The sum of the total self-reflections provided by each participant were also obtained.

Phase 2

Phase 2 was conducted with IBM SPSS Statistics version 27. Once the frequencies for each code for barriers and facilitators, TDF domains, exercise records and total number of self-

reflections recorded by each participant were collected descriptive statistics and correlation between self-reflections and self-report of PA were obtained using SPSS.

2.2.6. Measures

Means, frequencies, minimums and maximus of codes for barriers and facilitators, TDF domains, exercise records, and number of self-reflections were calculated in this analysis. Correlations between self-reflections and self-report of PA was calculated too.

2.3 Results

The coding of the 6,680 self-reflections for barriers and facilitators and TDF domains resulted in substantial agreement (Cohen's kappa =0.85, PABAK=0.91 for barriers and facilitators and Cohen's kappa =0.74, PABAK=0.87 for TDF domains) indicating substantial agreement. IRR by teams is reported in Table 2.3.

2.3.1. Averages and frequencies

Data from 86 participants was analysed, only 3 participants did not record self-reflections at all. Out of the 86 participants, 72% were female and 28% male (62 female and 24 male). On average, participants wrote 78 self-reflections during the year, while the maximum number of self-reflections written by a participant was 343 for the year. Regarding self-reporting of exercise, on average, participants reported that they did exercise 143/365days, they did not do exercise 16/365days and reported a day off 108/365 days. On average, participants did not respond to the question "Did you exercise?" 98 days out of 365. See Tables 2.4 and 2.5 for more detailed information about self-monitoring of PA and self-reflections.

On average, an as a descriptive overview, female participants wrote more self-reflections than male participants during the 365 days of this analysis (84 days>62 days) and exercised more

often (154 days >115 days). Male participants did not self-report exercise more often than female participants (140 days > 82 days). However, female participants answered more often "No" to the question "*Did you exercise?*" than male participants (18 days > 10 days). Regarding days off of exercise, female participants reported more than male participants (111 days>100 days).

The most frequent barriers and facilitators were *Self-monitoring of exercise* (4,872) and *Facilitator exercised* (3,190). The least frequent codes were *Facilitator, did not do exercise* (3) and *Both not exercised* (8). The most common TDF domains were *Behavioural regulation* (5,018), *Environmental context and resources* (4,532), *Emotion* (863), and *Knowledge* (795). The least used TDF domains were *Optimism* (148), *Memory, attention, and decision processes* (142), *Skills* (110), and *Goals* (79). See Tables 2.6 and 2.7 for more detailed information about frequencies of Barriers and Facilitators and TDF codes.

Most reflections were categorised under a combination of the codes *self-monitoring of exercise* and *facilitator exercised* for barriers and facilitators, and *behavioural regulation* and *environmental context and resources* within the TDF domains. Some examples include:

Had a workout with a trainer at the GoodLife gym. Worked on lower body mostly. With some arms. Did super sets. (participant 30, day 24)

Elliptical and running (participant 51, day 27)

Yard work (participant 20, day 223).

Regarding barriers and facilitators, the next most common code was *barrier not overcame (869)*, some examples are:

Harvest day + a last minute haircut! (participant 11, day 227)

Picked up a 12 hour shift today (participant 52, day 228)

Too busy with exam today (participant 11, day 225)

In the other hand, for *barrier overcome*; some examples of self-reflections under this category were:

Sore from yesterday so did lots of stretching (participant 1, day 221)

Lovely walk in the rain...had a headache all morning...had a headache when finished walking...but I also had the satisfaction of having exercised! (participant 52, day 226)

The next most frequent TDF domain was *Emotions.* Reflections under this code showed situations expressed as good or bad or causing feelings of happiness or sadness. For example:

Great conversation, enjoyed the stationary bike. Felt happier, relaxed, and clear-headed after! (participant 61, day 4)

Back on track! Really proud. Was worried I couldn't do it but I did!!! Feel really great. I thought after 2t being able to do my intervals lately that I could walk mod then walk intense but I actually had to walk 1 min jog 1 min (participant 3, day 34)

Sad to stop working out with a trainer but excited to start on my own (participant 53, day 4)

Intervals on elliptical. Workout with trainer. It has been a rough couple weeks a friend of mine, his son committed suicide. I am having a hard time with it. (participant 30, day 340)

The next most common domain within TDF was *knowledge*. *Knowledge* (awareness of the existence of something) was mainly used for situations where participants expressed a health condition such as a sickness or injury which impacted their PA. Some examples are:

> *Yoga. Have headache again. Can't run with headache.* (participant 32, day 134)

> *Have a cold very hard to breath. Elliptical. Seem to have little more energy.* (participant 30, day 13)

> *Felt good after 3 days. Been very stressed. But very sore need. Couldn't go as hard* (participant 14, day 226)

A variety of situations were described by SSBC participants. Self-reflection, the process of examining, and assessing one's own thoughts, feelings, and behaviours (Roberts & Stark, 2008) was achieved. Individuals expressed their desires and actions to adopt new healthy habits to their lifestyles. Self-efficacy, people's perceptions of their ability to perform under any circumstances (Michie et al., 2014) was a common self-reflective thought in this secondary analysis. One participant noted the following:

> *Still not up to speed...but improving...lovely walk* (participant 52, day 211)

Through the practice of self-reflection participants increased awareness on their actions and a expressed a sense of accountability towards their PA behaviour.

