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Physical Activity for Health Research Group

Exploring, through an integrative systematic review, qualitative study and mixed methods study, the integration of activity trackers into clinical care to support physical activity and reduce sedentary behaviour in adults diagnosed with or at risk of type 2 diabetes

by

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Submitted to the University of Strathclyde as a thesis for the degree of Doctor of Philosophy in Physical Activity for Health

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Declaration of authenticity and author's rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: William Hodgson

Date: 9 December 2025

Declaration of contribution to thesis

In the studies that are presented in this thesis, the work is directly attributable to the PhD student. Supervisors and co-authors have been involved in the formulation of research ideas and in editing manuscripts. All investigations, analyses and reporting have been carried out solely by the named PhD student, in keeping with the requirements of the degree of Doctor of Philosophy in Physical Activity for Health.

Motivation for PhD

Between 1985 and 2015 I served as a police officer in both Strathclyde Police and Police Scotland. During my police career, I worked in various roles including operational policing, community policing, mountain rescue, physical education instructor at the Scottish Police College, police search advisor and counter terrorist security coordinator. I retired in 2015 as a Police Inspector. I have always had a personal interest in sports and keeping fit. In 2016 I applied to the University of Strathclyde to study for a degree in Sport and Physical Activity for Health. I graduated in 2020 with a first class honours degree. My degree dissertation focused on using a fitness test app with adults diagnosed with type 2 diabetes. My degree dissertation supervisor Dr Alison Kirk suggested I continue with my studies and with her support I completed an MRes in Physical Activity for Health. My area of research was to use Fitbit activity trackers to support an active lifestyle in adults diagnosed with type 2 diabetes. In 2021 again with the support of Dr Alison Kirk, I received an excellence award from the University of Strathclyde to undertake this PhD. During my studies, I have worked as a research assistant at the University of Strathclyde on various digital solution projects for unpaid caregivers (physical activity) and more recently frontline workers exposed to trauma.

Acknowledgements

Firstly, I would like to thank my supervisors Alison Kirk, Xanne Janssen and Marilyn Lennon who have provided me with invaluable support, guidance and encouragement throughout my studies. This academic journey started in 2016 as a lifelong personal goal to obtain a degree at undergraduate level. You have believed in me and encouraged me to progress with my MRes and now PhD. I can never thank you enough for this support.

I would also like to thank each member of the Physical Activity for Health department. Each member of the team has played a significant part in my development. In particular, I would like to thank Allan Hewitt who made this journey possible by accepting me onto the BSc in Sport and Physical Activity for Health.

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Last but not least, I would like to thank my wife Margaret and my two sons Alisdair and Calum. You are my world and have been with me throughout providing support and encouragement. I love you from the bottom of my heart.

Abstract

Background

The rising prevalence of Type 2 diabetes (T2D) is strongly linked to insufficient physical activity and high sedentary behaviour. Consumer activity trackers may support behaviour change, but their integration into clinical care has been inconsistent. The RE-AIM framework (Reach, Effectiveness, Adoption, Implementation, Maintenance) provides a structured lens to evaluate their potential for real-world impact.

Aim

This thesis examined how activity trackers can be integrated into T2D clinical care using the RE-AIM framework to identify barriers, enablers, and recommendations across research, patient, and healthcare system perspectives.

Methods

A three-study mixed-methods programme was undertaken. An integrative systematic review assessed the extent to which RE-AIM dimensions were reported in chronic disease interventions using activity trackers. A qualitative study explored patient and healthcare professional perspectives on tracker use within T2D care. A pragmatic mixed-methods study embedded Fitbit devices into the NHS Weigh to Go programme, evaluating quantitative outcomes alongside qualitative feedback from participants and staff.

Results

Across studies, Reach was constrained by low awareness and cost barriers but improved when free devices were provided. Effectiveness was supported by personalised feedback and integration with existing care but limited by technical issues. Adoption was hampered by poor promotion and staff uncertainty. Implementation required clear protocols and training, while inconsistent device performance undermined fidelity. Maintenance was challenged by short-term engagement and limited long-term support structures. Quantitative findings demonstrated significant short-term increases in step counts, but sustainability was weak.

Conclusion

Using the RE-AIM framework, this thesis shows that activity trackers can be feasibly integrated into T2D care, but impact depends on systematically addressing gaps across all five dimensions. Recommendations include enhancing awareness and access, embedding personalised feedback, training healthcare staff, establishing governance protocols, and ensuring long-term support. These findings highlight both the promise of trackers for diabetes care and the need for structured, system-wide integration strategies.

Glossary of terms

Activity tracker – Any device capable of measuring the users physical activity including steps taken, distance moved and level of physical activity intensity.

Adoption - The absolute number, proportion, and representativeness of settings and intervention agents who are willing to initiate an intervention or program.

Effectiveness - The impact of an intervention on important outcomes, including potential negative effects, quality of life, and economic outcomes.

Implementation - Concerned with setting level implementation and is defined as the intervention agents' fidelity to the various elements of an intervention's protocol.

Light-intensity physical activity - Any bodily movement which requires an exertion that measures between 1.5 and 3.0 METs.

Maintenance - At the individual level, maintenance has been defined as the long-term effects of a program on outcomes six or more months after the most recent intervention contact. At the setting level, it is defined as the extent to which a program or policy becomes institutionalised or part of routine organisational practices and policies.

Moderate intensity physical activity - Any bodily movement which requires an exertion that measures between 3.0 and 6.0 METs.

Moderate to Vigorous intensity physical activity (MVPA) - Any bodily movement which requires an exertion greater than 3.0 METs.

RE-AIM Framework - An evaluation framework which was developed specifically to assist researchers in the assessment of the potential for an intervention to have impact in real world settings.

Reach - The absolute number, proportion and representativeness of individuals who are willing to participate in a given initiative.

Sedentary Behaviour - Any waking behaviour characterised by an energy expenditure of ≤1.5 METs whilst in a sitting or reclining posture.

Type 2 Diabetes – A chronic non-communicable disease which occurs when the body cannot produce sufficient insulin.

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Summary of thesis publications and presentations

Chapter 2.
Hodgson, W., Kirk, A., Lennon, M., Janssen, X., Russell, E., Wani, C., & Eskandarani, D. (2023). RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) Evaluation of the Use of Activity Trackers in the Clinical Care of Adults Diagnosed with a Chronic Disease: Integrative Systematic Review. Journal of Medical Internet Research, 25(1), e44919–e44919. https://doi.org/10.2196/44919

Chapter 3.
Hodgson, W., Kirk, A., Lennon, M., & Janssen, X. (2024). Exploring the Use of Activity Trackers to Support Physical Activity and Reduce Sedentary Behaviour in Adults Diagnosed with Type 2 Diabetes: A Qualitative Interview Study Using the RE-AIM Framework. Journal of Medical Internet Research Diabetes, 9, e60066.
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Scottish Physical Activity Research Connections Conference 2023.
Abstract accepted and presented as a poster presentation. Title: RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) Evaluation of the Use of Activity Trackers in the Clinical Care of Adults Diagnosed with a Chronic Disease: Integrative Systematic Review.

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Scottish Physical Activity Research Connections Conference 2024.
Abstract accepted and presented as a poster presentation. Title: Exploring the use of activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes: A qualitative interview study using the RE-AIM Framework.

Scottish Physical Activity Research Connections Conference 2025.
Abstract accepted and presented as a poster presentation. Title: Exploring the integration of consumer activity trackers into a community weight management intervention to support physical activity in adults at risk or with type 2 diabetes: A mixed methods study using the RE-AIM framework.

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Chapter 1: Introduction

Statement of the problem

Type 2 diabetes mellitus is a chronic non-communicable disease (International Diabetes Federation, 2021). Risk factors for developing type 2 diabetes are obesity, sedentary behaviour, low levels of physical activity, older age and family history (genetics) (Deshpande, Harris-Hayes, & Schootman, 2008). If left untreated, type 2 diabetes can lead to further chronic health conditions, including cardiovascular disease, kidney failure (nephropathy) and blindness (retinopathy) (Deshpande, Harris-Hayes, & Schootman, 2008). Globally, the number of adults diagnosed with type 2 diabetes is increasing and this is placing health care resources under greater pressure (Sun, et al., 2022). Adults diagnosed with type 2 diabetes have been found to be less physically active and spend more time engaged in sedentary behaviour than those without the disease (Kuziemski, Slominski, & Jassem, 2019). Interventions, which encourage people with type 2 diabetes to be more physically active and reduce sedentary time can lower blood glucose levels and lessen the risk of further health complications (Dunbar, et al., 2015). Health professionals involved in the care of patients diagnosed with type 2 diabetes find the promotion of physical activity interventions challenging due to limited structured programmes, little behavioural change training and time constraints (Matthews, Kirk, & Mutrie, 2014). Physical activity behaviour change interventions, particularly those based on goal setting, have been shown to increase physical activity levels in adults diagnosed with a noncommunicable chronic disease, including type 2 diabetes, though these interventions seldom make it into routine clinical care due to being time consuming for health care professionals (Coughlin & Stewart, 2016). This results in few physical activity interventions being integrated within type 2 diabetes clinical care, which further increases the risk of patients developing complications of diabetes and further chronic health diseases, such as coronary heart disease (Coughlin & Stewart, 2016).

Modern wearable technology is playing an increasingly important role in clinical care and offers an alternative strategy for the long-term implementation of physical activity interventions (Franssen, Franssen, Spaas, Solmi, & Eijnde, 2020). Wearable devices such as consumer activity trackers were initially developed for the sport and fitness communities, though a limited number of research studies have explored their use within type 2 diabetes clinical care (Jo, Coronel, Coakes, & Mainous, 2019). Consumer activity trackers can record the users' steps, distance moved, physical activity intensity, sedentary behaviour, heart rate and sleep. They offer the user instant feedback and in some devices recommendations in respect of physical activity and sedentary behaviour (Franssen, Franssen, Spaas, Solmi, & Eijnde, 2020). Interventions, which incorporate consumer activity trackers within the clinical care of adults diagnosed with a chronic disease, including type 2 diabetes, have been shown to significantly increase levels of physical activity, reduce blood glucose levels, reduce weight and reduce levels of low-density lipoprotein. When consumer activity trackers are combined with behavioural change programmes or website/mobile applications, as part of a type 2 diabetes intervention, physical activity levels have been found to increase, and glycated haemoglobin decreases (De Groot, et al., 2018).

At present, despite their potential benefits to increase physical activity, reduce sedentary behaviour and provide individuals and health care professionals with valuable activity data, consumer activity trackers are not being routinely used within type 2 diabetes clinical care.

The overall aim of this PhD thesis is to investigate the integration of activity trackers into clinical care to support physical activity and reduce sedentary behaviour in adults diagnosed with or at risk of type 2 diabetes.

This introduction and literature review will examine the background and academic literature to support this aim. The Literature Review will introduce essential background concepts and definitions in relation to type 2 diabetes, physical activity and sedentary behaviour before reviewing the literature on activity trackers. The sections focusing on activity trackers will not just discuss the technological aspects of these devices but highlight complex factors, which could influence their integration into clinical care, such as reliability, validity, barriers to use and behavioural change concepts. The literature review will continue with a section on the My Diabetes My Way diabetes support platform and how this could be improved in relation to reach and integration of consumer activity trackers to support patient care. The literature review concludes with a section discussing the RE-AIM framework and in addition to its background a rationale for its use as a planning and evaluation tool throughout this thesis.

Type 2 diabetes

Type 2 diabetes mellitus is a chronic non-communicable disease, which causes increased levels of glucose in the blood (hyperglycaemia) (Deshpande, Harris-Hayes, & Schootman, 2008). Hyperglycaemia occurs when the beta cells in the pancreas fail to produce enough or any of the hormone insulin. Insulin facilitates the uptake of glucose from the blood into the cells of the body to produce energy (Deshpande, Harris-Hayes, & Schootman, 2008). The International Diabetes Federation states that diabetes is diagnosed if one or more of the following criteria is met: Fasting plasma glucose ≥ 7.0 mmol/L or Two-hour plasma glucose ≥ 11.1 mmol/L, HbA1c ≥ 48 mmol/mol or Random plasma glucose ≥ 11.1 mmol/L (see Figure 1) (International Diabetes Federation, 2021).

Test	Diabetes Should be diagnosed if ONE OR MORE of the following criteria are met	Impaired Glucose Tolerance (IGT) Should be diagnosed if BOTH of the following criteria are met	Impaired Fasting Glucose (IFG) Should be diagnosed if THE FIRST OR BOTH of the following are met
Fasting plasma glucose	≥7.0 mmol/L (126 mg/dL)	<7.0 mmol/L (126 mg/dL)	6.1 – 6.9 mmol/L (110 – 125 mg/dL)
	or	and	and if measured
Two-hour plasma glucose after 75g oral glucose load (oral glucose tolerance test (OGTT))	≥11.1 mmol/L (200 mg/dL)	≥7.8 and <11.1 mmol/L (140–200 mg/dL)	<7.8 mmol/L (140 mg/dL)
	or		
HbA1c	≥48 mmol/mol (equivalent to 6.5%)		
	or		
Random plasma glucose in the presence of symptoms of hyperglycaemia	≥11.1 mmol/L (200 mg/dL)		

Figure 1: Modified diagnostic criteria for diabetes *(International Diabetes Federation, 2021)*.

For people diagnosed with type 2 diabetes insulin initially becomes inefficient in facilitating the uptake of glucose from the blood into cells. At this stage, many people are unaware that they have developed type 2 diabetes. This is known as insulin resistance. As blood glucose levels rise the pancreas responds by producing more insulin. Over time the prolonged overload of the beta cells, within the pancreas, results in decreasing amounts of insulin being produced (Deshpande, Harris-Hayes, & Schootman, 2008). The main symptoms of type 2 diabetes are increased thirst, frequent urination, extreme tiredness, weight loss, increased risk of infection and blurred vision (Deshpande, Harris-Hayes, & Schootman, 2008). These symptoms may not be initially obvious and as a result, it is estimated that in one-third to one-half of adults type 2 diabetes is undiagnosed (World Health Organization, 2006). If left undiagnosed and untreated type 2 diabetes can lead to health complications including coronary heart disease, kidney failure and blindness (Gregg, et al., 2014). Though the exact causes of type 2 diabetes are not fully known major risk factors include being overweight, low levels of physical activity, high levels of sedentary behaviour, unhealthy diet, older age and family history (genetics) (Deshpande, Harris-Hayes, & Schootman, 2008).

Treatments for type 2 diabetes include a healthy lifestyle (diet and physical activity), oral hypoglycaemic agents and insulin injections (Deshpande, Harris-Hayes, & Schootman, 2008). Lifestyle modification is a central component of diabetes management, particularly because it targets modifiable behavioural and metabolic risk factors. Combined dietary change and increased physical activity are consistently identified as the most effective non-pharmacological strategies for improving glycaemic control and supporting weight management in adults with or at risk of type 2 diabetes.

Dietary modification aims to improve glucose regulation, reduce excess body weight, and improve cardiometabolic health through strategies such as reducing overall energy intake, moderating carbohydrate quality and quantity, increasing dietary fibre, and limiting ultra-processed foods (Ley et al., 2014). A substantial body of evidence demonstrates that structured dietary interventions, when paired with physical activity, result in clinically meaningful improvements in HbA1c, fasting glucose and body mass (Chiang et al., 2021; Neuenschwander et al., 2019). Similarly, physical activity contributes to improved insulin sensitivity, reduced visceral adiposity, enhanced glucose uptake in skeletal muscle, and improved cardiovascular fitness (Colberg et al., 2016). Meta-analyses consistently show that lifestyle interventions combining diet and physical activity produce larger reductions in

HbA1c and body weight than either component alone. For example, Umpierre et al. (2011) found that lifestyle programmes incorporating both dietary change and moderate to vigorous physical activity produced reductions in HbA1c of approximately 0.7–1.0%, a magnitude similar to some pharmacological treatments. Likewise, the Diabetes Prevention Program and subsequent systematic reviews indicate that combined diet and physical activity interventions reduce the incidence of type 2 diabetes by 40–60% in high-risk adults (Knowler et al., 2002; Pan et al., 2015). Despite the clear effectiveness of integrated diet and physical activity interventions, many health systems face challenges implementing comprehensive lifestyle programmes within routine care, including limited consultation time, lack of specialist training, and resource constraints (Matthews, Kirk, & Mutrie, 2014). As a result, some behavioural components, particularly physical activity, are promoted inconsistently despite their recognised benefits.

The focus of this thesis is specifically on the physical activity component of lifestyle intervention, rather than diet, for three key reasons. First, adults with type 2 diabetes consistently report low levels of physical activity and high levels of sedentary behaviour, representing a prominent and actionable risk factor (Kennerly & Kirk, 2018). Second, physical activity interventions lend themselves particularly well to digital support via wearable technologies, enabling remote monitoring, personalised feedback and integration into routine clinical encounters (Heizmann, et al., 2023). Finally, compared with dietary counselling, physical activity promotion is an area in which health professionals report greater uncertainty and fewer structured tools, highlighting a clear opportunity for innovation and improved clinical delivery (Osinaike, Copeland, Myers, & Hardcastle, 2025). In this context, investigating how consumer activity trackers can support the physical activity component of lifestyle management is both timely and clinically relevant, offering potential for scalable, sustained behaviour change within diabetes care pathways.

Globally the prevalence of type 2 diabetes is increasing, placing health care resources under greater pressure. Worldwide it is estimated that 483 million adults (20-79 years of age) are living with type 2 diabetes. Estimations indicate that by 2045 the number of adults living with type 2 diabetes will rise to 705 million. Annually 6 million adults die prematurely due to type 2 diabetes (Sun, et al., 2022). In the UK, 5 million adults have been diagnosed with type 2 diabetes. Treating patients in the UK diagnosed with type 2 diabetes costs the National Health Service (NHS) approximately £12 billion each year (Diabetes UK, 2025).

Chronic diseases

Chronic diseases, also known as non-communicable diseases, include coronary heart disease, respiratory diseases, cancers, kidney disease, stroke and diabetes (type 1, type 2 and gestational) (World Health Organization, 2023). The term chronic refers to a condition that is long term and usually lasting longer than 3 months. Worldwide chronic diseases are the main cause of premature death for an estimated 41 million people. Chronic diseases account for 74% of all recorded deaths (World Health Organization, 2023). In the UK chronic diseases account for 88% of all recorded deaths (Office for National Statistics, 2025). Each year, globally 17 million people die prematurely before the age of 70 years with 86% of these deaths occurring in low to middle-income countries (World Health Organization, 2023). Of all deaths from a chronic disease 77% occur in low to middle-income countries. Cardiovascular diseases, chronic respiratory diseases, cancers, and all types of diabetes (type 1, type 2 and gestational) account for 80% of all chronic noncommunicable deaths.