> *8 pm realized I had not exercised. Road stationary bike and lifted weights for 52 mins. So I did not have a failure day. This program works!* (participant 48, day 116)

> *This will be the first time I have stuck to an exercise program while traveling. Was far easier than I anticipated. I think it's something I'm gonna be able to continue*

doing in the future. I use it as an adventure and go to see things that I would normally see. I'm not sure I would use the word guilty but, I do feel a sense of obligation to make sure that exercise. (participant 83, day 30)

There were self-reflections where participants did not necessarily describe the situation that helped or prevented them (or both) to exercise. Some of them used the self-reflection to express daily life events and their feelings towards them.

Busy day and very crappy day, looks like I lost my wallet or someone took it yesterday. My mind was consumed with having to get my stuff canceled and figured out what I need to replace. Very frustrating day, but I did get great one on one time with my kids and realized not to sweat the small things. Had a great dinner (I made stuffed peppers in a tomato base) with a nice Caesar salad. (participant 34, day 9)

2.3.2. Correlations

Pearson correlations were calculated to examine the relationship between self-reflections and self-report of PA. A positive, moderate and statistically significant relationship was found between self-reflection and exercised days (r (0.000)= 0.424, p=0.01). See Table 2.8 for more detailed information about correlations.

2.4 Discussion

Two main insights were obtained from this analysis. First, self-reflections most commonly included more detailed information on the exercises that participants completed (i.e., self-monitoring of exercise) and descriptions of facilitators to exercising. The most commonly identified TDF domains were *Behavioural regulation* and *Environmental context and resources*. These results suggest that, for SSBC participants, elaborating on their PA behaviour by

providing details such as what activity they did, where, and how, is the preferred way to self-reflect. Second, there is also a positive and significant relationship between self-reflections and the days of exercise reported by SSBC participants during the RCT $(\mathrm{r}\ (0.000) = 0.424, \mathrm{p} = 0.01)$. Such result offers insights about how self-regulatory processes can complement PA behaviour change (St Quinton & Brunton, 2017).

These findings demonstrate how self-reflection complements Small Steps for Big Changes and can help foster autonomy among participants. This is in accordance with existing literature, which suggest that self-reflection is central for self-regulation of behaviour (Roberts & Stark, 2008). So far, large-scale DPPs have reported implementing self-regulation tools among their participants but often fail to explicitly outline which tools these are (Eaglehouse et al., 2015). Integrating BCTs with digital features to track behaviours and outcomes may be one way to effectively optimise diabetes prevention interventions (Van Rhoon et al., 2020).

PA is a key behaviour for the prevention of T2D (Amanat et al., 2020). Regular PA for people living at risk of T2D remains a challenge (Laaksonen et al., 2005; Vita, et al., 2016). Understanding the barriers and facilitators that people face in real-world settings provide valuable information that can be used to develop more sophisticated and effective strategies for PA interventions.

Perceived self-efficacy is the most influential self-reflective thought to guide individuals' actions (Michie et al., 2014). Self-efficacy has proven to be a consistent predictor of initiation and maintenance of PA (French et al., 2014). Self-monitoring has been shown to be a BCT able to increase PA self-efficacy and PA behaviour among non-clinical samples of older adults (French et al., 2014). Results from this secondary analysis show that self-monitoring of PA was one of the most frequent ways to self-reflect, and is aligned with existing evidence.

mHealth technology has the potential to help deliver behaviour change interventions in a practical, large-scale, and cost-effective manner (Direito et al., 2017; Dao et al., 2021; de Vries et al., 2020). Interventions implementing mHealth devices, such as smartphones, have demonstrated success in the delivery of lifestyle interventions targeting PA (Zapata et al., 2020; Dao et al., 2021). In the context of SSBC, the use of a mobile app to record self-reflections was a widely used feature among participants during the RCT.

Finally, the use of in-the-moment self-report techniques are a helpful way to examine self-reporting by minimizing memory recall biases and allowing for the opportunity of in-depth self-reflection. By providing individuals with more practical and adaptative intervention tools researchers could access more reliable and accurate data. While mHealth is still novel and further research is needed to validate its efficacy, there appears to be economical and practical potential for its inclusion in large-scale interventions (Dao et al., 2021).

2.4.1 Strengths and limitations

Strengths

So far, little is known about the PA patterns among individuals at risk of T2D (Steeves et al., 2015). This study offered information about the PA patterns during the 12-months after completion of a DPP program. Additionally, this analysis presented a wide perspective of the real-world factors influencing PA among prediabetic population. Enablers and drawbacks to PA were identified through the qualitative data analysis of self-reflections, a method not seen in the literature in the context of diabetes prevention interventions yet.

Having the opportunity to implement mHealth technology (smartphones and PA mobile application) during the SSBC RCT (Jung et al., 2020) permitted the opportunity to collect in-the-moment data from participants. In-the-moment data collection minimized the common risks with

conventional retrospective data collection methods (Zapata et al., 2020). Similarly, since participants were prompted only once per day to self-monitor PA and voluntary write self-reflections, risk of reporting burden was also minimized (Dao et al., 2021).