Smoking, physical inactivity, sedentary behaviour, excess alcohol consumption and poor air quality are all major risk factors for developing a chronic noncommunicable disease (World Health Organization, 2023). Low levels of physical activity are estimated to be a contributary factor in 830,000 premature deaths annually (Abbasi-Kangevari, et al., 2020). Metabolic risk factors including high blood pressure, overweight/obesity, hyperglycaemia (high blood glucose levels) and hyperlipidaemia (high levels of fat in the blood) increase the risk of developing a chronic disease. The burden of chronic diseases is steadily rising worldwide, particularly in developed countries. In 2023, the estimated cost of treating chronic diseases was $47 trillion (World Health Organization, 2023).

Physical activity

Physical activity is described as 'any bodily movement produced by the skeletal muscles that results in a substantial increase over resting energy expenditure' and includes active living, sport and exercise (Caspersen, Powell, & Christenson, 1985). Components of physical activity include active living ('any form of physical activity that is performed as part of everyday life'), exercise ('planned, structured and repetitive body movement done to improve or maintain physical fitness') and sport ('any form of physical activity aimed at improving fitness and mental wellbeing, forming social relationships or obtaining results at a competitive levels') (Caspersen, Powell, & Christenson, 1985). Frequency (times per week), intensity (level of exertion), time (duration of activity) and type (aerobic, anaerobic, resistance) make up the dimensions of physical activity (Caspersen, Powell, & Christenson, 1985). Aerobic physical activity is 'any activity which the body's large muscles move in a rhythmic manner for a sustained period of time' and improves cardiorespiratory fitness. Anaerobic physical activity consists of intense bursts of exercise, where oxygen demand surpasses oxygen supply. Resistance training is a form of physical activity which is designed to improve muscular fitness and bone strength by exercising a specific muscle group (Caspersen, Powell, & Christenson, 1985). Intensity of physical activity is normally measured on a continuum of metabolic equivalents (MET's) (see Figure 2) (Montoye & Taylor, 1984).

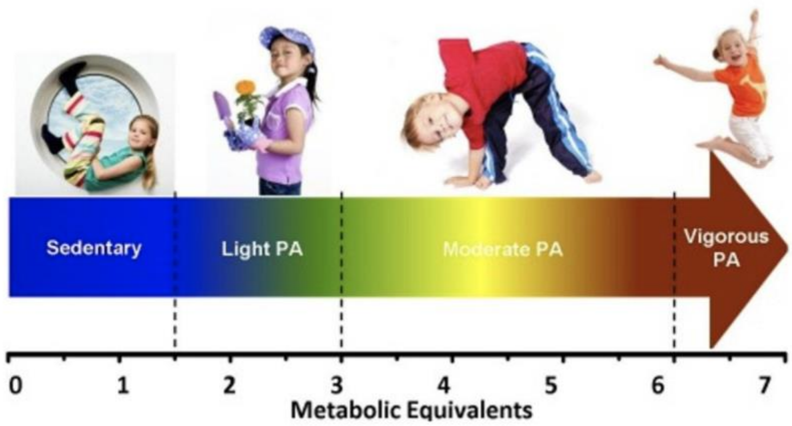

Figure 2: The energy expenditure continuum *(Montoye & Taylor, 1984)*.

One metabolic equivalent (MET) is defined as the amount of oxygen consumed by the body while sleeping or at rest and is equal to 3.5 ml of oxygen per kg of body weight x minutes. Low intensity physical activity is 1.5 – 3 MET's (e.g. slow walking). Moderate intensity physical activity is 3 – 6 MET's (e.g. brisk walking) and vigorous intensity physical activity is > 6 MET's (e.g. running) (Montoye & Taylor, 1984).

Focusing on the epidemiological relationship between physical activity and type 2 diabetes is multifaceted, encompassing aspects such as overall volume, intensity, type, and step count. Accumulating evidence underscores the significance of these factors in modulating type 2 diabetes risk. Higher volumes of physical activity are inversely associated with the risk of developing type 2 diabetes. Studies indicate that each 1,000-step increase in daily step count correlates with a 2–3% reduction in type 2 diabetes risk over several years (Cuthbertson, et al., 2022). The intensity of physical activity plays a crucial role in type 2 diabetes prevention. Moderate to vigorous intensity activities have been shown to improve insulin sensitivity and glycaemic control (Smith & Brown, 2021). Notably, walking at speeds of 2.5 mph or higher is associated with a significant reduction in diabetes risk (Hamasaki, 2016). While structured exercises are beneficial, daily activities such as walking, also contribute positively to type 2 diabetes risk reduction (Richardson, et al., 2007). A review highlighted that walking for at least 30 minutes daily could reduce type 2 risk by approximately 50% (Richardson, et al., 2007). Daily step count is a practical measure of physical activity linked to type 2 diabetes risk. Research indicates that accumulating more steps per day is associated with a lower risk of developing the disease. Additionally, higher step cadences, particularly those sustained over 30 minutes, are linked to improved cardiometabolic health (Ballin, et al., 2020).

In conclusion, increasing the overall volume of physical activity, focusing on moderate to vigorous intensity exercises, engaging in various types of physical activities, and aiming for higher daily step counts are all effective strategies in reducing the risk of type 2 diabetes. These findings emphasise the importance of integrating regular physical activity into daily routines as a preventive measure against type 2 diabetes and as an element within the clinical care of those diagnosed with the disease.

Physical activity guidelines

International and national organisations have published physical activity guidelines for adults. The World Health Organization recommends that adults 18 - 64 years of age undertake regular physical activity to confer health benefits for the following health outcomes: reduced risk of; all-cause mortality, cardiovascular disease, hypertension, cancers, type-2 diabetes and improved mental health, and sleep (World Health Organization, 2006). Adults should undertake at least 150 – 300 minutes of moderate intensity physical activity; or at least 75 – 150 minutes of vigorous intensity aerobic physical activity; or an equivalent combination of moderate and vigorous intensity activity throughout the week, for substantial health benefits (World Health Organization, 2006). Adults should also do muscle strengthening activities at moderate or greater intensity that involves all major muscle groups on 2 or more days a week, as these provide additional health benefits (World Health Organization, 2006). Adults may increase moderate intensity aerobic physical activity to more than 300 minutes; or do more than 150 minutes of vigorous intensity aerobic physical activity or do an equivalent combination of moderate and vigorous intensity activity throughout the week for additional health benefits (World Health Organization, 2006). In a good practice statement, the World Health Organization suggests that doing some physical activity is better than doing none, especially for adults who are not meeting the guidelines (World Health Organization, 2006).

In the UK, the Chief Medical Officers for England, Scotland, Wales and Northern Island have set and published the physical activity guidelines for adults (19 – 64 years of age), which align with those published by the World Health Organization (Department of Health and Social Care, 2019).

It is estimated that more than a quarter of the world's adult population (1.4 billion adults) are failing to undertake the recommended doses of physical activity (World Health Organization, 2022). Globally about 33% of adult females and 25% of adult males are not undertaking enough physical activity to maintain their health (World Health Organization, 2022). Levels of inactivity are twice as high in high income countries compared with adults from low-income countries. Globally no improvement in adult physical activity levels has been recorded since 2001. Worldwide it is estimated that 28% of all adults over the age of 18 years are not meeting the World Health Organization's recommended levels of physical activity (32% females and 23% males). This is having a major negative impact on health care resources, economic development, the environment, quality of life and community wellbeing. To tackle the global inactivity problem the World Health Organization recommend that healthcare providers advise and support patients in relation to physical activity and invest in new technologies, innovation and research to develop cost effective approaches to increasing physical activity (World Health Organization, 2022). In the UK, physical inactivity is a contributary factor in 1 out of 6 deaths (Office for Health Improvements and Disparities, 2024). Physical inactivity is estimated to cost the UK economy £7.4 billion each year and the National Health Service (NHS) £0.9 billion. Research has indicated that the UK population is 20% less active now than in 1960. If this trend continues it is estimated that this figure will rise to 40% by 2030. Around 42% of females and 34% of males are not undertaking enough physical activity for good health. The UK Government has suggested that 25% of adults would be more active if provided with advice and support from a healthcare professional (Office for Health Improvements and Disparities, 2024).

National and international physical activity guidelines have traditionally been formulated from data obtained through self-reported physical activity questionnaires (Bull, et al., 2020). Studies have shown that self-reported methods of assessing physical activity overestimate moderate to vigorous intensity physical activity. They are also unlikely to accurately measure light intensity physical activity and cannot capture very short bouts of physical activity at any intensity (Bull, et al., 2020). These limitations have the potential to hinder the future development of physical activity guidelines and future physical activity interventions (Gill, et al., 2023). Recent studies using wearable technology, such as consumer activity trackers, have enhanced our knowledge and understanding of the link between physical activity and health outcomes (Walmsley, et al., 2022). Evidence from these studies indicates that the relationship between physical activity and health is stronger than that obtained through self-report questionnaires (Walmsley, et al., 2022). Results obtained through the use of wearable technology suggest that smaller doses of moderate to vigorous intensity physical activity (~40 – 80 mins per week) or more doses of light intensity physical activity bring about health benefits (Ekelund, et al., 2019). As such it has been suggested that more research should be undertaken into the use of wearable technology by academics, healthcare providers and international health departments, with a view to developing future physical activity guidelines (Gill, et al., 2023).

Sedentary behaviour

Sedentary behaviour is described as any behaviour (sitting, lying or reclining) undertaken during waking hours, which involves energy expenditures of ≤ 1.5 metabolic equivalents (Tremblay, et al., 2017). Sitting is described as a position in which one's weight is supported by one's buttocks rather than one's feet, and in which one's back is upright (Sedentary Behaviour Research Network, 2024). Reclining is described as a body position between sitting and lying (Sedentary Behaviour Research Network, 2024). Examples of sedentary behaviour are driving a car, desk-based work, playing video games, and sitting watching television (Tremblay, et al., 2017). Sedentary behaviour differs from physical inactivity where a person fails to meet the recommended physical activity guidelines (Tremblay, et al., 2017). A sedentary behaviour pattern refers to the way sedentary behaviour is accumulated throughout the day rather than individual bouts (Sedentary Behaviour Research Network, 2024). A multi-country study found that globally adults spend on average 8.65 hours per day engaged in sedentary behaviour and this is steadily increasing (Ku, Steptoe, Liao, Hsueh, & Chen, 2018). The rise in sedentary behaviour is thought to be influenced by multiple factors including traffic congestion, air pollution, office-based work, home working, shortage of parks, lack of sport and leisure facilities, television viewing, rise in video game use and increase in mobile phone ownership (World Health Organization, 2022). Few studies have been undertaken that look at the patterns of prolonged sedentary behaviour and those that pose the greatest health risk (Diaz, et al., 2019). Sedentary behaviour on its own is a serious health risk and it is estimated to be responsible for 3.8% of all-cause mortality in adults and globally contributes to 3.2 million premature deaths annually (Biddle, et al., 2019). A sedentary lifestyle increases the risk of developing a chronic noncommunicable disease, including cardiovascular disease, type 2 diabetes, hypertension and cancers (breast, colon, colorectal, endometrial, and epithelial ovarian cancer) (Rezende, et al., 2016). Sedentary behaviour is linked to metabolic dysfunctions such as elevated plasma triglycerides, high-density lipoprotein (HDL) cholesterol and reduced insulin sensitivity (Park, Moon, Kim, Kong, & Oh, 2020). Lipoprotein lipase (LPL) is a protein that interacts at the cellular level, and a low LPL concentration is known to decrease the HDL cholesterol level while affecting the prevalence of diabetes-induced dyslipidaemia, metabolic disorders caused by ageing, metabolic syndrome, and coronary artery diseases. LPL activity is diminished by low levels of physical activity. Additionally, low levels of physical activity inhibit LPL activity in skeletal muscles and rapidly signals for impaired lipid metabolism (del Pozo-Cruz, et al., 2018). The fact that muscle LPL activity is highly sensitive to levels of physical activity and low-intensity muscular contractile activity supports the theory that sedentary behaviour is a risk factor for various metabolic disorders (Yanagibori, et al., 1998). Research has shown that the risk of type 2 diabetes increases with increasing sedentary time (HR, 1.91; 95% CI, 1.64–2.22) (Biswas, et al., 2015). Reducing periods of sedentary behaviour with intermittent bouts of physical activity has been shown to have significant health benefits (Healy, et al., 2008). By reducing sedentary time and replacing it with bouts of moderate to vigorous intensity physical activity can significantly reduce waist circumference (2.9 cm/30 minutes, $\beta = -2.95$, 95% CI= –3.88, –2.03, p=0.005) (Del Pozo-Cruz, et al., 2018). Furthermore, when the sedentary time is interrupted with light or moderate intensity physical activity, systolic and diastolic blood pressures dropped by 2–3 mm Hg (Larsen, et al., 2017). Interrupting sedentary time every 20 minutes with 2 minutes of light intensity physical activity in patients with type 2 diabetes decreased their systolic blood pressure by 14–16 mm Hg and the diastolic blood pressure by 8–10 mm Hg (Dempsey, et al., 2016).

Sedentary behaviour guidelines

Compared with physical activity there have been fewer studies undertaken with respect of sedentary behaviour and the dose response of activity required to minimise the risk to health (Patterson, et al., 2018). As a result, the World Health Organization has stated that there is insufficient scientific evidence to set time-based (frequency and duration) activity recommendations to counter the health risks of sedentary behaviour (World Health Organization, 2020). For adults (18 – 64 years of age) the World Health Organization has published the following sedentary behaviour recommendations (World Health Organization, 2020):

1. Adults should limit the amount of time spent being sedentary. Replacing sedentary time with physical activity of any intensity (including light intensity) provides health benefits.
2. To help reduce the detrimental effects of high levels of sedentary behaviour on health, adults should aim to do more than the recommended levels of moderate to vigorous intensity physical activity.

In summary, Figure 3 shows the relationship between sedentary behaviour, physical activity and the health risk.

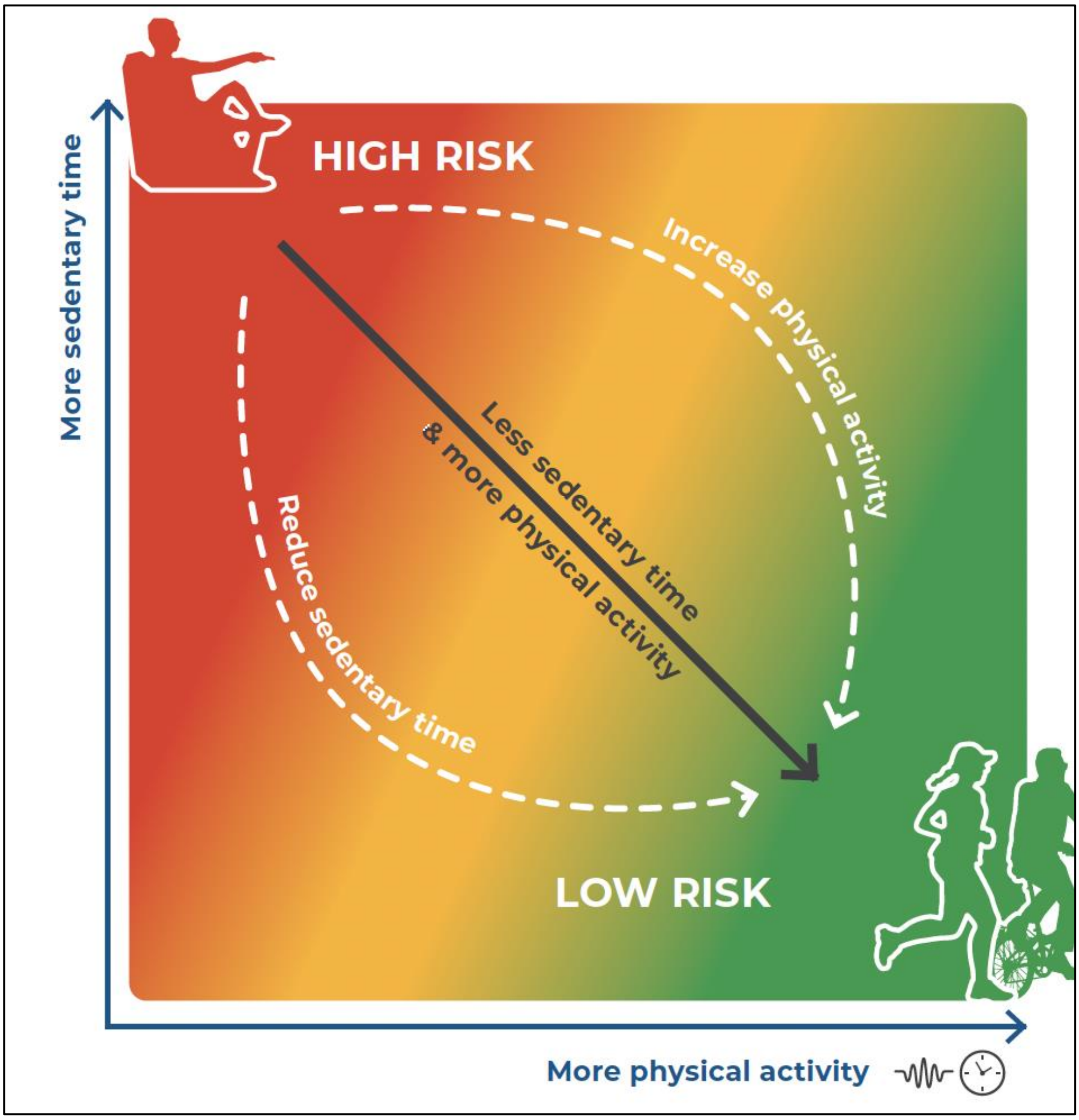

Figure 3: The relationship between levels of sedentary behaviour, physical activity and risk to health *(DiPietro, et al., 2019)*.

The chief medical officers of the UK (England, Scotland, Wales, and Northern Ireland) have reiterated the point that currently there is insufficient evidence to make specific recommendations on threshold levels of activity that would mitigate the negative impacts of sedentary time (Department of Health and Social Care, 2019). For adults (19 – 64 years of age) the UK Chief Medical Officers have published the following sedentary behaviour recommendation (Department of Health and Social Care, 2019). Adults should aim to minimise the amount of time spent being sedentary, and when physically possible should break up long periods of inactivity with at least light physical activity (Department of Health and Social Care, 2019).

Relationship between physical activity and sedentary behaviour

Historically, sedentary behaviour was viewed as an independent risk factor for conditions such as cardiovascular disease, diabetes, and early mortality, regardless of physical activity levels. This perspective led to recommendations focusing solely on reducing sedentary time (Henson, De Craemer, & Yates, 2023). Recent studies, however, have highlighted the importance of considering both physical activity and sedentary behaviour together. Research indicates that replacing sedentary time with physical activity, even light-intensity activities, can significantly reduce the risk of all-cause and cause-specific mortality. For instance, substituting 30 minutes of sedentary time with light physical activity daily has been associated with a 3.5% reduction in all-cause mortality risk (Chang, et al., 2024). Moreover, a systematic review and meta-analysis revealed that every hour spent sedentary corresponds to a 5% increased risk of fatal and non-fatal cardiovascular disease events. However, substituting one hour of sedentary behaviour with light-intensity physical activity reduced this risk by 16% (Onagbiye, et al., 2024). These findings underscore the importance of integrating physical activity into daily routines to counteract the negative effects of sedentary behaviour. Even small amounts of physical activity, such as brisk walking or light exercises, can have substantial health benefits. Health guidelines now emphasize the dual approach of reducing sedentary time and increasing physical activity. For example, the World Health Organization recommends adults engage in 150–300 minutes of moderate-intensity or 75–150 minutes of vigorous-intensity physical activity per week, while also limiting sedentary time (World Health Organization, 2020).

The shift in perspective reflects a more nuanced understanding of how physical activity and sedentary behaviour interact. Rather than viewing them as separate entities, it is now recognised that increasing physical activity can effectively offset the health risks associated with sedentary lifestyles. This integrated approach offers a more comprehensive strategy for improving public health outcomes.

Physical activity, sedentary behaviour and type 2 diabetes

The relationships between physical activity, sedentary behaviour, and type 2 diabetes are well-documented, with substantial evidence linking these behaviours to both the incidence and prevalence of type 2 diabetes (Henson, De Craemer, & Yates, 2023). Moreover, understanding the underlying mechanisms by which these behaviours influence type 2 diabetes is crucial for effective management and prevention strategies.

Regular physical activity is associated with a significantly reduced risk of developing type 2 diabetes (Onagbiye, et al., 2024). Epidemiological studies have demonstrated that individuals who engage in moderate-to-vigorous physical activity have a 30–50% lower risk of developing type 2 diabetes compared to inactive individuals (Aune, Norat, Leitzmann, Tonstad, & Vatten, 2015). For instance, a study within the Multi-Ethnic Study of Atherosclerosis cohort found that vigorous physical activity and faster walking pace were inversely associated with incident type 2 diabetes, even after adjusting for body mass index (BMI) (Joseph, et al., 2016).

In contrast, prolonged sedentary behaviour, such as extended periods of sitting or screen time, is associated with an increased risk of type 2 diabetes (Wilmot, et al., 2012). A meta-analysis indicated that each additional hour of daily sedentary activity is linked to a 5% increase in type 2 diabetes risk, independent of physical activity levels (Lin, Li, Wang, & Gong, 2015). Furthermore, replacing sedentary time with physical activities, even light-intensity ones like household chores or walking, can significantly reduce type 2 diabetes risk (Wang, Temprosa, Zhang, & Gregg, 2021).

The underlying mechanisms linking physical activity and sedentary behaviour to type 2 diabetes include insulin sensitivity and glucose metabolism, inflammation and oxidative stress, body composition and fat distribution, and mitochondrial function and muscle health (Silva, Duarte-Mendes, Teixeira, Soares, & Ferreira, 2024). In respect of insulin sensitivity and glucose metabolism, physical activity enhances insulin sensitivity by increasing glucose uptake into muscles via the GLUT-4 transporter, reducing blood glucose levels and improving overall glycaemic control (Bird & Hawley, 2017). On the other hand, sedentary behaviour leads to decreased muscle contraction, impairing glucose uptake and increasing insulin resistance. Prolonged sitting also reduces lipoprotein lipase (LPL) activity, an enzyme crucial for lipid metabolism, leading to elevated triglyceride levels and increased glucose levels (Zderic & Hamilton, 2006). In respect of inflammation and oxidative stress, physical activity has anti-inflammatory effects, reducing levels of pro-inflammatory markers such as C-reactive protein (CRP) and interleukin-6 (IL-6), which are associated with improved insulin sensitivity (Magni, Arnaoutis, & Panagiotakos, 2025). Sedentary behaviour is linked to increased systemic inflammation and oxidative stress, which can impair insulin signalling pathways and contribute to the development of type 2 diabetes (Gratas-Delamarche, Derbré, Vincent, & Cillard, 2014). In respect of body composition and fat distribution, regular physical activity helps maintain healthy body weight and reduces visceral fat, a key driver of insulin resistance. It also promotes the conversion of white adipose tissue to brown adipose tissue, enhancing energy expenditure (Dewal & Stanford, 2019). Sedentary behaviour is linked to increased systemic inflammation and oxidative stress, which can impair insulin signalling pathways and contribute to the development of type 2 diabetes (Yaribeygi, Maleki, Sathyapalan, Jamialahmadi, & Sahebkar, 2021). In respect of mitochondrial function and muscle health, physical activity improves mitochondrial function and increases mitochondrial biogenesis in skeletal muscles, enhancing aerobic capacity and energy metabolism (Abrego-Guandique, et al., 2025). Sedentary behaviour is associated with muscle atrophy and reduced mitochondrial function, leading to decreased muscle mass and strength, which are risk factors for type 2 diabetes (Safdar, et al., 2010).

The implications and role of physical activity as part of type 2 diabetes management are improved glycaemic control, cardiovascular benefits and mental health (Colberg, et al., 2016). Regular physical activity reduces HbA1c levels by approximately 0.5 – 0.7 % aiding better blood glucose management (Umpierre, et al., 2011). Physical activity reduces blood pressure, improves lipid profiles, and enhances endothelial function, reducing cardiovascular risk associated with type 2 diabetes (Colberg, et al., 2016). Physical activity alleviates diabetes-related distress, anxiety, and depression, improving overall quality of life for individuals with type 2 diabetes (Colberg, et al., 2016).

The importance of reducing sedentary behaviour as part of the management of type 2 diabetes should include interrupting prolonged periods of sitting and making behavioural modifications (Dempsey, Larsen, Dunstan, Owen, & Kingwell, 2018). Breaking up long periods of sitting with short bouts of light activity can lower postprandial glucose and insulin concentrations, contributing to better glycaemic control and encouraging individuals to reduce sedentary time and increase light-intensity activities can lead to significant improvements in metabolic health and a reduction in type 2 diabetes risk (Dempsey, et al., 2016). The benefit of undertaking physical activity and reducing the blood glucose levels of adults diagnosed with or at risk of developing type 2 diabetes has been reported in the following studies. In a systematic review and meta-analysis conducted by Umpierre et al. (2011), the effect of structured exercise (planned, personalised and supervised) on blood glucose levels (HbA1c) of people diagnosed with type 2 diabetes was examined. Structured exercise was found to significantly reduce the HbA1c levels of participants (weighted mean difference (WMD) -0.67%) and programmes which involved more than 150 mins of moderate to vigorous intensity physical activity (MVPA) per week produced the greatest difference in participants HbA1c levels (WMD -0.89%) (Umpierre, et al., 2011). The effect of progressive aerobic exercise on the HbA1c levels of adult participants diagnosed with type 2 diabetes was examined in a systematic review and meta-analysis by Delavatti, et al. (2019). In the study aerobic exercise was classified as endurance based such as running or cycling and > 150 mins per week of MVPA. Progression was measured by the increase in minutes of aerobic exercise over a 12-week intervention period. The mean weekly increase in minutes of aerobic exercise was 46 mins. Progressive aerobic exercise was found to significantly reduce participants HbA1c (WMD 0.86%) (Delevatti, et al., 2019).

The levels of physical activity and sedentary behaviour within adults diagnosed with type 2 diabetes were examined in a systematic review conducted by Kennerly and Kirk, (2018). Across all identified studies adults with type 2 diabetes were found to be less physically active and spent more time being sedentary than those without the disease (Kennerly & Kirk, 2018). The study concluded that lifestyle interventions including physical activity should be incorporated into the health care of diabetes patients (Kennerly & Kirk, 2018).

The link between sedentary time and improved health for adults diagnosed with or at risk of developing type 2 diabetes was reported in a study by Sardinha, Magalhães, Santos, and Júdice (2017). They found that reducing the sedentary time by undertaking even light levels of physical activity (> 1.5 metabolic equivalents) can reduce the risk of developing type 2 diabetes and for those diagnosed with the disease improve insulin sensitivity (Sardinha, Magalhães, Santos, & Júdice, 2017).

Physical activity behaviour change interventions have been shown to improve metabolic factors in adults diagnosed with type 2 diabetes. A systematic review and meta-analysis by Avery, Flynn, van Wersch, Sniehotta and Trenell (2012) examined the benefits of physical activity behavioural interventions for people diagnosed with type 2 diabetes. The focus of this study was on free-living physical activity levels, blood glucose levels (HbA1c) and body mass index (BMI). The research team found that physical activity behavioural interventions, based on the transtheoretical model and social cognitive theory, significantly increased both objectively and self-reported measures of free-living physical activity (Standardised Mean Difference (SMD) 0.45 and 0.79 respectively). After the intervention participants' HbA1c levels and BMI were both significantly reduced (WMD -0.32% and -1.05 kg/m^2 respectively)

(Avery, Flynn, van Wersch, Sniehotta, & Trenell, 2012). The effect of physical activity behaviour change interventions on the blood glucose levels (HbA1c) of patients diagnosed with type 2 diabetes was the subject of a meta-analysis conducted by Chen et al. (2015). Behaviour change physical activity interventions, which incorporate goal setting and are personalised for the individual participant, were found to significantly reduce HbA1c levels (WMD – 0.37) (Chen et al. 2015)

In a qualitative study, Matthews, Kirk and Mutrie (2014) set out to explore the experiences of health professionals involved in the clinical care of patients diagnosed with type 2 diabetes. The focus of this study was the future delivery and promotion of routine physical activity interventions within type 2 diabetes clinical care. Participants involved in primary care, secondary care and health management completed an online survey to explore their views of physical activity delivery within diabetes health care. Practice nurses and dedicated diabetes nurses were identified as those best placed to deliver physical activity advice. Access to a structured physical activity referral system, staff training and dedicated physical activity advisors were highlighted as the main improvements that could be made. The health care professionals chose physical activity behaviour change consultations, and physical activity discussions with a practice nurse or dietician during routine clinics as the main strategies for improving a patient's physical activity. Following on from the survey health care professionals were interviewed as part of a qualitative analysis to understand their perception of physical activity within type 2 diabetes health care. Three main themes were identified: current physical activity promotion, facilitators and barriers to the promotion of physical activity and future strategies that could be implemented to improve physical activity promotion. Sub-themes specifically identified that physical activity played an important role in the care of patients with type 2 diabetes. Suggested future strategies included an improved referral scheme for patients, identification of specific staff to deliver physical activity interventions, linking physical activity interventions to the specific needs of patients and the improved promotion of physical activity within health care (Matthews, Kirk, & Mutrie, 2014).

The delivery of physical activity promotion within diabetes health care was examined in a UK based formative study by Kime, Pringle, Zwolinsky and Vishnubala (2020). Healthcare professionals completed an online survey and took part in semi-structured interviews with follow-up thematic analysis undertaken. Results indicated that the delivery of physical activity guidance to diabetes patients was limited and usually only undertaken at a basic level. Though committed to the concept participants found physical activity challenging and cited a lack of education, lack of training, lack of knowledge about the national physical activity guidelines, lack of proper referral options, lack of time and lack of access to appropriate resources. There was evidence in this study that new programmes are being developed to support healthcare professionals in the delivery of physical activity interventions (Kime, Pringle, Zwolinsky, & Vishnubala, 2020). One such pilot study is a sport and exercise medicine programme developed by researchers from Oxford University and Sports England which incorporates peer-led training and an active hospital toolkit (Sports England, 2024). The “Moving Medicine” programme is a physical activity interactive intervention tool, which incorporates intervention consultations, promotional material and online patient support (Moving Medicine, 2024).

A multidimensional physical activity behaviour change intervention designed for use within NHS England primary care for patients diagnosed with type 2 diabetes was developed by Avery et al. (2016). A four-stage development programme which included qualitative analysis interviews with primary diabetes health care professionals, workshops with type 2 diabetes patients, a systematic review of available physical activity interventions and testing of developed interventions within health care environments was delivered. The main findings from the interviews with health care professionals included a present reliance on the prescription of diabetes medication, difficulty in communicating physical activity advice to patients, patients not taking responsibility for the self-management of their condition, a lack of physical activity training, time constraints and a need to develop online physical activity interventions. The key findings from the patient workshops were a feeling that primary health care professionals did not appear fully knowledgeable about type 2 diabetes and only provided limited advice about physical activity, a lack of specific physical activity support, limited physical activity information and a preference for face-to-face physical activity advice. During the systematic review and subsequent meta-analysis, the research team found that physical activity behaviour change interventions improved glycaemic control (HbA1c -0.32%). Subsequently, the research team developed an online accredited physical activity behaviour change intervention training programme for health professionals and a type 2 diabetes physical activity intervention for use within a clinical environment. The intervention programme was based on the social cognitive theory and theory of planned behaviour (Avery, et al., 2016). Avery et al. (2014) describe in detail the components of the intervention which included an initial patient centred consultation conducted by a qualified health professional (seven-day physical activity recall, decisional balance analysis and measure of self-efficacy), follow-up consultation focusing on goal setting and self-management, use of activity trackers and planners, issue of a pedometer to measure steps, relapse prevention, follow-up consultation and long-term goal setting. During tests of the intervention, healthcare professionals reported a high satisfaction with the structure of the intervention and a recommendation to share the programme with colleagues. The patients reported high satisfaction with the intervention especially when combined with routine diabetes consultations (Avery, et al., 2014).

In a systematic review by Timm et al. 2021, the delivery of physical activity promotion within type 2 diabetes health care was explored. Results indicated that most physical activity promotion occurred within a single organisation or department, which placed additional strain on staff and departmental budgets (Timm, et al., 2021). Recommendations included enhancing and developing stronger links between different sectors to support the delivery of physical activity promotion. This would allow for the sharing of resources, knowledge and support (Timm, et al., 2021).

In summary, for adults diagnosed with or at risk of type 2 diabetes evidence suggests that they should:

- **Engage in Regular physical activity**: Aim for at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic activity per week, combined with muscle-strengthening activities on two or more days per week.
- **Reduce sedentary behaviour**: Limit sedentary time by incorporating standing or light activities throughout the day, especially during prolonged periods of sitting.
- **Monitor and Adjust**: Regularly assess physical activity levels and sedentary behaviour and make adjustments as needed to maintain optimal metabolic health.

Physical activity is a critical therapeutic element in type 2 diabetes management, delivering consistent improvements in glycaemic control and cardiovascular risk markers. Sedentary behaviour, conversely, independently contributes to metabolic dysfunction and should be specifically targeted in clinical and lifestyle interventions. The integration of technology further enhances the potential for sustained behaviour change. A holistic approach that promotes regular, progressive physical activity while minimising sedentary time is essential for optimal type 2 diabetes management and prevention.

Additional contributory factors influencing the global type 2 diabetes epidemic

Though increasing levels of physical activity and reducing sedentary behaviour can play a significant role in the management of type 2 diabetes additional contributary factors need to be considered within the clinical care of patients and when developing appropriate interventions. Global trends indicate that while type 2 diabetes prevalence is rising, levels of physical inactivity are not increasing at the same rate. This discrepancy suggests that other factors beyond physical activity and sedentary behaviour are influencing the type 2 diabetes epidemic (Sun, et al., 2022). Some of these additional factors include the rise in obesity and high body mass index (BMI), an aging population, socioeconomic and environmental factors, genetic and epigenetic factors, nutritional transition and ultra-processed foods and nighttime light exposure.

Obesity remains the most significant risk factor for type 2 diabetes, accounting for over half of the associated disability adjusted life years globally. This trend is expected to continue, with high BMI contributing more than 60% of type 2 diabetes related disability adjusted life years in regions like North Africa, the Middle East, and Latin America (Sun, et al., 2022). The global increase in life expectancy leads to a higher proportion of older adults, who are more susceptible to type 2 diabetes. In every country, individuals aged 65 and older exhibit a diabetes prevalence rate exceeding 20%, with the highest rates observed in North Africa and the Middle East (Hossain, Al-Mamun, & Islam, 2024). Lower socioeconomic status is associated with higher T2D prevalence, particularly in developed countries. Factors such as limited access to healthy foods, healthcare, and safe environments for physical activity exacerbate this risk (Stafford, et al., 2023). Genetic predispositions, including variants in genes like TCF7L2, GCK, and SLC30A8, increase the risk of type 2 diabetes. Additionally, epigenetic modifications, such as DNA methylation changes, can influence insulin resistance and glucose metabolism (Herder & Roden, 2011). The global shift towards diets high in refined carbohydrates and ultra-processed foods contributes to obesity and insulin resistance, particularly in low- and middle-income countries (Stafford, et al., 2023). Exposure to bright light during night time disrupts circadian rhythms, impairing insulin secretion and glucose metabolism, thereby increasing type 2 diabetes risk (Windred, et al., 2024).

In conclusion. while promoting physical activity and reducing sedentary behaviour are crucial in mitigating type 2 diabetes risk, addressing the multifaceted determinants is essential for effectively curbing the projected rise in type 2 diabetes cases.