It is important to highlight that recording self-reflections was completely voluntary. In this sense, participants recorded information they wanted to share and at the moments they wanted to do so. No specific questions were prompted to participants; thus, self-reflections were completely free and spontaneous. Their analysis offered a new perspective of the results related to task self-efficacy reported in the primary study.

Finally, multiple reviewers during the process of coding and the high IRR was a strength of this analysis. Weekly meetings and agreements made on common described situations found through self-reflections were helpful at this stage. Communication through coders made the process clear and transparent, meetings encouraged reflexivity and dialogue within reviewers' teams (O'Connor & Joffe, 2020).

Limitations

Retrospective collection data biases were minimised by prompted participants every day, however it is not known how long it passed between the moment individuals did exercise and the moment they reported in the app what they did and recorded self-reflections. In this sense, there could be some degree of bias included in self-reflections. Factors such as mood (Shiffman et al., 2008) could affect participants' recall if they did not record self-reflections at the moment they completed their PA session.

Additionally, the mobile application provided to participants only allowed recording of PA self-monitoring and self-reflection once per day. There is potential data lost from participants

who exercised more than once per day and wanted to report on that. Giving the option to record information more than once per day could allow us to learn more about PA patterns and barriers and facilitators faced by people at risk of T2D.

2.4.2 Future directions

Future research could add to these findings by implementing new methods to collect in-the-moment data. Ecological Momentary Assessment (EMA) techniques offer an alternative to obtain data on PA behaviour from real-world contexts by prompting participants more often than traditional data collection methods (Shiffman et al., 2008; Atkins et al., 2017). mHealth technology such as smartphones seems to be an adequate tool to collect data in real-word environments since it is easily adaptable to people's lifestyles (de Vires et al., 2020).

Isolating variables to find causality effects among self-reflections and PA behaviour should be considered in future research. Examining self-reflections individually and adding different independent variables to a model would provide more information about PA patterns among people at risk of T2D.

2.4.3 Implications

This study identified the most frequent real-world barriers and facilitators found through participants' self-reflections during the SSBC RCT through self-reflections, as well as the most common categorisation of those barriers and facilitators within the TDF domains. A correlation analysis between self-reflections and days of exercise reported by participants demonstrated that self-reflections had a positive and significant relationship with the number of days individuals did exercise. These results suggest that self-monitoring of PA and providing details of the environmental contexts were the preferred way of self-reflections recorded by SSBC

participants. Additionally, it was shown that self-reflections had a positive and significant relationship with the number of days individuals did exercise.

Within SSBC, providing further details of PA performance was the preferred way to self-reflect among individuals, this opens the possibility for the program to enhance ways of self-monitoring. The tools and materials that are provided to participants during the program represent an opportunity to encourage self-reflection. Digital materials could represent an opportunity to include ways that participants can use to self-monitor more extensively (e.g., suggest participants a PA mobile application or technology devices).

Self-reflection has proven to be central for self-regulation among individuals in the process of behaviour change (Roberts & Stark, 2008; French et al., 2014). In the context of SSBC in particular, and DPPs in general, integrating BCTs such as self-reflection with digital features is a helpful way to learn from individuals' life during participation. Knowing the challenges participants face in real-world settings allow to enhance strategies to support them in the process of improving PA behaviour.

These results are relevant for any DPP. It has been shown that PA behaviour is still a challenge among DPPs participants (Laaksonen et al., 2005; Vita, et al., 2016). Thus, complementing behavioural interventions with self-reflection tools which can capture information about PA performance and environmental contexts seems to be a powerful way to help maintain regular PA during and following participation in DPPs. However, it is important to consider that these interventions need to easily adapt to individuals' needs and contexts to drive PA behaviour (Dao et al., 2021).

Chapter 3: Conclusion

SSBC is an evidence-based DPP which seeks to empower individuals living with prediabetes to make and sustain dietary and PA behaviours to prevent their risk to develop T2D (Jung et al., 2020). SSBC implements motivational interviewing to deliver its content, which is a person-centred conversation style designed to enhance an individuals' own motivation and commitment to change (Miller & Rollnick, 2003). One of the main goals of this program is to foster participant's autonomy. Self-reflection is essential in the process of creating autonomy as it supports self-efficacy, people's perceptions of their ability to learn and maintain PA behaviours (Larsen et al., 2020).

This study identified the most frequent real-world barriers and facilitators expressed by participants after a two-week RCT through their own voluntary self-reflections for one year, and mapped these most commonly reported barriers and facilitators within the TDF. A correlation between self-reflections and days exercised reported by participants was also calculated. Self-reflections most commonly included more detailed information on the exercises that participants completed (i.e., self-monitoring of exercise) and descriptions of facilitators to exercising.

The most commonly identified TDF domains were *Behavioural regulation* and *Environmental context and resources*. As such, the description of the circumstances and scenarios when exercising were relevant aspects to reflect on among individuals who voluntarily used the self-reflection feature. These results suggest that self-monitoring of PA and providing details of the environmental contexts where the PA happened were the preferred way of self-reflecting recorded by SSBC participants. Additionally, it was shown that self-reflections had a positive and significant relationship with the number of days individuals did exercise.