Consumer activity trackers

Having identified the importance that physical activity and reducing sedentary behaviour plays in the management of type 2 diabetes, the ability to measure these factors has the potential to support both patients and healthcare professionals. Wearable technology is playing an increasingly important role in the public domain (recreation and leisure), sports, research and clinical health care (Shei, Holder, Oumsang, Paris, & Paris, 2022). Such technology includes blood glucose monitors, oximeters, blood pressure monitors, electrocardiograms, energy expenditure devices and activity trackers. In respect of healthcare, these devices have the potential to improve patient care and reduce the burden on overloaded health resources through remote data access by healthcare professionals and patient self-monitoring. Modern wearable consumer activity trackers were initially developed from basic mechanical pedometers. The first mechanical pedometers were produced in the 1700's. These rudimentary devices were designed to measure the number of steps taken by the individual (Shei, Holder, Oumsang, Paris, & Paris, 2022). In 1965 Dr Yoshiro Hatano developed an electronic pedometer for use in combating obesity (Tudor-Locke, et al., 2011). This device was later sold commercially under the brand name 'Manpo-kei' which translates into '10,000 steps meter'. Dr Hatano suggested that 10,000 steps each day provided the proper balance of caloric intake and activity-based calorie expenditure to maintain a healthy body. To this day manufacturers of modern commercial activity trackers still recommend 10,000 steps as the daily benchmark activity goal for adults, though research indicates that the health benefits depend on additional factors such as physical activity intensity (Tudor-Locke, et al., 2011). Modern commercial activity trackers provide the user with instant feedback and these include fitness trackers, smartwatches, mobile applications on smartphones and pedometers (Degroote, et al., 2020). These devices are relatively affordable, user friendly and visually appealing (Degroote, et al., 2020). Advances in technology have led to more sensors being integrated into wearable activity trackers, which can measure a variety of physiological markers (Shei, Holder, Oumsang, Paris, & Paris, 2022). These newer sensors include 3-axis accelerometers, gyroscopes, thermometers, barometers, magnetometers and global positioning system (GPS) (Shei, Holder, Oumsang, Paris, & Paris, 2022). The devices have inbuilt software including algorithms, which can analyse the data collected via the sensors and display the outputs through the tracker or via a connected mobile application (Shei, Holder, Oumsang, Paris, & Paris, 2022). Depending on the manufacturer and model, activity trackers can undertake several functions including measuring the users' steps, physical activity intensity, distance moved, sedentary behaviour, sleep, heart rate, maximal oxygen consumption and energy expenditure (Degroote, et al., 2020). Globally the popularity of commercial activity trackers has risen significantly with user numbers increasing from 136 million in 2019 to 289 million in 2023 (Maher, Ryan, Ambrosi, & Edney, 2017). Global sales of consumer activity trackers in 2023 were estimated to be $54.34 billion (Maher, Ryan, Ambrosi, & Edney, 2017). The most popular brands and their share of the market are Fitbit (52%), Garmin (15%), Apple watch (9%), Polar (4%), TomTom (4%), Samsung Gear (2%) and all others (14%) (Statistica, 2025). The growing ownership and use of activity trackers within the general population presents an opportunity for their routine use within health care though a better understanding of their reliability and validity and consensus around the use of these terms in respect of the measurements being undertaken is required.

Reliability, validity and challenges of using commercial activity trackers to measure physical activity and sedentary behaviour

As wearable technologies and accelerometery based methods become more widespread in physical activity and sedentary behaviour research and clinical health care, it is necessary to understand what is being measured and evaluate measurement quality (Kelly, Fitzsimons, &

Baker, 2016). Traditionally, validity (the extent to which a method measures what it is intended to measure) and reliability (the consistency or repeatability of that measurement) have been the methods of evaluating physical activity instruments. However, many measures of physical activity and sedentary behaviour are validated against doubly labelled water, which is set as the “gold standard”. It has been highlighted that doubly labelled water is a good measure of total energy expenditure but a poor measure of frequency, intensity, type and duration (Kelly, Fitzsimons, & Baker, 2016). As such it has been proposed that a shift toward more nuanced interpretations of ecological validity, interpretive validity, and functional reliability is warranted (Troiano, McClain, Brychta, & Chen, 2014). Rather than seeking a single "gold standard" measure, researchers may benefit from embracing a multi-method approach that acknowledges different tools serve distinct research purposes and clinical use e.g., accelerometers for volume and intensity, self-reports for context and intention (Prince, et al., 2008). Device-based measures often offer strong technical validity but may lack behavioural specificity, misclassify static postures or fail to capture activities such as resistance training and cycling (Atkin, et al., 2012). Meanwhile, subjective measures, while less precise, can offer critical insight into the motivational and social dimensions of activity behaviour (Ding, et al., 2020). Given these challenges, it may be more constructive to move away from binary judgments of validity and reliability and instead consider the appropriateness of a measurement tool relative to the research question, population, and setting (Reilly, et al., 2008). This reframing also calls for broader use of triangulation, data fusion, and transparency in reporting measurement protocols (Kelly, Fitzsimons, & Baker, 2016).

The Edinburgh Framework was developed to offer a comprehensive approach to evaluating the validity and reliability of physical activity and sedentary behaviour measurement methods, addressing the complexities and challenges inherent in accurately assessing these behaviours (Kelly, Fitzsimons, & Baker, 2016). The key components of the Edinburgh Framework are (Kelly, Fitzsimons, & Baker, 2016):

1. The purpose of measurement. This recognises that the intended use of a measurement tool influences its design and evaluation.
2. Conceptual clarity. This emphasises the importance of clear definitions of physical activity and sedentary behaviour, acknowledging that these constructs are multifaceted and context dependent.
3. Validity dimensions. These take into account the accuracy and precision of the measurement tool (technical validity), alignment with theoretical constructs of physical activity and sedentary behaviour (conceptual validity), relevance and applicability in real world settings (ecological validity) and feasibility and acceptability for end users (pragmatic validity).
4. Reliability. This acknowledges that consistency over time and across different contexts is crucial but must be considered alongside validity.
5. Stakeholder perspectives. This incorporates views from researchers, practitioners, and participants to ensure the measurement tool meets the needs of all involved.

Figure 4 shows the Edinburgh Framework v1.0 for validity and reliability in physical activity and sedentary behaviour measurement.

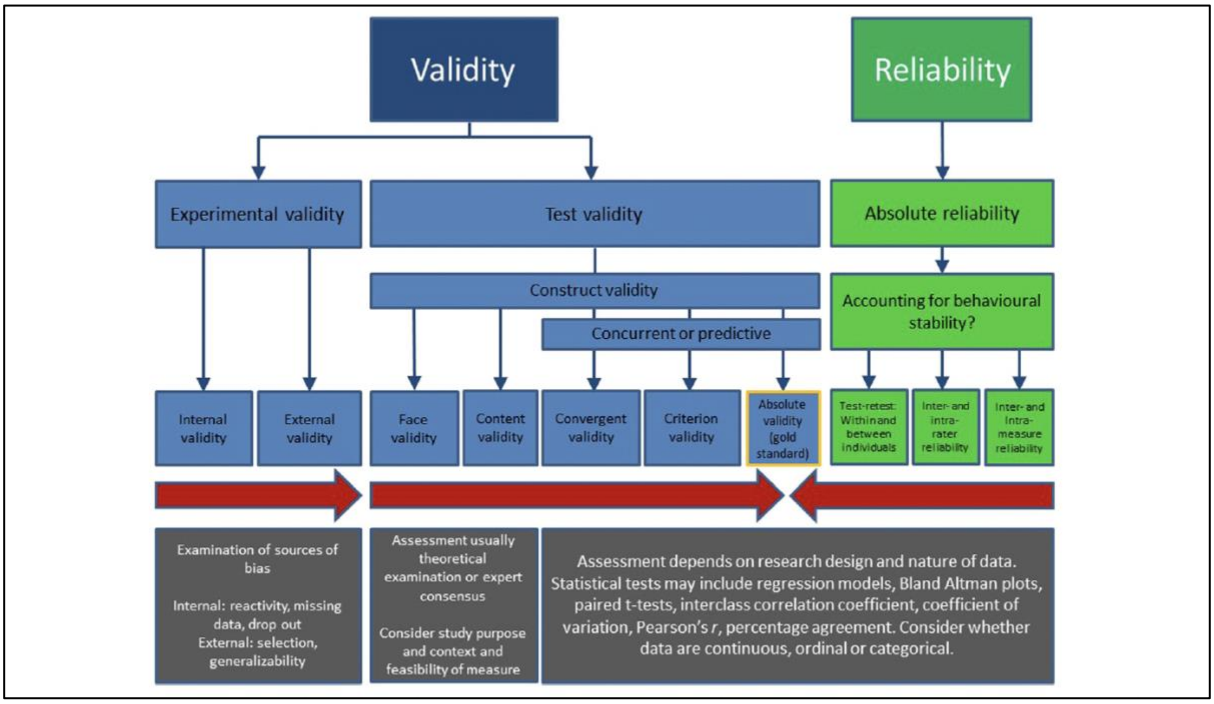

Figure 4: The Edinburgh Frame work v1.0 for validity and reliability in physical activity and sedentary behaviour measurement *(Kelly, Fitzsimons, & Baker, 2016)*.

In summary, the Edinburgh Framework encourages a broader, integrated perspective, recognising purpose specific measurement, multi-dimensional nature of physical activity and sedentary behaviour, interconnectedness of validity and reliability and the role of feasibility, generalisability and responsiveness. It improves clarity when choosing or comparing measurement tools, helps researchers justify tool selection based on study goals and encourages development of tools that are fit for purpose, rather than aiming for abstract validity (Kelly, Fitzsimons, & Baker, 2016). Nonetheless, its limited coverage of certain validity/reliability domains, lack of empirical validation, practical burdens, and restricted methodological scope require careful supplementation and adaptation. Graduate-level research should treat the framework as a foundational scaffold, not a definitive solution, integrating broader methodological safeguards to ensure instruments are truly valid, reliable, and fit for their intended purpose (Kelly, Fitzsimons, & Baker, 2016).

While the preceding section outlines general considerations regarding the reliability and validity of physical activity and sedentary behaviour measures, it is essential to explicitly situate these issues within the context of commercial wearable activity trackers, as these devices form the core measurement tool in this thesis. Commercial trackers, although increasingly sophisticated, rely on proprietary algorithms that estimate step count, energy expenditure, activity intensity and sedentary time using accelerometery-derived data (Feehan et al., 2018). These algorithms are rarely transparent, making it difficult to fully evaluate or replicate device outputs (Bunn, Navalta, Fountaine, & Reece, 2018). Consequently, although many consumer devices show acceptable reliability for step counts and moderate to vigorous physical activity under free-living conditions, their accuracy for sedentary behaviour, light intensity activity or energy expenditure is more inconsistent, particularly among individuals with chronic conditions such as type 2 diabetes (Wang et al., 2022; Xiang et al., 2020). These limitations are highly relevant to this thesis because activity trackers will be used both as a behavioural intervention tool and as a measurement source; therefore, understanding their strengths and weaknesses is critical for interpreting the physical activity and sedentary behaviour outcomes collected in the study. By acknowledging these measurement constraints, this thesis adopts a pragmatic approach using trackers to capture trends, patterns and changes in activity rather than precise absolute values, while also recognising their potential to enhance motivation, self-monitoring and clinician–patient communication in type 2 diabetes management (Brickwood et al., 2019; Mercer et al., 2016).

In a study, by Strain et al. (2022) the potential and challenges of using consumer wearable devices and smartphones for monitoring physical activity and sedentary behaviour at the population level were discussed. While these technologies offer promising avenues for large-scale surveillance, several key considerations were discussed to ensure their effectiveness and reliability. The key considerations included representativeness of data, wear time and compliance, validity and reliability of measurements, device compatibility and data harmonisation and ethical and privacy concerns. A significant concern is the potential for selection bias. Individuals who own and use wearable devices may differ systematically from those who do not, leading to data that may not accurately represent the broader population. This bias can skew findings and limit the generalisability of conclusions drawn from such data. For accurate physical activity measurement, consistent wear time is crucial. However, ensuring that participants adhere to wearing the devices as required can be challenging. Factors such as device comfort, battery life, and ease of use influence compliance rates. Non-compliance can lead to gaps in data, affecting the quality and reliability of the surveillance efforts. The accuracy of data collected by consumer-grade devices is another critical issue. Studies have shown that these devices may not always provide measurements that align with gold-standard methods. For instance, discrepancies in step counts and energy expenditure estimates have been observed. Such inaccuracies can undermine the validity of the data and affect the conclusions drawn from them. Different manufacturers employ proprietary algorithms, leading to variations in data processing and interpretation. This lack of standardisation makes it challenging to combine data from multiple sources, hindering efforts to create a cohesive dataset for population-level analysis. The continuous collection of personal data raises significant ethical issues. There are concerns about data security, informed consent, and the potential misuse of information. Ensuring that participants' privacy is protected and that data are used responsibly is paramount in maintaining public trust and the integrity of the research. To address these challenges the authors of this study recommended that devices be standardised by providing participants with the same device, which has the potential to reduce variability and improve data comparability. Establish clear protocols for device usage, data collection, and analysis to ensure consistency and reliability. Provide participants with transparent information how data will handled including collection, storage and use. This will help build trust and ensure ethical practices are being followed. Conduct continuous monitoring and evaluation by regularly assessing the effectiveness of the surveillance system will allow for timely adjustments and improvements (Strain, Wijndaele, Pearce, & Brage, 2022).

While consumer grade wearables and smartphones hold significant potential for enhancing population-level physical activity surveillance, addressing the outlined considerations above is essential for their successful implementation. By adopting standardised practices and ethical guidelines, researchers can harness these technologies to obtain accurate and representative data, ultimately informing public health strategies and interventions (Strain, Wijndaele, Pearce, & Brage, 2022).

Understanding the barriers to digital health adoption and how to overcome these were reported in a study by Mair et al. (2025). Through a patient and public involvement approach five key themes emerged highlighting the main barriers to adopting digital health solutions. The main themes were awareness of digital health solutions, weighting benefits against burdens, accessibility, trust in digital health developers and technology and impact of user experience. Many participants were unaware of available DH solutions, highlighting the need for increased promotion and community outreach. Individuals assessed the perceived benefits of digital health solutions against the effort or burden of using them. Barriers related to digital literacy, language diversity, and upfront costs were significant concerns. Concerns over data security and the credibility of developers influenced willingness to adopt digital health solutions. The design and usability of digital health tools played a crucial role in their adoption. From these main themes five key strategies were proposed to enhance digital health adoption community based promotion and digital literacy training (increasing awareness and understanding of digital health solutions through community efforts), brief counselling at opportune moments in health care settings (providing timely information and support during healthcare interactions), variable rewards tied to personal values (implementing incentive structures that resonate with individual values), policies ensuring accessibility and regulation (developing policies that address accessibility barriers and regulate digital health solutions) and gamified, user friendly designs emphasising feedback and behavioural cues (creating engaging and intuitive digital health tools that provide feedback and guidance) (Mair, et al., 2025).

In conclusion, the complexity of integrating activity trackers into the clinical care of adults diagnosed with or at risk of developing type 2 diabetes requires detailed consideration of the reliability, validity and barriers associated with adopting digital health solutions. These solutions need to be incorporated into intervention policies and protocols.

Type 2 Diabetes consumer activity tracker interventions

Type 2 diabetes is a complex, chronic condition that requires long-term self-management involving lifestyle modification, particularly increased physical activity. Among a growing array of digital tools, consumer activity trackers have emerged as scalable and user-friendly devices that may support physical activity and behavioural change in people living with type 2 diabetes. These trackers, such as Fitbit, Apple Watch, and Garmin devices, are now increasingly integrated into both standalone and multi-component research interventions targeting glycaemic control, cardiovascular risk reduction, and diabetes self-management. Although many of these devices are marketed for general wellness, their design features are highly relevant to behavioural strategies that have been shown to be effective in clinical and real-world type 2 diabetes contexts.

Consumer activity tracker interventions operate on the principle of self-regulation (O'Carroll, 2020), enabling users to set goals, monitor progress, receive feedback, and adjust behaviour accordingly. These functions map onto well-established behaviour change techniques (BCTs), as outlined in the Behaviour Change Technique Taxonomy (Michie, et al., 2013). For instance, tracking daily steps or activity minutes reflects self-monitoring of behaviour, while dynamic feedback and real-time progress bars align with feedback on behaviour and discrepancy between current behaviour and goal. Features such as daily goals, haptic reminders, and achievement badges engage goal setting, prompts, and rewards, which are central to maintaining motivation and adherence in long-term conditions like type 2 diabetes (Michie, et al., 2013) ((Mähs, et al., 2022).

These BCTs are not implemented by chance; they align with key constructs in behavioural theory. In particular, Social Cognitive Theory highlights the importance of self-efficacy, which activity trackers can enhance by making behaviour visible and progress measurable (Bandura, 1986). Control Theory underpins the feedback loop enabled by trackers, where behaviour is monitored and compared against personal goals (Carver & Scheier, 1982). The

Health Action Process Approach also applies and shows that consumer devices can support both the motivational phase (through intention formation and goal setting) and the volitional phase (by facilitating action planning, monitoring, and relapse prevention) (Schwarzer, 2008).

A growing body of evidence supports the utility of consumer activity trackers for individuals with type 2 diabetes. A systematic review by Yerrakalva et al. (2019) found that wearable activity monitors used in interventions for people with type 2 diabetes were associated with increased physical activity and modest but significant reductions in HbA1c levels (Yerrakalva, Yerrakalva, Hajna, & Griffin, 2019). Importantly, interventions that included multiple BCTs, especially self-monitoring, feedback, and goal setting, produced the most favourable outcomes. A more recent meta-analysis by Wu et al. (2021) confirmed that interventions incorporating commercial wearable trackers significantly improved both physical activity and glycaemic control among adults with type 2 diabetes (Wu, et al., 2017). These effects were more pronounced when trackers were used in conjunction with structured behavioural support, such as coaching or mobile health (mHealth) apps.

However, the effectiveness of tracker-based interventions depends heavily on engagement, accessibility, and context. As highlighted by Houlden et al. (2022), disparities in digital literacy, socioeconomic status, and age can influence who benefits from wearable-based interventions. Additionally, attrition is a challenge: many users reduce or stop tracker use over time, particularly if the device is not meaningfully integrated into a broader behavioural support strategy. For individuals managing type 2 diabetes, interventions are most successful when trackers are embedded within multi-level frameworks that also support medication adherence, dietary change, and emotional wellbeing (Houlden, Gorbach, McManus, Vandelanotte, & Duncan, 2022).

Despite these challenges, the appeal of consumer wearables lies in their accessibility, affordability, and potential for real-time feedback, all of which are attractive in the self-management of a condition that requires daily attention. Unlike traditional clinic-based interventions, wearables enable patients to manage their activity levels in real-world settings and in a manner that can be personalised and adaptive. This aligns with global shifts toward patient-centred care and digital self-management strategies for chronic conditions. In summary, consumer activity tracker interventions represent a promising, behaviourally grounded approach to supporting physical activity in people living with type 2 diabetes. Their effectiveness lies in the integration of evidence-based behaviour change techniques, real-time feedback, and self-monitoring tools, all of which are consistent with theoretical models of health behaviour. Future research and implementation efforts should focus on improving user engagement, addressing digital inequalities, and embedding wearables within broader diabetes management systems to maximise long-term impact.

My Diabetes My Way

In addition to consumer activity trackers the use of technology and online interventions within diabetes clinical care is increasing. This is being driven by a need to manage health resources more efficiently and effectively (Pal, et al., 2013). E-health involves a link between the internet and health care systems and includes user interaction with health data, cross transfer of data between organisations and user to user communication. E-health systems were initially used by healthcare staff though more recently they are increasingly being used by patients as part of their clinical care (Eysenbach, 2001). Electronic personal health records (ePHR) have been shown to improve communication between healthcare staff and patients, improved patient self-care and greater patient engagement (Mold, de Lusignan, & Sheikh, 2015). My Diabetes My Way (MDMW) is an online and mobile application designed and developed in 2008 as a diabetes self-management portal for NHS Scotland (Wake, He, Czesak, Mughal, & Cunningham, 2016). MDMW incorporates diabetes educational material (including physical activity), patient access to their health records (ePHR), patient support, goal setting advice, peer to peer support through social media and a remote glucose monitoring system. In 2010 patients were able to access their clinical health records via the Scottish government's "My Account" citizen portal. Patient data on the MDMW platform is extracted from SCI-Diabetes, which is a national disease registry for Scotland. Through MDMW patients can access information such as weight, blood pressure, blood glucose measured (Hb1Ac %), eye and foot screening results, medication, clinical letters and clinical appointments (Wake, He, Czesak, Mughal, & Cunningham, 2016). Figures 5 to 7 shows simulated examples of pages available on the MDMW platform (simulated patient).

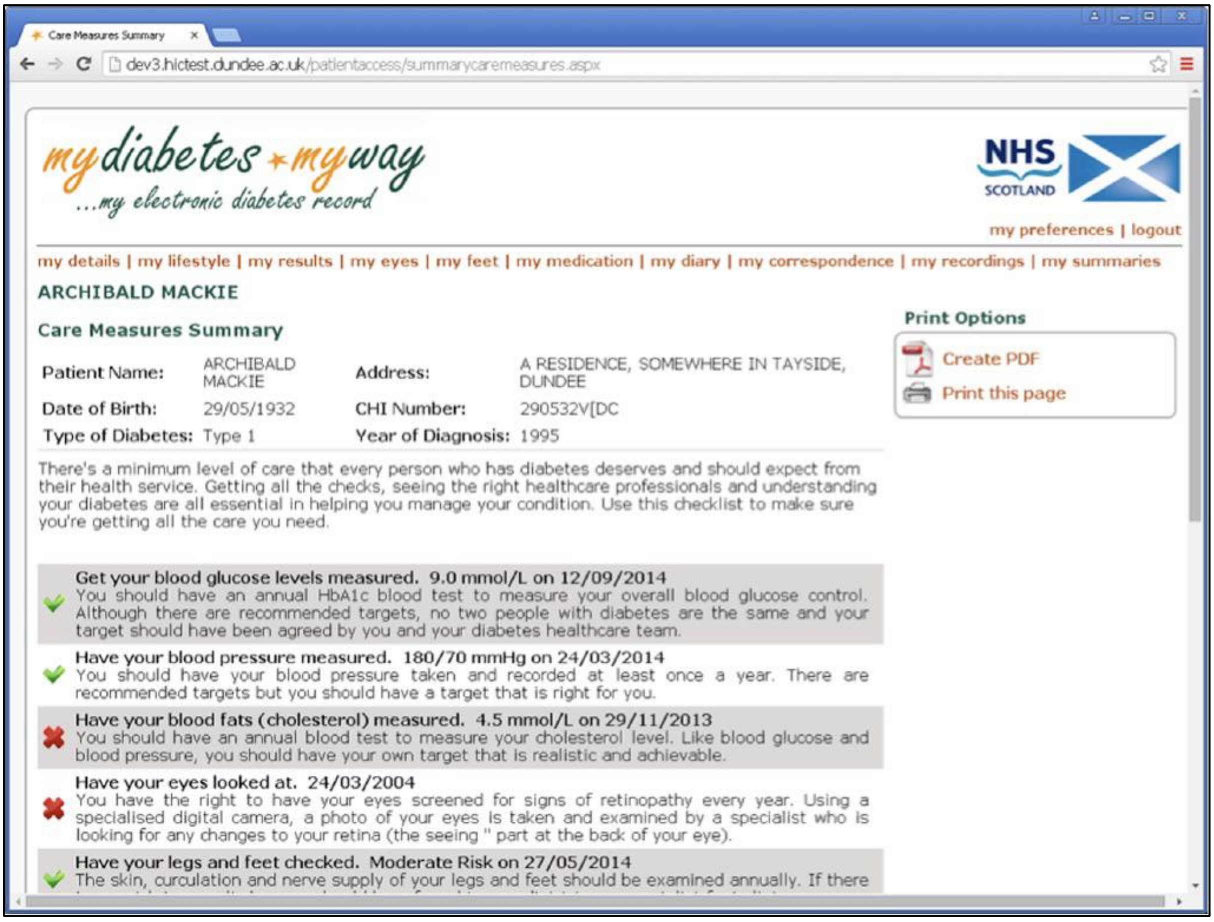

Figure 5: A simulated example of a page on the MDMW platform mapping an individual's (simulated patient) care parameters to a national standard (the Diabetes UK 15 care measures) *(Wake, He, Czesak, Mughal, & Cunningham, 2016).*

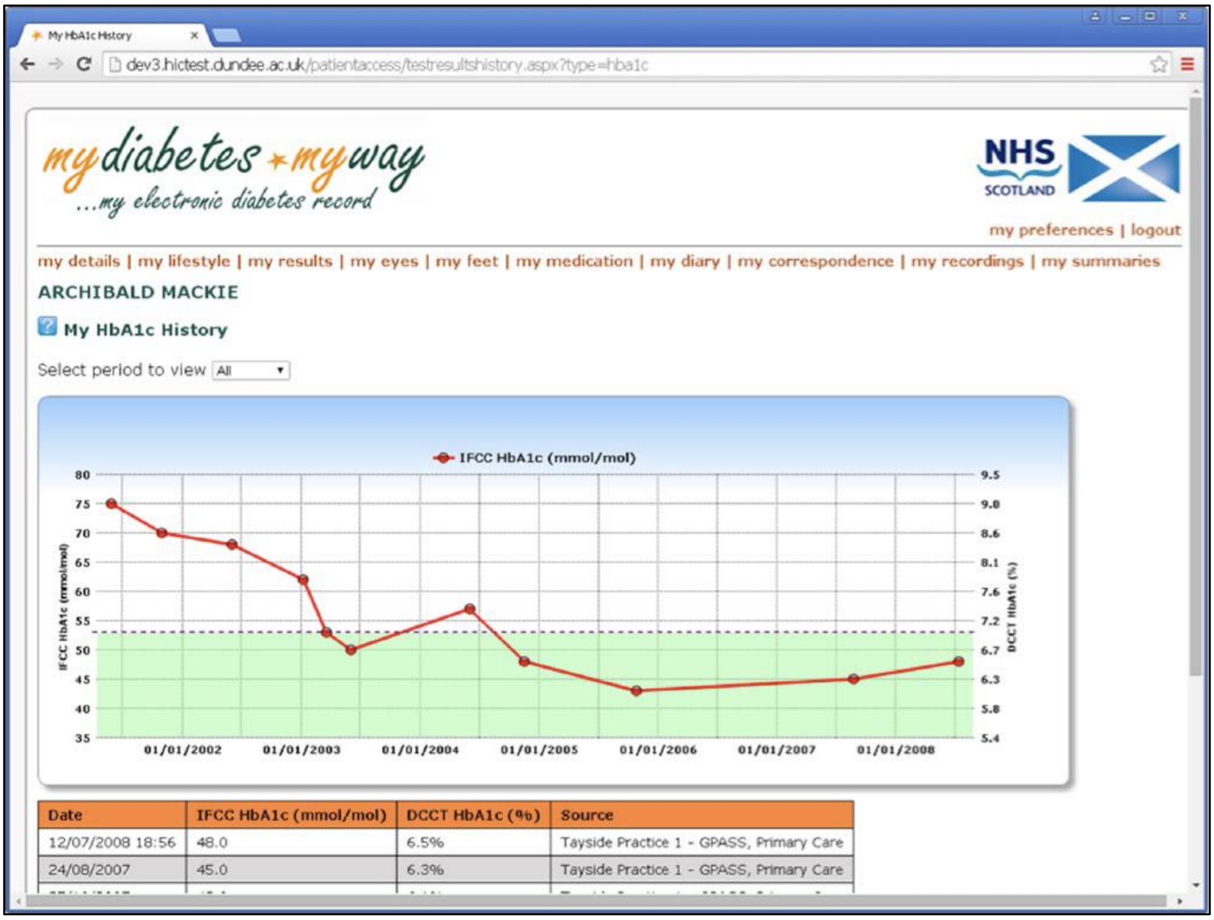

Figure 6: A simulated example of a page on the MDMW platform demonstrating a simulated patients HbA1c displayed in graphical format showing change over time and includes target ranges *(Wake, He, Czesak, Mughal, & Cunningham, 2016)*.

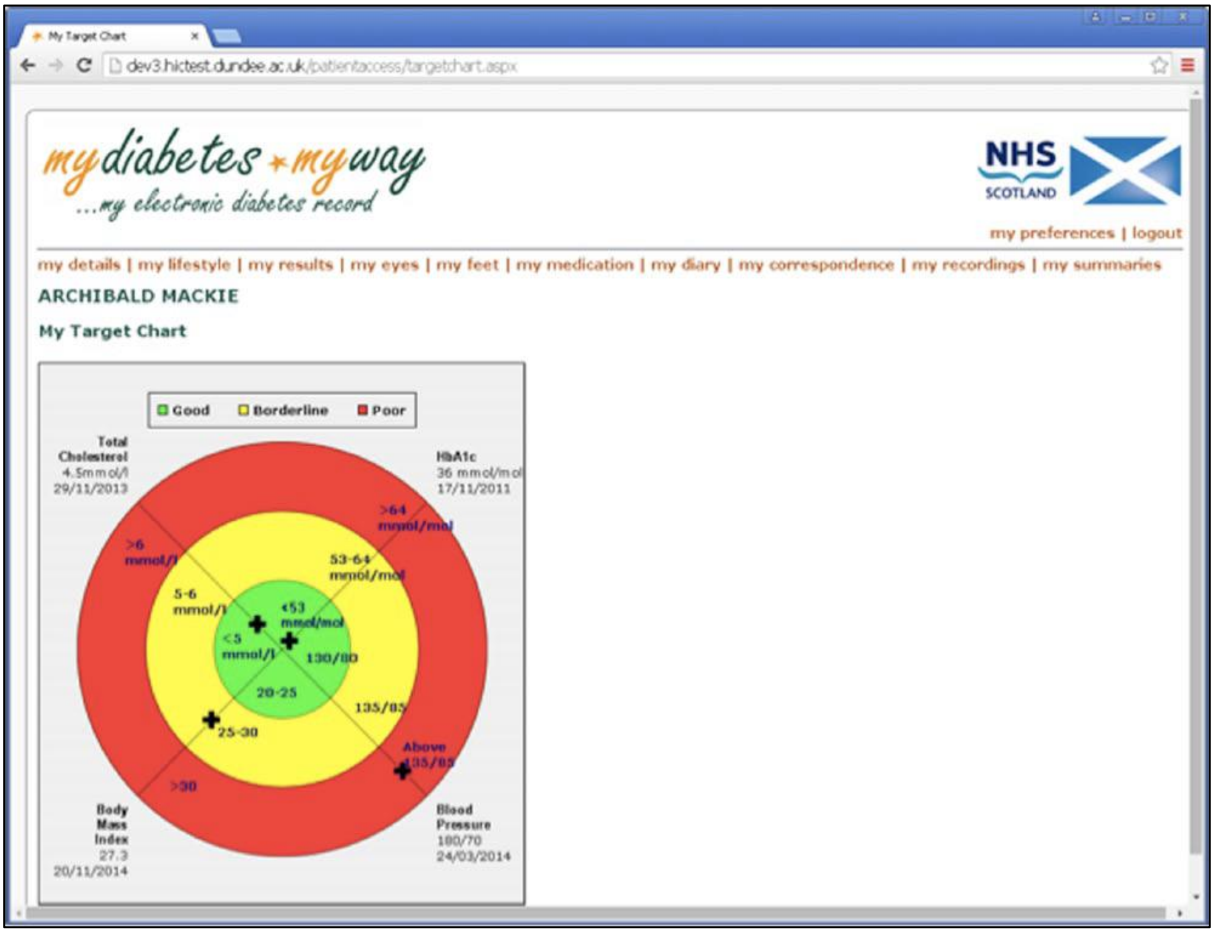

Figure 7: A simulated example of a page on the MDMW platform demonstrating a simulated patients data (HbA1c, cholesterol, blood pressure and BMI) displayed in a target format *(Wake, He, Czesak, Mughal, & Cunningham, 2016)*.

Importantly patients can also upload data onto the system themselves, such as blood glucose records, weight, blood pressure and smoking status (Wake, He, Czesak, Mughal, & Cunningham, 2016). In 2019, an interface was developed, which allowed patients to upload data from their personal Fitbit activity tracker to the MDMW platform, though at present the activity data is not being analysed by either the MDMW platform or healthcare professionals (Shields, Conway, Allardice, Wake, & Cunningham, 2023). The MDMW developers are planning to integrate algorithms, which will analyse the Fitbit data and provide the patient with physical activity feedback as part of their diabetes clinical care.

Longer term, other brands of consumer activity trackers will also be integrated with the MDMW platform (Shields, Conway, Allardice, Wake, & Cunningham, 2023). In a review examining the evolution of the MDMW platform feedback was obtained from patients. Users said that they seldom accessed the physical activity educational material available on the system (Shields, Conway, Allardice, Wake, & Cunningham, 2023).

At present it is estimated that in Scotland 267,615 adults are diagnosed with type 2 diabetes, yet only 32,000 (12%) are presently active users of the My Diabetes My Way platform (Shields, Conway, Allardice, Wake, & Cunningham, 2023). The MDMW system has also been expanded for use by the NHS in England. Further work is ongoing to expand the reach of the MDMW platform and the integration of consumer activity trackers for both patients and healthcare professionals. The platform has recently been rolled out in countries such as Belgium (Shields, Conway, Allardice, Wake, & Cunningham, 2023).

In conclusion, the MDMW platform provides information and support for adults diagnosed with or at risk of developing type 2 diabetes. Though this platform has been available since 2008, its reach could be improved both in respect of patients and healthcare professionals. By increasing the number of users, expanding the number of consumer activity trackers that can link into the system and providing patients with physical activity and sedentary behaviour advice from the uploaded activity data has the potential to significantly improve type 2 diabetes clinical care.

RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework

RE-AIM is an integrated framework developed to improve the adoption and sustainable implementation of evidence-based interventions in a wide range of health, public health, educational, community, and other settings. Glasgow, Vogt and Boles (1999) developed the RE-AIM framework as a planning and evaluation for health-related interventions. The framework comprises of 5 main dimensions: Reach, Effectiveness, Adoption, Implementation and Maintenance (Glasgow, Vogt, & Boles, 1999). This framework was chosen as both a planning and evaluation tool within this thesis. The rationale for its use are discussed below.

The majority of health-based research interventions are conducted in a controlled environment and tend to focus mainly on effectiveness outcomes. These interventions are seldom planned or evaluated through their transition from a research study into the real-world environment. As a result, many health-related interventions end up being expensive to implement, require intensive resources to run and are demanding upon both patients and healthcare providers. Other planning and evaluation frameworks are available, but these in summary tend to fail to measure the adoption of the intervention by a healthcare provider, how the intervention was implemented and the long-term maintenance of the programme (Glasgow, Vogt, & Boles, 1999). When compared with other frameworks and models for implementation and dissemination research, RE-AIM was described as; highly detailed, with step-by-step actions for completion of implementation and dissemination research processes; equally appropriate for disseminating evidence-based interventions to the target audience using planned strategies, as well as, implementing evidence-based interventions within diverse settings (Glasgow, Vogt, & Boles, 1999). Alternative frameworks and models include the PRECEDE-PROCEED Model, the Consolidated Framework for Implementation Research (CFIR), the Socio-Ecological Model (SEM), the Health Belief Model (MBM), the Logic Model and the Diffusion of Innovation Theory (Tabak, Khoong, Chambers, & Brownson, 2012). Compared to the PRECEDE-PROCEED Model the benefits of the RE-AIM framework are that it is more focused on the outcomes of the intervention, with clear criteria for evaluation, making it easier to quantify and assess the impact of health programmes. It is also quicker and simpler to implement compared to the step by step nature of the PRECEDE-PROCEED Model, which requires more detailed planning and data collection before the intervention. Compared to the Consolidated Framework for Implementation Research (CFIR) the RE-AIM framework is more practical and applicable to diverse settings, with its focus on the real world outcomes of the interventions, whereas the CFIR is more theoretical and focused on barriers and facilitators. Compared to the Socio-Ecological Model (SEM) and the Health Belief Model (HBM) the RE-AIM framework focuses on quantifiable measures of an interventions success, while the SEM and HBM tend to focus on psychological factors, though these can complement the RE-AIM framework if either is combined with it. The Logic Model is primarily a planning tool, whereas the RE-AIM framework is both a planning and evaluation tool that focuses on assessing the success and impact of health programmes. The Diffusion of Innovation Theory focuses mainly on the early phases of the adoption dimension and compared with the RE-AIM framework has less focus on the long term sustainability and effectiveness of interventions (Tabak, Khoong, Chambers, & Brownson, 2012).