A variety of contexts were described by SSBC participants through self-reflections beyond self-monitoring. Facilitators that helped and barriers that prevented participants to exercise (i.e. *Facilitator exercised* and *Barrier not overcome*) were the second and third most common barriers and facilitators categories identified through individuals' self-reflections. When participants reported facilitators that helped them exercise commonly expressed situations as part of their daily life that involved PA naturally, for example household chores such as gardening, removing snow, and cleaning up their houses, which according with the *Canadian 24-Hour Movement Guidelines for Adults*, are tasks recommended to stay active (Canadian Society for Exercise Physiology, 2021). Other common described situations were related to gym facilities, exercise coaches or exercise programs that enabled participants to keep active, for example exercising with Pilates or yoga programs, having a personal trainer, and having access to a gym facility.

In the case of barriers that prevented them exercise, commonly described situations were related to being busy because of work, trips, family responsibilities and health conditions such as injuries and recent surgeries, and being sore from exercise on previous days were reported. Learning about *barriers no overcame* is particularly valuable because they offer the opportunity to plan and design strategies in real-world-setting and common contexts normally not contemplated within DPPs (Laaksonen et al., 2005; Steeves et al., 2015; Vita, et al., 2016). The scope of action for DPPs is limited when suggestions are made for participants to do regular PA without consideration of individuals' contexts.

In the case of TDF, *Emotions* and *Knowledge* were the next most common domains identified through participants' self-reflections. As *Emotions*, participants expressed feelings like happiness, sadness, and excitement about their PA. While *Knowledge* was commonly identified

as a barrier to exercise, for example when individuals expressed being sick, in physical pain, or when anticipating busy schedules. *Knowledge* was also identified in situations where participants self-monitored themselves during exercise and noticed certain effects, for example, when they realized the exercise was hard for them, or the opposite, when individuals realized they were able to easily perform activities that felt harder in the past. In the context of SSBC, awareness of the contexts experienced during participation in the program offered information about the valuable factors considered by participants regarding their time, health and physical condition.

Since self-reflection was prompted and provided daily through a mobile application, the collection of this data was similar to what is done in studies using diaries (Bolger et al, 2003). The results of this study were aligned with the available literature about studies using diaries (Bolger et al, 2003), since it was possible to capture particular details of SSBC participants' daily life and experiences that wouldn't be possible to learn with conventional data collection methods such as questionnaires, interviews or focus groups (Zapata et al., 2020).

Previous studies within SSBC have been performed to examine mobile health technology (mHealth) (MacPherson et al., 2019), however, there are tools and features that have yet to be explored. The present findings open the possibility to use mHealth technology together with other data collection methods such as EMA techniques, to be able to capture as much information as possible about the subjective experience that SSBC participants face during their journey in the program. Ultimately, this data would permit a thorough understanding of participants' PA behaviour and subsequently enable relevant PA promotion strategies that could be incorporated in future iterations of SSBC and other DPPs.

Behavior change is a complex process. In the context of PA, diverse interventions have demonstrated positive results, however PA maintenance has shown to decrease after the

interventions end (Murray et al., 2017). As such, there is a need for complementing lifestyle interventions with tools which enable participants to sustain and adhere to the changes made during the intervention. Self-regulation techniques, such as self-reflective processes have demonstrated being an effective way to accompany behaviour change (St Quinton & Brunton, 2017).

Regular PA and mental health have a positive association (World Health Organization 2017 in Zapata et al., 2020). However, perceptions of well-being fluctuate over time and situations (e.g., stay active in nature environments is associated with higher well-being) (de Vries et al., 2020). Thus, inspecting information about subjective experiences in changing contexts is essential since emotions and cognitive states influence behaviours and are constantly changing (Dao et al., 2021).

3.1 Strengths and limitations

3.1.1. Strengths

SSBC participants self-reported PA and self-reflections in an opportune and entirely voluntary manner allowing for the exploration of PA behaviour in a real-world context. In-the-moment self-monitoring and self-reflection methods allowed for more in-depth analyses regarding the barriers and facilitators that individuals at risk of T2D face on a daily basis. Information about their preferred and most common types of PA, exercise facilities frequently used, and progression of the PA behaviour were identified in this analysis.

This study offered a novel way to examine PA behaviour in real-world contexts among individuals at risk of T2D. Participants were not prompted several times per day to record self-reflections such as with invasive EMA methods – but rather in this study participants were prompted once per day, minimizing recording burden in the RCT.

The mode of self-reflection (expressed freely through an open text box) represents another strength of this study. No specific questions were asked, and participants recorded their thoughts at their convenience. Inaccurate and biased recalls due to the natural process of retrieval and memory variation, as well as experiences of enumeration and aggregation, two common deficiencies from conventional retrospective self-reports (Shiffman et al., 2008), were minimised.

These open-ended response opportunities also allowed participants to express what they wished to share. Since they were not provided with established options when answering the self-reflection prompt, they expressed valuable information beyond their mood including reflection on their satisfaction. Satisfaction is a cognitive aspect of well-being (Ryff 1989; Ryan and Deci 2001 in De Vries et al., 2021). Thus far, many studies have been conducted related to PA and mood, but no study has examined the association between PA and life satisfaction (De Vries et al., 2021). This is relevant as people freely expressed themselves and additional data about real-world contexts was reported.