Reach is set at an individual level (patient or employee) (Glasgow, Vogt, & Boles, Evaluating the public health impact of health promotion interventions: the RE-AIM framework, 1999).

It is described as ‘the absolute number, proportion, and representativeness of individuals who are willing to participate in a given initiative, intervention, or program, and reasons why or why not’ (RE-AIM, 2024). Most health promotion intervention studies report the size of the study sample and the proportion of individuals who are willing to participate. The proportion is calculated as the participation rate, which is calculated as those who participate divided by the total number of eligible individuals. Few studies report the representativeness of the study sample. Representativeness is defined as the similarity or differences between those who participate and those who are eligible but do not. If differences do exist, a given intervention may have a differential impact based on these variables that cannot be determined due to the lack of representativeness of the sample. If differences do not exist, then a stronger case for the generalisation of the intervention into real-world settings may be made. Comparisons should be made on basic demographic characteristics and, when possible, on primary outcomes (RE-AIM, 2024).

Effectiveness is set at an individual level just like reach (Glasgow, Vogt, & Boles, 1999). Effectiveness is described as the impact of an intervention on important individual outcomes, including potential negative effects, and broader impact on for example quality of life and economic outcomes; and variability across subgroups (RE-AIM, 2024). Within the RE-AIM framework, effectiveness is reflective of the success of an intervention when implemented as per intervention guidelines under optimal conditions or in real-world situations, respectively. When reporting on effectiveness, it is important to document the possible negative or unintended consequences of the intervention on quality of life and related factors. Few studies evaluate the potential negative or iatrogenic impacts of intervention. The determination of the effectiveness of an intervention is often finalised by examining the effect size associated with a given intervention and specified outcomes (RE-AIM, 2024).

Adoption is set at the organisation level (Glasgow, Vogt, & Boles, 1999). Adoption is described as 'the absolute number, proportion, and representativeness of settings and intervention agents (people who deliver the program) who are willing to initiate a program, and why' (RE-AIM, 2024). Adoption can have many levels. Because different settings (e.g., worksites, clinical care providers, schools, communities; governing agencies) and agents (e.g., teachers, doctors, health care professionals) can vary based on the number of resources, level of expertise, and commitment to intervention programs, understanding how adoption of interventions varies among settings and intervention agents is critical to the current and potential impact of an intervention. Except for the absolute number of settings involved, researchers seldom report on issues of adoption. As with reach, having information about representativeness unavailable is important. If differences do exist between participating sites or agents compared to those who do not, this is evidence of differential adoption. Comparisons should be made on basic information such as resource availability, setting size, location, and expertise (RE-AIM, 2024).

Implementation is set at the organisational level (Glasgow, Vogt, & Boles, 1999). Implementation is described as at the setting level, implementation refers to the intervention agents' fidelity to the various elements of an intervention's key functions or components, including consistency of delivery as intended and the time and cost of the intervention. Importantly, it also includes adaptations made to interventions and implementation strategies (RE-AIM, 2024). Implementation is assessed by reporting on what percentage of process objectives were achieved (e.g., what proportion of pamphlets were distributed, how many class hours were taught, or prescribed phone calls completed). Very few studies report costs or specific staff time commitments associated with intervention implementation. This information is very important for determining if others will attempt to try and implement an intervention (RE-AIM, 2024).

Maintenance is set at both the individual and organisational level (Glasgow, Vogt, & Boles, 1999). Maintenance is described as 'the extent, at the setting level, to which a program or policy becomes institutionalised or part of the routine organisational practices and policies'. Within the RE-AIM framework, maintenance also applies at the individual level. At the individual level, maintenance has been defined as the long-term effects of a program on outcomes after a program is completed. The specific time frame for assessment of maintenance or sustainment varies across projects (RE-AIM, 2024). Often intervention studies concentrate on reporting early findings related to their programs few provide information on the long-term follow up of study participants or program sustainability, particularly beyond 6 months (RE-AIM, 2024).

The main RE-AIM dimensions are supported by 28 identifiable indicators (Reach = 7, Effectiveness = 6, Adoption = 6, Implementation = 5, Maintenance = 4) (Macdonald, Janssen, Kirk, Patience, & Gibson, 2018). These specifically clarify the component elements for each dimension, which should be considered during the planning and evaluation of health interventions (Macdonald, Janssen, Kirk, Patience, & Gibson, 2018). Table 1 lists the indicators for each of the main RE-AIM dimensions (Macdonald, Janssen, Kirk, Patience, & Gibson, 2018).

Table 1: Indicators for each of the RE-AIM dimensions.

Main RE-AIM dimension	Indicator
Reach	1. Method used to identify the target population. 2. Inclusion criteria. 3. Exclusion criteria. 4. Use of qualitative methods to understand reach or recruitment. 5. Sample size. 6. Participation rate. 7. Sample representatives.
Effectiveness	1. Assessment of the effect on outcomes at shortest assessment point. 2. Imputation procedures reported (how missing data is processed. 3. The presence of quality-of-life measure. 4. Effects at longest follow-up. 5. Use of qualitative methods to understand outcomes. 6. Percent attrition or dropout rate.
Adoption	1. Method of identifying target agent. 2. Level of expertise of delivery agents. 3. Inclusion and exclusion criteria for target agent. 4. The adoption rate. 5. Comparison of settings/participants of adoption v non-adoption settings. 6. Use of qualitative methods to understand either adoption at setting or staff participation.
Implementation	1. The intervention type (individual component v multi-component). 2. Intensity (components of intervention). 3. The extent the protocol was delivered as intended. 4. A measure of cost. 5. Use of qualitative methods to understand the implementation of the study.
Maintenance	1. Was an individual's behaviour assessed at least six months

	following completion of the intervention. 2. Is the program still in place. 3. Was the program modified. 4. Use of qualitative methods to understand the long-term effects.

The RE-AIM framework continues to evolve as an evaluation tool. Practitioners are encouraged to adapt, expand, test empirically and apply RE-AIM in new ways across new settings and populations (Holtrop, et al., 2021). The RE-AIM framework can be used in conjunction with other frameworks. For example, RE-AIM can be used in conjunction with the Consolidated Framework for Implementation Research to evaluate in detail the dimension of implementation (King, et al., 2020). Before using the RE-AIM framework practitioners are encouraged to familiarise themselves with each dimension, any updates to the framework and any adaptions to its use (Holtrop, et al., 2021).

The RE-AIM framework was chosen for use throughout this PhD after being compared against alternative evaluation and planning tools such as the Consolidated Framework (King, et al., 2020). The main advantages of using the RE-AIM framework were identified as:

1. **Comprehensive Evaluation** (King, et al., 2020)
    a. **RE-AIM:** It evaluates interventions across five dimensions, providing a holistic understanding of the intervention’s impact, from the initial reach to long-term maintenance.
    b. **Other tools:** Other evaluation tools focus primarily on outcomes or process measures without considering broader implementation factors.

2. **Focus on Real-World Effectiveness** (King, et al., 2020)
    a. **RE-AIM:** Emphasises external validity and generalisability by considering how interventions perform across diverse settings and populations.
    b. **Other tools:** Many tools focus mainly on efficacy under controlled conditions, potentially missing insights about how interventions perform in real-world environments.

3. **Sustainability and Long-Term Impact** (King, et al., 2020)
    a. **RE-AIM:** One of its core dimensions is Maintenance, which assesses both the long-term sustainability of the intervention and its continued effectiveness over time.
    b. **Other tools:** Other frameworks or tools tend to not give adequate attention to long-term sustainability, which is critical for public health interventions.

4. **Practicality and Feasibility** (King, et al., 2020)
    a. **RE-AIM:** It is designed to be applicable in both research and practice, meaning that its criteria are useful for both evaluating the scientific rigour and the practical feasibility of an intervention.
    b. **Other tools:** Other frameworks tend to be more research-focused and fail to address practical concerns such as how an intervention can be sustained or scaled.

5. **Focus on Equity** (King, et al., 2020)

a. **RE-AIM:** The Reach component considers how well the intervention targets diverse populations, ensuring that vulnerable or underserved groups are included.
b. **Other tools:** Other tools tend to not fully capture the equity dimension, potentially overlooking disparities in how different populations are reached or affected by an intervention.

6. **Flexibility for Different Contexts** (King, et al., 2020)
   a. **RE-AIM:** Its framework is adaptable to a wide variety of intervention types, from community-based programs to healthcare settings, and it works in multiple contexts such as policy, individual behaviour change, or healthcare systems.
   b. **Other tools:** Other evaluation tools tend to be more specialised, limiting their applicability to certain types of interventions or settings.

7. **Encourages a Systems Perspective** (King, et al., 2020)
   a. **RE-AIM:** It takes a systems-level approach by considering not only individual-level outcomes but also organisational and environmental factors that influence intervention success.
   b. **Other tools:** Many other frameworks focus more narrowly on individual behaviours or specific outcomes without considering the broader systems involved in intervention delivery and sustainability.

8. **Actionable Insights for Decision Making** (King, et al., 2020)

a. **RE-AIM:** It provides actionable insights that are useful for stakeholders, policymakers and practitioners to improve the intervention's design, reach, and effectiveness.
b. **Other tools:** Some frameworks lack the actionable dimensions needed to inform real-world decisions and improvements in ongoing programs.

In summary, the RE-AIM framework stands out because of its holistic, practical, and comprehensive approach, making it an effective tool for assessing the effectiveness and sustainability of public health interventions in a variety of real-world contexts.

In summary, consumer activity tracker interventions within controlled research environments have been shown to improve metabolic factors, increase levels of physical activity and reduce sedentary behaviour in adults. For those diagnosed with type 2 diabetes blood glucose levels and insulin sensitivity have been found to improve.

Summary

The introduction highlighted the growing number of adults diagnosed or at risk of developing type 2 diabetes. In addition to the impact on the health of these adults, this is placing limited healthcare resources under greater strain. Increasing levels of physical activity and reducing sedentary behaviour can improve metabolic factors in adults diagnosed with the disease and reduce the risk of developing type 2 diabetes. Physical activity interventions which combine behavioural change programmes and incorporate the use of consumer activity trackers have been shown to reduce blood glucose levels, increase physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes.

Though these benefits to patient health have been well researched the routine use of activity trackers in clinical type 2 diabetes health care has failed to materialise.

Thesis Aim

This PhD thesis aimed to investigate the integration of activity trackers into clinical care to support physical activity and reduce sedentary behaviour in adults diagnosed with or at risk of type 2 diabetes.

Through the PhD research projects (Chapters 2-4) the following research questions have been addressed to achieve the overall aim of the thesis:

Chapter 2

1. What are the reported gaps in the 5 main RE-AIM dimensions (reach, effectiveness, adoption, implementation, maintenance) in interventions that used activity trackers in the clinical care of adults diagnosed with a chronic disease?

Chapter 3

1. What are the views of adults diagnosed with type 2 diabetes and health care professionals on the integration of activity trackers into type 2 diabetes clinical care?

Chapter 4

1. What is the feasibility of integrating activity trackers into an established weight management intervention to support physical activity in adults at risk of or with type 2 diabetes?

Structure of Thesis

This thesis consists of three studies (Chapters 2-4). Each of these chapters includes a preface section, which is followed by a manuscript of the specific PhD study undertaken. In the preface sections of each chapter, the study will be introduced by providing the reader with the rationale and background information needed to contextualise the study. A full list of references is provided in the reference section. Each of the 3 studies have been written for publication and in the format and structure recommended by the specific peer-reviewed journal. Chapter 2 has been peer reviewed and published in the Journal of Medical Internet Research. Chapter 3 has been peer reviewed and published in the Journal of Medical Internet Research Diabetes. Chapter 4 will be submitted to the Journal of Medical Internet Research Diabetes for peer review and consideration for publication.

Chapter 2

RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) evaluation of the use of activity trackers in the clinical care of adults diagnosed with a chronic disease: Integrative Systematic Review

Preface

Following on from Chapter 1 the author set out in the first instance, through Study 1 (an integrative systematic review), to develop a greater understanding of the use of activity trackers in the clinical care of adults diagnosed with a chronic disease. The RE-AIM framework was utilised to evaluate the 5 main dimensions (Reach, Effectiveness, Adoption, Implementation, and Maintenance) reported in the reviews identified studies (Glasgow, Vogt, & Boles, 1999). The RE-AIM framework was chosen by the author because it is a practical, outcome focused framework for evaluating public health interventions across 5 main dimensions. It is particularly valuable for practitioners who need to assess and compare the real world impact and sustainability of interventions. Compared to other frameworks like the PRECEDE-PROCEED model and the Consolidated Framework for Implementation Research (CFIR), which focus more on process and planning, RE-AIM provides a simplified but comprehensive approach to measuring success and long-term impact. It's also more directly applicable to a broad range of interventions, including those addressing individual, organisational, and societal levels, which makes it versatile across various contexts and settings (Tabak, Khoong, Chambers, & Brownson, 2012). With guidance from his supervisors (Dr Alison Kirk, Dr Marilyn Lennon, Dr Xanne Janssen), on how best to undertake an integrative systematic review the author led this study throughout. The author chose an integrative systematic review as this combines and synthesises various forms of research evidence in a systematic manner (Whittemore & Knafl, 2005). It typically focuses on integrating studies from different methodologies or disciplines (qualitative, quantitative, and/or mixed methods) (Whittemore & Knafl, 2005). This approach aimed to provide a comprehensive understanding of the specific research topic, which would form the building blocks for the PhD. As this was the first systematic review undertaken by the author, correct procedures were identified for how to conduct the review. In this instance, the review was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis 2020 (PRISMA) statement (Page, et al., 2021). Initially, the author set out the inclusion/exclusion within a PICOS and SPIDER statement and the protocol was registered in the PROSPERO International Prospective Register of Systematic Reviews (Page, et al., 2021). Undertaking these stages allowed the author to identify and focus on the specific search criteria for the review. To develop the appropriate search criteria and search methods, the author sought guidance from both the University librarian and the PhD supervisors. This led to the development of both the search strategy and the identification of appropriate search engines. The author developed new skills with respect to the search formula to be used in each search engine. On running each search, identified articles were initially uploaded by the author onto EndNote and duplicates were removed. The author had previous experience with the screening process using both the Covidence and Rayyan systems, but due to the costs involved in accessing the Covidence system, the Rayyan screening platform was chosen for this stage of the review. With assistance from the co-authors (Eilidh Russell, Carolina Wani, Dina Eskandarani) the identified journal articles were screened through the topic, title and abstract, and finally full text. Working as a team, but led by the author all conflicts were resolved and quality checked by the PhD supervisors. Through further research, the author identified a validated RE-AIM extraction tool in Microsoft Excel format

(Harden, et al., 2015) (Allen, Zoellner, Motley, & Estabrooks, 2011) (Estabrooks, Dzewaltowski, Glasgow, & Klesges, 2002). The author utilised this to identify the main RE-AIM dimensions and 28 supporting indicators within each of the final identified journal articles. Though this process was undertaken fully by the author, the PhD supervisors assisted with quality checks to reduce any bias within this process. From this, the author was able to identify the underreporting of the main RE-AIM dimensions, which acted as a strong basis for the design of paper 2 and the methods to be utilised. Paper 1 was subsequently submitted by the author for peer review in the Journal of Medical Internet Research and this was published.

Paper 1

RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) evaluation of the use of activity trackers in the clinical care of adults diagnosed with a chronic disease: Integrative Systematic Review

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Tables: 11

Figures: 1

Appendices: 1

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Abstract

Background: Chronic diseases are a leading cause of adult mortality, accounting for 41 million deaths globally each year. Low levels of physical activity and sedentary behaviour are major risk factors for adults to develop a chronic disease. Physical activity interventions can help support patients in clinical care to be more active. Commercial activity trackers that can measure daily steps, physical activity intensity, sedentary behaviour, and distance moved are being more frequently used within health-related interventions. The RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) framework is a planning and evaluation approach to explore the reach, effectiveness, adoption, implementation, and maintenance of interventions.

Objective: The objective of this study is to conduct an integrative systematic review and report the 5 main RE-AIM dimensions in interventions that used activity trackers in clinical care to improve physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases.

Methods: A search strategy and study protocol were developed and registered on the PROSPERO platform. Inclusion criteria included adults (18 years and older) diagnosed with a chronic disease and have used an activity tracker within their clinical care. Searches of 10 databases and grey literature were conducted, and qualitative, quantitative, and mixed methods studies were included. Screening was undertaken by more than 1 researcher to reduce the risk of bias. After screening, the final studies were analysed using a RE-AIM framework data extraction evaluation tool. This tool assisted in identifying the 28 RE-AIM indicators within the studies and linked them to the 5 main RE-AIM dimensions.

Results: The initial search identified 4585 potential studies. After a title and abstract review followed by full-text screening, 15 studies were identified for data extraction. The analysis of the extracted data found that the RE-AIM dimensions of adoption (n=1, 7% of studies) and maintenance (n=2, 13% of studies) were underreported. The use of qualitative thematic analysis to understand the individual RE-AIM dimensions was also underreported and only used in 3 of the studies. Two studies used qualitative analysis to explore the effectiveness of the project, while 1 study used thematic analysis to understand the implementation of an intervention.

Conclusions: Further research is required in the use of activity trackers to support patients to lead a more active lifestyle. Such studies should consider using the RE-AIM framework at the planning stage with a greater focus on the dimensions of adoption and maintenance and using qualitative methods to understand the main RE-AIM dimensions within their design. These results should form the basis for establishing long-term interventions in clinical care.

KEYWORDS

activity trackers; clinical care; physical activity; sedentary behaviour; adults; chronic diseases; Reach, Effectiveness, Adoption, Implementation, and Maintenance; RE-AIM; mortality; sedentary lifestyle; intervention; mobile phone

Introduction

Noncommunicable diseases, also referred to as chronic diseases, are a major cause of premature death. They include cardiovascular disease, chronic respiratory disease, cancer, and diabetes mellitus. It is estimated that globally 41 million people die each year from chronic diseases, and this accounts for 71% of all deaths worldwide (World Health Organization, 2021). Major risk factors for the development of chronic diseases are low levels of physical activity and high levels of sedentary behaviour (Department of Health and Social Care, 2019). It is estimated that globally 23% of adults are failing to achieve the recommended physical activity guidelines set by the World Health Organization (World Health Organization, 2021). The adult guidelines recommend 150 minutes of moderate to vigorous intensity physical activity per week, undertake muscle exercises at least 2 days per week, and reduce sedentary time (World Health Organization, 2018).