Finally, another strength was the high level of interrater reliability (IRR) between reviewers during the process of coding. Multiple reviewers coded independently maintaining rigour and consistency. Weekly meeting helped to compare codes, make agreements, and reconcile through discussion (Belur et al., 2018;2021).

3.1.2. Limitations

Even though self-reports were inputted the same day participants completed their exercise sessions, some may have been recorded with some delay. It is unknown how long after the PA session participants recorded their self-reflections, meaning that reports may have been biased by factors like weather, environment, or personal events (De Vries et al., 2021).

Despite having thousands of self-reflections to analyse, not all participants recorded self-reflections; however, they recorded self-monitoring instead. For example, a brief description of their PA was reported but no additional content was included in the reflection. There may be important differences to note between people who decided to input self-reflections from those who did not, this is why the barriers and facilitators found in this analysis could not be generalized.

Additionally, during the RCT participants were recommended to exercise three times a week (Jung et al., 2020). Nevertheless, there were cases where individuals exercised more than once a day, however they only had the opportunity to self-monitor their PA and write self-reflections once per day. Thus, the analysis may have lost important information related to people who exercised more than once per day or kept active throughout the day.

Although results suggest a positive significant relationship, it is not possible to determine which variable is predictive of the other one. This secondary study does not have sufficient elements to determine causality relationship since self-reflections were categorised as barriers or facilitators (or both) depending on the self-report of PA through the responses provided to the question “Did you exercise today?” whose answers could be “yes”, “no” or “day off”. Thus, running a regression under these circumstances would imply a high risk of multicollinearity (Alin, 2010).

3.2 Future directions

There is a need for complementing health behaviour change interventions with further strategies that assist people at risk of T2D to stick to regular PA maintenance during and following DPPs. Self-reflection has demonstrated to have a positive and significant relationship

with PA behaviour during participation in a DPP. Additionally, the integration of digital features has proven to offer optimal outcomes (Van Rhoon et al., 2020).

The findings from this research project could have many implications for DPPs including PA intervention components, and specifically for the Small Steps for Big Changes program. Understanding the determinants of PA behaviours among past participants gives insight into common barriers and facilitators that individuals face during their daily lives. Knowing about what prevents or enables them to stick to regular PA behaviour provides valuable information which can be used to design and refine strategies to help people increase their adherence to PA.

Comprehending the different influences of PA behaviour, such as the affective, social and environmental, provides the opportunity to explore it integrally in the context where it occurs (Cane, et al., 2012; Atkins et al., 2017). The TDF gives us the unique opportunity to identify the main theoretical constructs that intervene with the target behaviour avoiding missing, not including, or overlapping important ones (Cane, et al., 2012). This thesis project suggests, a potential number of TDF domains represent key targets to enhance PA in DPPs.

As discussed, the domains of the TDF are distinctly related to the Behaviour Change Wheel (BCW), which uses the COM-B model to explain the three overarching influencers of behaviour: capability (psychological and physical), opportunity (social and physical) and motivation (automatic and reflective). This integration within the BCW allows results from this work to be linked to BCTs for future Small Steps for Big Changes interventional materials. Beyond this, since the theory-based framework used in this research project is widely used in health behaviour change science, the derived results could be used to strengthen other DPPs.

Related to the aforementioned, the use of the TDF to classify barriers and facilitators from unprompted self-reflections is a novel method. Traditional data collection methods usually use the TDF to group barriers and facilitators identified through guided responses from interviews, questionnaires, or focus groups (Shiffman et al., 2008; Atkins et al., 2017). In this particular analysis, the TDF was used to categorize barriers and facilitators identified within free responses from participants' voluntary reflections. Coding agreements and rules were established during the data analysis process; such agreements and rules have the potential to be implemented to train artificial intelligence and machine learning to "automatically extract, synthesise and interpret findings from behaviour change intervention in the future" (Michie et al., 2017).

Self-reflection was demonstrated to be a powerful BCT used to enhance self-efficacy and autonomy among SSBC participants. Providing a detailed description of the exercise performed in a particular day, was the most common way to use the self-reflection feature by individuals. Future research should add to these findings by including elements which allow to determine predictability between self-reflection and PA behaviour.

DPPs in general, and Small Steps for Big Changes in particular, could take advantage of technology made available by smart mobile devices, and complement conventional self-monitoring data with real-time and contextual data with images and voice notes (Zapata-Lamana et al., 2020). Research in this area is needed to determine the cost-effectiveness of integrating digital features with ecological momentary assessment techniques in DPPs and how to design a "comprehensive, interactive and responsive intervention delivery" (Direito et al., 2017).

3.3 Conclusion

Identifying real-world barriers and facilitators to PA individuals face during participation in a DPP offers the opportunity for researchers and healthcare providers to design tailored

helpful strategies for participants. Regular PA is a difficult behaviour to maintain following a diabetes prevention intervention (Laaksonen et al., 2005; Steeves et al., 2015; Vita, et al., 2016). Understanding common present challenges and enablers in the real-world settings may help to improve adherence. Extensive self-monitoring of PA, by providing further details of the performed activity and the environmental context where it happens, seems to be the preferred way for individuals participating in a DPP to reflect on their own PA behaviour. This study has many implications for diabetes prevention interventions to offer tools and materials that can make in-the-moment self-reflection possible. mHealth has proven to be an effective alternative since it can be very adaptable to individuals' life, at the time it is a practical way with potential to provide more information about people's lifestyles to health researchers in comparison to conventional methods.