Physical activity interventions have been developed in an effort to encourage individuals to be more active within both primary health care and community-based settings (Westland, et al., 2019). Activity trackers, such as Fitbit (Fitbit), Polar (Polar Electro), and Garmin (Garmin Ltd), which can monitor and provide feedback on steps, physical activity intensity, distance moved, and sedentary behaviour, can support patients in leading a more active lifestyle and could be a cost-effective public health intervention (Vaes, et al., 2013).

During test and retest trials, activity trackers and pedometers were found to be valid and reliable methods of measuring steps (Misfit Shine, Withings Pulse, Fitbit Zip, and Digiwalker) (Kooiman, et al., 2015). Fitbit's (Ultra, One, Zip, Flex, Force, Charge, Charge HR, and Surge), for example, have been shown to have high interdevice reliability in respect of distance moved, steps, and energy expenditure (Evenson, Goto, & Furberg, 2015). A recent systematic review highlighted that the use of activity trackers by patients diagnosed with a chronic disease (chronic respiratory disease, type 2 diabetes, and cardiovascular disease) would significantly increase the number of daily steps taken (2123) and decrease a patient's systolic blood pressure (–3.79 mm Hg), waist circumference (–0.99 cm), and low-density lipoprotein cholesterol concentration (–5.70 mg/dL) (Franssen, Franssen, Spaas, Solmi, & Eijnde, 2020).

Interventions involving changes in lifestyle such as increased physical activity, reduction in sedentary time, and weight loss can significantly reduce the risk of adults developing chronic diseases and related health complications. Weight loss programs involving dietary and physical activity education coupled with the use of an activity tracker have been shown to significantly reduce the weight of participants (Westland, et al., 2019).

While many studies involving public health interventions focus on effect and efficacy, these fail to fully evaluate the impact of such research when applied to real-world settings. The RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) framework was developed as both a planning and evaluation tool aimed at understanding the full impact of a public health intervention and how this could best be introduced into patient health care (Glasgow, Vogt, & Boles, 1999). The framework comprises 5 main dimensions: Reach, Effectiveness, Adoption, Implementation, and Maintenance. Reach seeks to measure the proportion of the targeted population who took part in the intervention. Effectiveness aims to understand the success of the intervention. Adoption covers the number of settings, practices, and plans that will engage with the intervention. Implementation looks at how the intervention was applied in practice. Maintenance seeks to understand the long-term viability of the project (Glasgow, Vogt, & Boles, 1999). Each dimension should be considered when planning or evaluating a public health intervention. The main dimensions are subsequently subdivided into indicators that facilitate a detailed evaluation of each dimension (Glasgow, Vogt, & Boles, 1999). Though each dimension should be considered at the planning stage of an intervention, it is not imperative to report in detail all components. Greater focus on those applicable to the individual study or clinical organization has been shown to improve the translation from research into practical health care, which has proved to be a barrier in the past (Glasgow, Vogt, & Boles, 1999).

The aim of this integrative systematic review was to comprehensively explore the reporting of the reach, effectiveness, adoption, implementation, and maintenance of using activity trackers in clinical care to support physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases. The integrative methodology allows for the review of quantitative, qualitative, and mixed methods research while developing a comprehensive understanding of the RE-AIM elements reported and the particular health care problem under review (Whittemore & Knafl, 2005).

Methods

Study Design

The protocol (Appendix A) for this integrative systematic review was registered in the PROSPERO international prospective register of systematic reviews on March 23, 2022 (CRD42022319635). The review was undertaken in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) 2020 statement (Page, et al., 2021). All published papers in English between 2015 and 2022 were included.

Eligibility Criteria

Table 2 provides a summary of the inclusion criteria using PICOS (population, intervention type, and comparator, outcomes of interest and study type) for quantitative studies and SPIDER (sample, phenomenon of interest, study design, evaluation, and research type) for qualitative studies.

Table 2: Inclusion criteria based on PICOS (population, intervention type, comparisons, outcomes of interest, and study type) and SPIDER (sample, phenomenon of interest, study design, evaluation, and research type).

PICOS table

- Population: Adults (18 years and older) diagnosed with a chronic disease
- Intervention type: Individual or combined use of an activity tracker within outpatient clinical care
- Comparisons: All control or comparison groups
- Outcomes of interest: RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) dimensions of using an activity tracker within outpatient clinical care
- Study type: Intervention or experimental and observational

SPIDER table

- Sample: Adults (18 years and older) diagnosed with a chronic disease, and adult (18 years and older) health care professionals working within a clinical capacity
- Phenomenon of interest: Experiences of using an activity tracker within outpatient clinical care
- Study design: Qualitative and mixed methods

- Evaluation: RE-AIM dimensions of using an activity tracker within outpatient clinical care
- Research type: Qualitative and mixed methods (qualitative and quantitative)

Search Strategy and Information Sources

A detailed search strategy (Appendix B) was developed, with guidance from a qualified University librarian, around the core themes and RE-AIM dimensions. The key search words are displayed in Table 3. These were developed around the key original terms, activity trackers, clinical care, physical activity, sedentary behaviour, adults, chronic diseases, and RE-AIM.

Table 3: Key search words focusing on the core themes and RE-AIM dimensions.

Original term	Broader terms
Activity trackers	Activity monitor, wearable technology, wearable device, eHealth, mHealth, fitness tracker, fitness device, digital intervention, digital tracker, digital monitor, digital device, wearable activity tracker, pedometer, accelerometer, step counter
Clinical care	Health care, healthcare, primary care, outpatient, out-patient, clinical practice, public health, clinical, care, health promotion
Physical activity	Physical fitness, active lifestyles, fitness, physical health, activity, exercise, intervention
Sedentary behaviour	Sedentary, sedentary time, sitting time, sitting, sitting behaviour, screen time, screen based, chair based, deskbound, physical inactivity, inactive lifestyle, lack of activity
Adult	Adult, adults

Chronic diseases	Chronic illness, noncommunicable disease, noncommunicable, non-communicable, chronic disease, chronic, illness, disease
RE-AIM	Validity, external validity, behaviour change, policy change, community change, participation, quality of life, reach, influences, effectiveness, success, usefulness, efficacy, adoption, acceptance, maintenance, preservation, acceptability, rate, appraise, analysis, implement*, implementation, deliver

The study searches were undertaken on the computer-based databases: Web of Science—Core Collection (all editions; Clarivate), MEDLINE (ProQuest; ProQuest), ACM (Digital Library; ACM Digital Library), APA PsycINFO (EBSCO), Cochrane Library (Cochrane), MEDLINE (Ovid, Embase, and Embase Classic; Medline), and grey literature (GreyNet; GreyNet International), CORE (Core), OAlster and WorldCat.org (oclc), and Open Access Thesis and Dissertations (OATD)).

Screening Process

Papers identified during the search phase were initially uploaded onto EndNote (Clarivate). Duplicates were identified and removed. Papers were subsequently uploaded onto the Rayyan (Rayyan Systems Inc) collaborative systematic review screening system. All remaining papers were screened on the Rayyan system by 4 authors (WH, ER, CW, and DE) based on the topic, title, and abstract. Last, a full-text screening of the remaining papers was conducted by 2 authors (WH and ER). Conflicts were resolved at each stage through discussion between the screening authors without the need for an independent review.

Data Extraction

The final papers identified for review were uploaded onto a validated RE-AIM extraction Microsoft Excel spreadsheet (Appendix C). This spreadsheet was developed by combining 2 validated RE-AIM extraction tools, and it contains details of each paper, the 5 main RE-AIM dimensions (Reach, Effectiveness, Adoption, Implementation, and Maintenance), and 28 RE-AIM indicators (Harden, et al., 2015) (Allen, Zoellner, Motley, & Estabrooks, 2011) (Estabrooks, Dzewaltowski, Glasgow, & Klesges, 2002). The identified papers were screened, and data were extracted by the main author (WH). This data extraction was quality-checked by 3 authors (AK, XJ, and ML), who reviewed 2 separate papers each. Conflicts were resolved through discussion between all data extraction authors.

Data Items

Basic participant demographic details were extracted from each paper including number of participants, mean age, and gender. Each of the 5 main RE-AIM dimensions is supported by identifiable indicators (Reach: n=7, Effectiveness: n=6, Adoption: n=6, Implementation: n=5, and Maintenance: n=4) (Harden, et al., 2015) (Allen, Zoellner, Motley, & Estabrooks, 2011) (Estabrooks, Dzewaltowski, Glasgow, & Klesges, 2002). The main RE-AIM dimensions and supporting indicators are displayed in Table 4.

Table 4: Main RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) dimensions and supporting indicators.

Reach

- Method used to identify the target population
- Inclusion criteria
- Exclusion criteria
- Use of qualitative methods to understand reach or recruitment
- Sample size
- Participation rate
- Sample representatives

Effectiveness

- Assessment of the effect on outcomes at the shortest assessment point
- Imputation procedures reported (how missing data are processed)
- The presence of quality-of-life measure
- Effects at the longest follow-up
- Use of qualitative methods to understand outcomes
- Percent attrition or dropout rate

Adoption

- Method of identifying target agent
- Level of expertise of delivery agents
- Inclusion and exclusion criteria for target agent
- The adoption rate
- Comparison of settings or participants of adoption versus nonadoption settings
- Use of qualitative methods to understand either adoption at the setting level or staff participation

Implementation

- The intervention type (individual component vs multicomponent)
- Intensity (components of intervention)
- The extent the protocol was delivered as intended
- A measure of cost
- Use of qualitative methods to understand the implementation of the study

Maintenance

- Was an individual's behavior assessed at least 6 months following completion of the intervention
- Is the program still in place
- Was the program modified
- Use of qualitative methods to understand the long-term effects

Each identified journal paper was screened as previously described, and the reporting of each RE-AIM indicator was recorded on the RE-AIM data extraction sheet. The percentage of papers reporting the individual indicator was calculated.

Study Risk of Bias Assessment and Reporting Bias Assessment

As the RE-AIM framework is an evaluation tool designed to identify and focus on the reporting of recommended dimensions and indicators within interventions, no additional risk of bias assessment was conducted (Allen, Zoellner, Motley, & Estabrooks, 2011).

Outcome Measures

The total percentage of individual RE-AIM indicators reported from all journal papers was the main outcome measure.

Results

Overview

The search strategy identified 5619 potential studies for further analysis. After checking for duplicates, the number of eligible studies was reduced to 4585. After the topic, title, and abstract screening process, 63 studies were eligible. Full-text screening reduced this number to 15 studies for final analysis. Figure 8 provides an overview of the screening process and the number of studies at each stage. The final 15 studies were published between 2016 and 2022 and from Australia (n=1), Spain and the Netherlands (n=1), Spain (n=2), the United States (n=7), Canada (n=3), and Taiwan (n=1). The studies included involved the following chronic diseases: lower back pain (n=1), cardiovascular disease (n=2), hemophilia (n=1), colorectal cancer (n=1), breast cancer (n=1), stroke (n=2), type 2 diabetes (n=2), inflammatory arthritis (n=1), kidney disease (n=3), and serious mental illness (n=1).

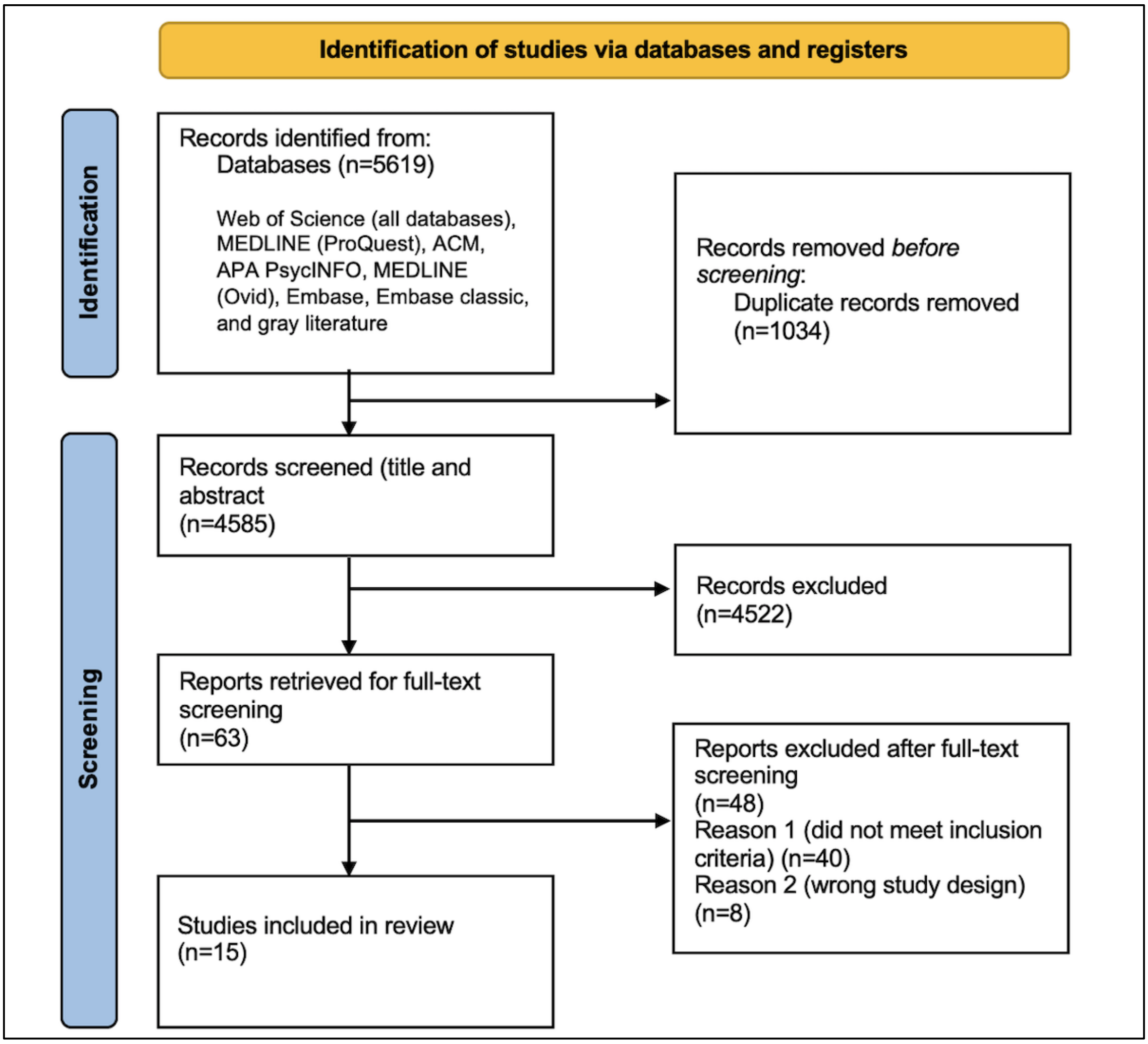

Figure 8: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) showing the study screening process and numbers identified at each stage *(Page, et al., 2021)*.

The characteristics (author, country, topic area, number of participants, mean age of participants, chronic diseases studied, activity tracker, study duration, and study design) of the 15 studies are reported in Table 5. Context summary of activity tracker use in studies are reported in Table 6.

Table 5: Characteristics of studies.

Study Number	Author and Year of Study	Country	Topic Area	Number of Participants (n)	Mean Age of Participants (years ± SD)	Chronic Disease Studied	Activity Tracker	Study Duration	Study Design
1	Amorin 2019	Australia	Physical activity	n = 60	58.4 ± SD 13.4	Chronic lower back pain	Fitbit (model not reported)	6-months	Randomised control trial
2	Broers 2019	Spain and Netherlands	Physical activity	n = 150	61.1 ± SD 9.6	Cardiovascular disease	Fitbit Charge HR	6-months	Randomised control trial
3	Carrasco 2019	Spain	Physical activity	n = 26	37.2 ± SD 11.1	Haemophilia	Fitbit Flex	13-weeks	Observational study
4	Van Blarigan 2019	USA	Physical activity	n = 42	54.0 ± SD 8.9	Colorectal cancer	Fitbit Flex	12-weeks	Randomised control trial
5	Grau-Pellicer 2020	Spain	Physical activity	n = 41	64.6 ± SD 11.9	Stroke	Fitlab	8-weeks	Randomised unblinded trial
6	Jiwani 2022	USA	Physical activity	n = 20	67.8 ± SD 5.3	Type 2 diabetes	Fitbit (model not reported)	6-months	Single-arm study
7	Li 2020	Canada	Physical activity	n = 118	53.5 ± SD 14.7	Rheumatoid arthritis	Fitbit Flex 2	27-weeks	Randomised control trial
8	Li 2020	Taiwan	Physical activity	n = 60	51.2 ± SD 11.0	Kidney disease	Heart rate smart wristband (make and	90-days	Randomised control trial

							model not reported)		
9	McNeil 2021	Canada	Physical activity	n = 45	51.2 ± SD 9.0	Breast cancer	Polar M400 and A360	12-weeks	Randomised control trial
10	Naslund 2016	USA	Physical activity	n = 34	50.2 ± SD 11.0	Mental illness	Fitbit Zip	6-months	Exploratory study
11	O'Brien 2020	USA	Physical activity	n = 60	65.7 ± SD 4.9	Kidney disease	Fitbit Charge 2	6-months	Pilot feasibility study
12	Park 2021	USA	Physical activity	n = 60	68.0 ± SD 9.3	Cardiac rehabilitation	Fitbit Charge 2	3-months	Randomised control trial
13	Sheshadri 2020	USA	Physical activity	n = 60	58.0 ± SD 6.3	Kidney disease	Pedometer (make and model not reported)	6-months	Randomised control trial
14	Wamg 2018	USA	Physical activity	n = 26	56.4 ± SD 7.5	Type 2 diabetes	Pedometer (make and model not reported)	6-months	Pilot comparative trial
15	Ezeugwu 2018	Canada	Sedentary time and physical activity	n = 34	64.6 ± SD 12.5	Stroke	Misfit Flash	8-weeks	Single-group intervention study

Table 6: Context summary of activity tracker use in studies.