Table 1.1

Demographic Characteristics of Participants in the SSBC RCT

Sample characteristic	Frequency	Valid Percent
Year of birth		
1948-1957	18	18
1958-1967	32	32
1968-1977	32	32
1978-1987	15	15
Missing	2	2
Total	99	100
Biological sex		
Female	69	71
Male	28	29
Missing	2	2
Total	99	100
Ethnic origin		
White	88	91
Native/Aboriginal	2	2
Chinese	1	1
South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.)	2	2
Latin American	2	2

Sample characteristic	Frequency	Valid Percent
Other	2	2
Missing	2	
Total	99	100
Annual household income		
$0-$25,000	4	4
$25,000-$49,999	11	11
$50,000-74,999	18	19
$75,000-$99,999	20	21
$100,000-$124,999	20	21
$125,000-$149,000	13	13
$150,000-$174,999	5	5
$175,000-$199,999	5	5
$200,000-$224,999	1	1
Missing	2	
Total	99	100

Note. Gender information was not collected during the Small Steps for Big Changes Randomised Trial.

Table 2.1

Barriers and facilitators codes

Code	Barriers and facilitators
1	Barrier overcome
2	Barrier not overcome
3	Facilitator exercised
4	Facilitator didn't exercise
5	Both exercised
6	Both not exercised
7	Self-monitoring of exercise
0	N/A

Table 2.2

Codes for the TDF domains

Code	Theoretical Domains Framework domains
1	Knowledge (an awareness of the existence of something)
2	Skills (an ability or proficiency acquired through practice)
3	Social/profession role and identify (a coherent set of behaviour and displayed personal qualities of an individual in a social or work setting)
4	Beliefs about capabilities (acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use)
5	Optimism (the confidence that things will happen for the best or that desired goals will be attained)
6	Beliefs about consequences (acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation)
7	Reinforcement (increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)
8	Intentions (a conscious decision to perform a behaviour or a resolve to act in a certain way)
9	Goals (mental representation of outcomes or end states that an individual wants to achieve)
10	Memory, attention, and decision processes (the ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)

Code	Theoretical Domains Framework domains
11	Environmental context and resources (any circumstances of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour)
12	Social influences (those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)
13	Emotion (a complex reaction pattern, involving experiential, behavioural, and physiological elements by which the individual attempts to deal with a personally significant matter or event)
14	Behavioural regulation (anything aimed at managing or changing objectively observed or measured actions) – *__note__* behavioural regulation includes self-monitoring
0	N/A

Note. (Atkins et al., 2017)

Table 2.3

Kappa and PABAK for Barriers and Facilitators and TDF domains

Codification		Kappa	PABAK
Barriers and	Team 1	0.85	0.91
facilitators	Team 2	0.86	0.91
	Team 3	0.85	0.91
	Total	0.85	0.91
TDF	Team 1	0.71	0.86
	Team 2	0.77	0.88
	Team 3	0.74	0.88
	Total	0.74	0.87

Note. Totals represent the total average of the three teams per category.

Table 2.4

Frequencies of PA self-monitoring and self-reflections per sex

	N	Days exercised (mean)	Days no exercised (mean)	Days off (mean)	Days no report of exercise (mean)	Self-reflections (mean)
Female	62	154	18	111	82	84
Male	24	115	10	100	141	62
Sum	86	269	28	211	223	146

Table 2.5

Frequencies of self-report of exercise and self-reflections

Self-monitoring of PA	N	Min	Max	Sum	Mean	Std. Deviation
Days exercised	86	8	342	12304	143.07	70.299
Days no exercised	86	0	89	1353	15.73	18.839
Days off	86	0	196	9267	107.76	54.747
No report of exercise (days)	86	3	357	8466	98.44	99.596
Self-reflection (days)	86	0	343	6680	77.94	84.470
No self reflection (days)	86	22	365	24710	287.06	84.470

Table 2.6

Frequencies of barriers and facilitators

		Min	Max	Sum	Mean	Std. Deviation
1	Barrier overcome	0	59	569	6.62	9.952
2	Barrier not overcome	0	83	869	10.10	18.498
3	Facilitator exercised	0	233	3190	37.09	46.571
4	Facilitator did not do exercise	0	2	3	0.03	0.240
5	Both exercised	0	44	549	6.38	10.171
6	Both not exercised	0	1	8	0.09	0.292
7	Self-monitoring of exercise	0	243	4872	56.65	62.127
0	N/A	0	82	292	3.4	9.565

Table 2.7

Frequencies of TDF domains

Code	TDF domains	Min	Max	Sum	Mean	Std. Deviation
1	Knowledge	0	120	795	9.24	16.321
2	Skills	0	28	110	1.28	3.671
3	Social/profession role and identify	0	97	415	4.83	15.775
4	Beliefs about capabilities	0	64	366	4.26	9.817
5	Optimism	0	31	148	1.72	5.036
6	Beliefs about consequences	0	57	346	4.02	8.655
7	Reinforcement	0	134	347	4.03	15.474
8	Intentions	0	89	573	6.66	13.98
9	Goals	0	10	79	0.92	1.942
10	Memory, attention, and decision processes	0	28	142	1.65	4.405
11	Environmental context and resources	0	259	4532	52.7	62.061
12	Social influences	0	94	585	6.8	16.325
13	Emotion	0	132	863	10.03	19.179
14	Behavioural reg.	0	245	5018	58.35	63.24
0	N/A	0	81	292	3.4	9.789

Table 2.8

Correlations between self-reflections and self-report of PA

	Days exercised	Days no exercised	Days off	No report of exercise (days)	Self-reflection (days)
Days exercised					
Days no exercised	-.064				
	.558				
Days off	.178	.207			
	.102	.056			
No report of	-.791**	-.258*	-.714**		
exercise (days)	<.001	.017	<.001		
Self-reflection	.424**	.192	.226*	-.460**	
(days)	<.001	.076	.036	<.001	
No self-reflection	-.424**	-.192	-.226*	.460**	-1.000**
(days)	<.001	.076	.036	<.001	.000

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Appendices

Appendix A. Agreements during the coding process

Number	Agreement
1	For every 7 (self-monitoring) in barriers and facilitators (B&F), we will code 14 (behavioural regulation) for the TDF.
2	Every housework activity recorded as 1 by participants (answering the question "Did you exercise?"), will be considered as 3 (facilitator) and 7 (self-monitoring) for B&F and 14 (behavioural regulation) for the TDF.
3	Exercising in a hotel/vacation will be considered a barrier (1) for B&F, unless participants state otherwise.
4	Any time participants are exercising with another person, it will be considered a facilitator (3), unless they state otherwise
5	Any time people express they are using a fitness program or equipment to exercise, it will be considered as a facilitator (3) for B&F, and 11 for the TDF; also 14 for TDF if the person says what they did.
6	Reflections containing any word or adjective that indicates a feeling or emotion will be coded as 13 (emotion) for the TDF.
7	Commuting by biking or walking will be considered reinforcement (7) for the TDF.
8	For those days in which PA was not indicated, but reflections talk about an activity, we will code based on the reflection.

Number	Agreement
9	Every time participants mentioned they had a test in the lab, so they exercised because of that reason, that will be coded as facilitator (3) for B&F, and 11(Environmental context and resources) and 14 (Behavioural regulation) for TDF.
10	Regarding accumulative reflections, reflections related to previous days will be omitted. Only reflections corresponding to the day participants reported PA will be coded. .
11	Walking the dog will be considered a facilitator (3) and self-monitoring (7) within B&F and reinforcement (7) within the TDF.

Appendix B. Additional examples of reflections categorized within Barriers and facilitators and TDF domains

Barriers and facilitators

Code	Barriers and facilitators
1	Barrier overcome
"wanted to walk longer but ... family came first today.."	
"Walk was good ... Cool needed warmer cloths"	
"Walked. Injured back so taking easy as want back to heal"	
2	Barrier not overcome
"Injured lower back at Pilates. Have to reduce swelling so will need a couple day off"	
"Yesterday was a day off for me. I tried to sign in last night but it kept saying invalid login. I also did not receive a reminder yesterday?? Walked the dogs"	
"Sick"	
3	Facilitator exercised
"Went to h2o tonight and used elliptical. Heart rate average was 147 way higher than on treadmill. Felt good."	
"Dru yoga on line"	
"Walk downtown around lake with John and Adriano from Brazil. 45 people for birthday party for Pat and Clo."	
4	Facilitator didn't exercise
"Got into a smaller size pants that I bought for Africa last summer but couldn't wear because I was to fat. Good day today. Feel real good"	

Code	Barriers and facilitators
	"Feeling better but still hurting. People are starting to notice my body getting stronger."
	"thanks for your help :0)"
5	Both exercised
	"None I played ping pong at the hotel and my heart rate ranged from 126 up to 150! I loved it. My enjoyment was the highest it has been."
	"Treadmill stair climber and cycle hr 120-150 bpm. Exercising still feels very much like a chore, isn't getting any easier"
	"SWIMMING! 1 my back was so sore and sosome knee issues so tried to find someone to go swimming. Found no one. So went by myself for 50 minutes of awesomeness because I Am An Independent EXERCISER."
6	Both not exercised
	"Spent time playing at the beach with the kids after work tonight. Got out and was a bit active, but I wouldn't call it "exercise.""
	"Had a great day with my kids, they kept reminding me to let them know when it was going to be 11am so we could have a moment of silence
	Turns out we were at Home Depot and I was very pleased to hear an announcement over the PA that they were taking a moment of silence.
	After that we went and swam at the local pool for a good two hours.
	Feels good to have more wind to keep up with them. Now I'm standing in my kitchen making

Code	Barriers and facilitators
	them homemade pizza from scratch for their lunches tomorrow
	I know they will"
	"Found special boot for Aunt with broken ankle, looked after grandkids all day for Pro D day - (museum, trip to Boston Pizza, drop off at soccer) then back to hospital, return boot that was too big, home, make dinner, do the family phone calls for updates....tired and very sore from all of the walking!"
7	Self-monitoring of exercise
	"Running outside inm Knox mountain was just great!"
	"Steep climbs up mountain stairs makes your glutes hurt…"
	"10 intervals up hill. Two flat"
0	N/A
	"None"
	"Exercised yesterday, 40 mins, but postponed logging in..too late now."
	"Whew! !"

TDF domains

Code	TDF domain
1	Knowledge (an awareness of the existence of something)

"Last training session in the lab. Used the bike today. Tried a higher resistance, but my legs burned right away. Preferred a lower resistance (8 instead of) and higher cadence to get to my target heart rate. I feel proud I finished the whole two weeks!"

"Post training testing in the lab this morning. Improved VO2 max results: went from 166W to 172W. Muscles in legs were exhausted; going up and down the stairs at home today was tough."

"Busy day and very crappy day, looks like I lost my wallet or someone took it yesterday. My mind was consumed with having to get my stuff canceled and figured out what I need to replace. Very frustrating day, but I did get great one on one time with my kids and realized not to sweat the small things. Had a great dinner (I made stuffed peppers in a tomato base) with a nice Caesar salad.

My kids were great to snuggle with before bed and then as much as I wanted to just sit on the couch I put my shoes on an"

2	Skills (an ability or proficiency acquired through practice)

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"I had to jog to get my heart rate up. I think my body is getting used to the walking and the hills aren't steep enough."

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"Fighting a cold, so I did the elliptical. Upped my resistance level to 8, but did not feel like I was pushing myself too hard (exertion level 6). I think that speaks volumes! *Also, didn't like how my arms were flapping as I exercised, so I did 2 sets of dips afterwards.* *Also, blink 182 has a great tempo for this workout!"*	
3	Social/profession role and identify (a coherent set of behaviour and displayed personal qualities of an individual in a social or work setting)
"Busy day and very crappy day, looks like I lost my wallet or someone took it yesterday. My mind was consumed with having to get my stuff canceled and figured out what I need to replace. Very frustrating day, but I did get great one on one time with my kids and realized not to sweat the small things. Had a great dinner (I made stuffed peppers in a tomato base) with a nice Caesar salad. *My kids were great to snuggle with before bed and then as much as I wanted to just sit on the couch I put my shoes on an"* *"working"* *"Played at the beach and park with the kids. Went for a short walk, but it was leisurely."*	
4	Beliefs about capabilities (acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use)

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"I had to jog to get my heart rate up. I think my body is getting used to the walking and the hills aren't steep enough."	
"Felt great to move & on the road to recovery!"	
5	Optimism (the confidence that things will happen for the best or that desired goals will be attained)
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"Did 5 intervals on the bike before working out with trainer. Did another 5 intervals on rowing machine with trainer. Another bike when I got home with the dog, and half of that was up hill. This new puppy is going to get me in shape, she is wearing me out"	
"Treadmill for half hour. All the time had today but better than nothing."	
6	Beliefs about consequences (acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation)

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7	Reinforcement (increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)
"Walked the dogs - yard work"	
"walked the dogs 20 mins and raked leaves"	
"Didnt feel like it but once I got going it was great. Those surveys made me really think about my commitment."	
8	Intentions (a conscious decision to perform a behaviour or a resolve to act in a certain way)

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"Need to breathe a bit better. Can't stop coughing. Plan changed, I will plod jog tomorrow."	
"House is sold! 2w we've started looking for a new place. Free time will be house hunting and packing for a few weeks. I will try get in some exercise whenever I can. Looking forward to being settled."	
9	Goals (mental representation of outcomes or end states that an individual wants to achieve)
"Didn't get into perfect heart zone but did an extra interval and was aware of Kevin not being on top of his game. Went to a different route and enjoying the extra time out walking"	
"Feeling strong on the bike. Still hard to breath with cold, but I am committed to the process. Doctor figures I can start weights in December looking forward to that"	
"Felt it in my legs today & I think I sweated more. Completed even though I was busy"	
10	Memory, attention, and decision processes (the ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)
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	"I had a pinched nerve after working out Sunday night. I stayed home and rested Monday and appeared fine so I worked out Monday, Tuesday and Wednesday by Thursday my lower back was feeling sore again so I opted for a day off."
	"Bike. Have a very injured shoulder seemed hard to workout, due to the pain in my shoulder. not very focus because of it."
11	Environmental context and resources (any circumstances of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour)
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	"I had to jog to get my heart rate up. I think my body is getting used to the walking and the hills aren't steep enough."
12	Social influences (those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)
	"Pushed Toni in her manual chair on a rocky path.... Quite the work out"
	"Walked Morgan to school and then to work in the morning - did not feel heart rate rise very much."
	"Walked to grocery store with daughter."
13	Emotion (a complex reaction pattern, involving experiential, behavioural, and physiological elements by which the individual attempts to deal with a personally significant matter or event)
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"Totally different day. My sister-in-law left after a whole week :-))))). Re-cleaned my house after the big group last night. Read for 1/2 the day. Then got motivated and did a few things.

"Went downtown and walked. Micro bites for dinner. Awesome! Feeling happy and relaxed – phew"

"Felt great to move & on the road to recovery!"

14	Behavioural regulation (anything aimed at managing or changing objectively observed or measured actions) – *note* behavioural regulation includes self-monitoring

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"I had to jog to get my heart rate up. I think my body is getting used to the walking and the hills aren't steep enough."	
0	N/A
"None"	
"Exercised yesterday, 40 mins, but postponed logging in..too late now."	
"Whew!!"	