Study number	Author and year of study	Summary of activity tracker use in the study
1	(Amorim, et al., 2019)	The intervention group received a physical activity information booklet plus 1 face-to-face and 12 telephone-based health coaching sessions. The intervention was supported by a web-based application and an activity tracker (Fitbit).
2	(Broers, et al., 2020)	Participants were provided with information, during a cardiac outpatient visit, on how to use a Fitbit activity tracker, Beddit 3 sleep monitoring tracker, and Careportal-linked blood pressure monitor.
3	(Carrasco, et al., 2019)	This study aimed to monitor daily physical activity and analyze its evolution over time in a cohort of persons with hemophilia using a commercial activity tracker. In addition, the relationship between physical activity levels, demographics, and joint health status, as well as the acceptance and adherence to the activity tracker were measured.
4	(Van Blarigan, Van Loon, Kenfield, Chan, & Mitchell, 2019)	Participants who had completed curative-intent treatment for colorectal cancer completed a 3-month physical activity intervention using a Fitbit activity tracker and daily SMS text messages.
5	(Grau-Pellicer, Lalanza, Jovell-Fernández, & Capdevila, 2020)	Chronic stroke survivors were randomized into an intervention group and a control group. Participants in the intervention group were engaged in the multimodal rehabilitation program that consisted of supervising adherence to physical activity through a mobile health app and participating in an 8-week rehabilitation program that included aerobic, task-oriented, balance, and stretching exercises. The control group received a conventional rehabilitation program. Participants' physical activity was measured using a Fitlab activity tracker.
6	(Jiwani, et al., 2022)	Overweight older adults with self-reported type 2 diabetes were provided with a Fitbit activity tracker for self-monitoring of diet and physical activity. Additionally, they attended weight management sessions.
7	(Li, et al., 2020)	Participants with rheumatoid arthritis or systemic lupus erythematosus received education and counseling from a

		physical therapist, used a Fitbit and a web application to obtain feedback about their physical activity, and received 4 follow-up calls from the physical therapist.
8	(Li, et al., 2020)	Participants with chronic kidney disease were enrolled in the intervention group and control group. All participants were provided with wearable devices (make and model not reported) that collected exercise-related data. All participants maintained dietary diaries using a smartphone app. All dietary and exercise information was then uploaded to a health management platform. Suggestions about diet and exercise were provided to the intervention group only, and a social media group was created to inspire the participants in the intervention group.
9	(McNeil, et al., 2022)	Participants were randomized to a 12-week, home-based lower or higher intensity physical activity intervention or no intervention control group. Both intervention groups received a Polar A360 activity tracker. Study outcomes were assessed on a weekly basis with the activity tracker and included relative adherence to the prescribed physical activity.
10	(Naslund, et al., 2016)	Participants diagnosed with a serious mental health disorder were enrolled in a physical activity intervention. The behavioral change program was supported using a Fitbit activity monitor for measuring daily steps.
11	(O'Brien, et al., 2020)	Participants diagnosed with chronic kidney disease were enrolled in a feasibility study that incorporated the use of a behavioral change application and Fitbit activity tracker to help achieve daily step goals.
12	(Park, et al., 2021)	During the final week of outpatient cardiac rehabilitation, participants were randomized to an intervention group or usual care. The intervention group downloaded a motivational mobile app, received supportive push-through messages on motivation and educational messages related to cardiovascular disease management, and wore a Fitbit activity tracker to track step counts. Participants in the usual care group wore a pedometer and recorded their daily steps in a diary.
13	(Sheshadri, Kittiskulnam, Lazar, & Johansen, 2020)	The intervention consisted of providing participants with pedometers in conjunction with weekly semi scripted counseling sessions in which a member of the study team called the participant. Participants were asked to wear their pedometers each day and record their step counts. During the weekly counseling session, participants reported their step counts, and research personnel provided specific step goals for

		the upcoming week and advised about ways to incorporate more walking into the participant's daily routine.
14	(Wang, Cai, Padhye, Orlander, & Zare, 2018)	Participants were provided a Fitbit to collect physical activity data using the tracker and self-monitor physical activity using the tracker for instant feedback and website for daily physical activity summary data. Participants were also provided with 3 daily SMS text messages that prompted physical activity.
15	(Ezeugwu & Manns, 2018)	Participants were provided with a sedentary behavior and physical activity behavioral change intervention. This was supported by a motivational Misfit activity tracker.

Participants Demographics

In total, 844 adult participants took part in the 15 studies. Of these, 412 (48.8%) were male, and 432 (51.2%) were female. The mean age of all participants was 58.3 (SD 8.6) years.

Percentage Reporting Across RE-AIM Dimensions

The RE-AIM dimensions are supported by 28 indicators. Table 7 shows the mean total number of indicators reported across the 5 main dimensions.

Table 7: Mean total number and percentage of RE-AIM indicators reported across each dimension.

RE-AIM dimension	Indicators reported, n (%)
Reach	10 (67)
Effectiveness	10 (67)
Adoption	0.5 (3)
Implementation	9 (60)
Maintenance	2 (13)

Percentage Reporting Across the RE-AIM Indicators

Reach

The reach dimension is supported by 7 indicators, and the overall numbers and percentages reported are shown in Table 8.

Table 8: Overall numbers and percentages of Reach indicators reported.

Reach indicator	Studies reported, n (%)
Method used to identify the target population	14 (93)
Inclusion criteria	15 (100)
Exclusion criteria	14 (93)
Use of qualitative methods to understand reach or recruitment	0 (0)
Sample size	15 (100)
Participation rate	14 (93)
Sample representatives	0 (0)

Effectiveness

The effectiveness dimension was supported by 6 indicators, and the overall numbers and percentages reported are shown in Table 9.

Table 9: Overall numbers and percentages of Effectiveness indicators reported.

Effectiveness indicator	Studies reported, n (%)
Assessment of the effect on outcomes at the shortest assessment point	15 (100)
Imputation procedures reported (how missing data are processed)	2 (12)

The presence of quality-of-life follow-up	8 (53)
Effects at the longest follow-up	15 (100)
Use of qualitative methods to understand outcomes	2 (12)
Patient attrition or dropout rate	15 (100)

Adoption

The adoption dimension was supported by 6 indicators, and the overall numbers and percentages reported are shown in Table 10.

Table 10: Overall numbers and percentages of Adoption indicators reported.

Adoption indicator	Studies reported, n (%)
Method of identifying target agent	0 (0)
Level of expertise of delivery agent	2 (12)
Inclusion and exclusion criteria for target agent	0 (0)
The adoption rate	1 (7)
Comparison of settings or participants of adoption versus nonadoption settings	0 (0)
Use of qualitative methods to understand either adoption at the setting level or staff participation	0 (0)

Implementation

The implementation dimension was supported by 5 indicators, and the overall numbers and percentages reported are shown in Table 11.

Table 11: Overall numbers and percentages of Implementation indicators reported.

Implementation indicator	Studies reported, n (%)
The intervention type (individual component vs multicomponent)	15 (100)
Intensity (components of intervention)	15 (100)
The extent the protocol was delivered as intended	15 (100)
A measure of cost	0 (0)
Use of qualitative methods to understand the implementation of the study	1 (7)

Maintenance

The maintenance dimension was supported by 5 indicators, and the overall numbers and percentages reported are shown in Table 12.

Table 12: Overall numbers and percentages of Maintenance indicators reported.

Maintenance indicator	Studies reported, n (%)
Was an individual’s behavior assessed at least 6 months following completion of the study intervention	8 (53)
Is the program still in place	0 (0)
Was the program modified	1 (7)

Use of qualitative methods to understand the long-term effects	0 (0)

Discussion

Principal Findings

This integrative systematic review sets out to measure the level of reporting for each of the 28 RE-AIM indicators in studies, focused on using activity trackers in clinical care to support physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases. To the best of the lead author's knowledge, no similar studies have been undertaken, and it is hoped these findings will be informative in the planning and evaluation of future public health interventions to support the management of chronic diseases. In summary, this review found that the RE-AIM dimensions of adoption and maintenance were underreported. Analysis of the indicators found that the use of qualitative methods to understand each dimension was underreported.

The use of commercial activity trackers within physical activity interventions either on their own or when combined with behaviour change strategies has been shown to increase activity levels and reduce sedentary behaviour in people diagnosed with a chronic disease (Franssen, Franssen, Spaas, Solmi, & Eijnde, 2020). In 2020, Franssen et al in a systematic review identified 35 studies covering this area of research. The use of activity trackers specifically within clinical practice has been researched less. The search strategy undertaken for this review identified only 15 studies with all targeting physical activity and 1 targeting sedentary behavior. This indicates that their use in clinical practice could be increased and has a significant positive impact on the health of patients diagnosed with a chronic disease.

Understanding of the reach, effectiveness, adoption, implementation, and maintenance of these interventions is vital for future programs. Using the RE-AIM framework allows for the analysis of individual studies and identifies specific areas of strength and weakness in interventions . Each dimension of the RE-AIM framework in relation to the 15 identified studies is discussed in more detail in the following sections.

Reach

Reach is set at an individual level and measures participation factors such as number, proportion, and representativeness of those taking part in an intervention (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). RE-AIM research has shown that most health care studies report sample size and proportion of participants who are willing to take part (Glasgow, Klesges, Dzewaltowski, Estabrooks, & Vogt, 2006). On the other hand, few studies report if the participant sample is representative of a particular patient population (Stopponi, et al., 2009). Of the 15 studies identified in this review, 93%-100% reported the method used to identify the target population (93%), inclusion criteria (100%), exclusion criteria (93%), sample size (100%), and participation rate (93%). Representativeness and use of qualitative methods to understand reach were not reported in any of the studies. Understanding the needs and overall demographic makeup of a population is vital to the success of an intervention, especially when dealing with technology-based programs. Issues such as age, socioeconomic background, ethnicity (language), and employment status may act as barriers for patients to engage in eHealth interventions and as such should be considered in the planning stage of a study (Glasgow, McKay, Piette, & Reynolds, 2001). Qualitative methods to understand a program’s reach and in particular representativeness should be incorporated during the planning stage. This can aid the researcher’s understanding of why certain patients do or do not engage in a study at the recruitment stage.

Effectiveness

The effectiveness dimension aims to understand the impact of an intervention including outcomes, potential negative effects, wider issues such as quality of life, and variation outcomes between subgroups. These factors are vital when moving from a research environment into a real-world setting (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). In the 15 studies under review, the effectiveness indicators assessment of effect at the shortest and longest time points and patient attrition rate were reported in all papers. Reported to a lower degree were the indicators' imputation procedures (12%), presence of quality-of-life measures (53%), and use of qualitative methods to understand outcomes (12%). The lack of reported imputation procedures increases the chance of introducing bias and impacts the internal reliability of the study. Statistical methods, such as listwise deletion, dealing with missing data should be reported especially if interventions are to be applied in economic real-world environments (Glasgow, Klesges, Dzewaltowski, Estabrooks, & Vogt, 2006). Positive or negative impacts of an intervention on a patient's quality of life should also be considered in health-related studies. Focusing on just the physiological outcomes does not give a full indication of the effectiveness of an intervention. Factors such as mental and social well-being should also be considered. Qualitative methods to understand outcomes were also limited with only 2 studies reporting use. Qualitative methods can complement the quantitative data in health studies by exploring the psychological behavior change element of a patient's participation as well as their experience of the intervention overall (Gago, Cantu-Aldana, Maafs-Rodríguez, Caballero-Gonzalez, & Mattei, 2022).

Adoption

The adoption dimension moves away from individual participant level and focuses on the settings and intervention agents. In particular, this refers to where the intervention was delivered and by whom (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). Studies identified within this review were all undertaken within outpatient clinical care. The interventions were either delivered by the research team or health care professionals. Adoption is seldom reported in health-related studies, and this creates issues when the impact of an intervention is assessed or applied in a real-world setting. When adoption is fully reported and considered at the planning stage of a study, there is evidence that these interventions are more successful. Making comparisons between settings, sites, and the teams delivering an intervention (differential adoption) can help understand good practice (Estabrooks, Bradshaw, Dzewaltowski, & & Smith-Ray, 2008). The 15 studies identified during this review found low levels of reporting across the 6 indicators. In fact, only the indicators' level of expertise of the delivery agent (12%) and adoption rate (7%) were reported. Without this information, it is difficult to apply the methods studied in full clinical practice.

Implementation

The implementation dimension is set at the settings level and measures how reliable and committed the delivery agent was in applying the intervention as intended along with reported monetary cost and staff time (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). Implementation is important as it provides details of why an intervention was changed from that initially proposed. The cost factor is an important consideration for organizations intending on implementing any intervention, and this needs to be considered against the interventions' benefits. This dimension is generally not well reported in health behavior studies (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). This review found that implementation was overall well reported in 3 out of the 5 indicators recorded in the identified studies. The indicators' measure of cost (0%) and use of qualitative methods to understand the implementation of the study (7%) were poorly reported. As these studies were delivered in outpatient clinical care, a measure of cost would be required by health care management in a real-world setting. The use of qualitative methods would also provide a greater understanding of the implementation process and how staff perceived the intervention. This would help understand the training needs of staff and any requirements to amend the intervention.

Maintenance

The Maintenance dimension is set at both the setting and individual level. At the setting level, it refers to how well an intervention becomes part of routine health care. At an individual level, it is a measure of the long-term impact on the patient's health. As most interventions are tested over a relatively short timescale, this is seldom reported in studies (Glasgow, Klesges, Dzewaltowski, Bull, & Estabrooks, 2004). The RE-AIM evaluation framework identifies studies at or beyond 6 months as a measure of maintenance (Glasgow, 2013). This review found that 53% of studies applied an intervention for up to 6 months but not over. None are still in existence as far as the research team is aware. Only one study reported a modification to the intervention. None used qualitative methods to understand the long-term effect of the intervention. Stronger reporting across all 5 dimensions would help to understand why these interventions are no longer in operation. The use of qualitative methods for the maintenance dimension would have assisted in this understanding. Seven of the reviewed studies were either pilot or exploratory in design. By their very nature, these would only be planned over a short timescale.

Study Strengths and Limitations

After the initial search, all papers were double-screened at the initial title and abstract stage and full-text stage. The review was undertaken in accordance with the PRISMA 2020 statement (Page, et al., 2021).

The initial study protocol sets out to identify specific adult age categories within each of the identified studies, for example, 18-20 and 21-30 years. As these were not reported, the protocol was amended with the focus being on adults aged 18 years and older. The lead author conducted all the data extraction with 40% of papers being quality-checked by 3 of the coauthors.

Conclusions

This integrative systematic review sets out to comprehensively explore the Reach, Effectiveness, Adoption, Implementation, and Maintenance of using activity trackers in clinical care to support physical activity or reduce sedentary behavior in adults diagnosed with chronic diseases. Applying the RE-AIM framework over the 5 main dimensions and 28 indicators identified several areas that were both well and poorly reported in studies. For this area of research, improved measurement and reporting of the dimensions adoption and maintenance are required with a focus on the settings element within studies. At an indicator level, the main area of underreporting and use was that of qualitative methods. Such methods would allow for detailed exploration of the experiences of both staff and patients at each stage of an intervention and over all RE-AIM dimensions. This would provide a better understanding of the use of activity trackers within clinical care for adults diagnosed with a chronic disease. Qualitative thematic analysis involving one-to-one interviews or focus groups conducted at the pre-study, during the study, and poststudy stages with health care staff and participants would provide a greater understanding of the strengths and weaknesses of an intervention. The RE-AIM framework and findings from this systematic review also provide an insight into how such interventions could be applied in a clinical setting focusing on the dimensions of reach, effectiveness, adoption, implementation, and maintenance. The limited reporting of adoption and maintenance in studies makes it difficult to progress from a research study setting into the real-world health environment. Better reporting of these dimensions in studies would help clinicians in using activity trackers during patient care. The author compiled the final journal article and submitted this for publication in the Journal of Medical Internet Research.

Chapter 2 Sub-Section

Critical Appraisal of the Application of the RE-AIM Framework in Chapter 2

The RE-AIM framework, comprising Reach, Effectiveness, Adoption, Implementation, and Maintenance, was developed to guide the systematic evaluation of public health interventions and support their translation from controlled environments into real world practice (Glasgow et al., 1999). While it is a powerful tool for bridging the gap between research and implementation, its full utility depends on the availability of comprehensive data across all five dimensions. The integrative systematic review set out to assess the use of activity trackers in the clinical care of adults diagnosed with chronic disease through the RE-AIM lens. Although the review was ambitious in scope, aiming to evaluate the real world applicability of such interventions, the majority of included studies were early phase efficacy or feasibility trials, lacking the methodological features necessary to support robust RE-AIM reporting. This sub-section sets out to critically examine the misalignment between the stated aims of the review and the actual nature of the included studies, with particular attention to the underreporting of qualitative and implementation focused RE-AIM dimensions.

The systematic review identified and synthesised 15 studies that investigated the integration of wearable activity trackers into clinical care for adults with chronic conditions. The stated objective was to use the RE-AIM framework to evaluate these interventions, thereby determining their potential for implementation and sustainability in routine clinical care settings. However, most included studies were conducted under controlled conditions, with a focus on demonstrating short term effectiveness rather than implementation feasibility. Indeed, the systematic review reported that while Effectiveness was the most frequently addressed RE-AIM dimension (100% of studies), Adoption and Maintenance were substantially underreported, appearing in only 7% and 13% of studies respectively. This imbalance is indicative of a broader pattern. Many of the studies were pilot or proof of concept trials, primarily designed to assess the clinical or behavioural efficacy of activity trackers rather than their uptake by healthcare providers, their adaptability across contexts, or their long term integration into care pathways.

Limitations in Reporting Across RE-AIM Dimensions

Reach

Reach refers to the degree to which a target population is engaged in an intervention, and whether the sample is representative of the broader population (Glasgow et al., 1999). In the reviewed studies, Reach was only partially addressed. While participant numbers and some demographic information were typically reported, very few studies contextualised this data within broader population denominators or discussed recruitment barriers. Without such contextualisation, it is difficult to ascertain whether the interventions reached those most in need, such as individuals from underserved or marginalised communities.

Effectiveness

Effectiveness was the most comprehensively reported dimension. All studies included outcome measures related to physical activity, health status, or patient engagement. However, while outcome data were often robust, many studies still lacked assessments of potential negative effects or unintended consequences, an essential but often overlooked component of RE-AIM's Effectiveness criterion (Glasgow et al., 2019).

Adoption

Adoption, which involves the willingness and ability of clinical staff and organisations to implement an intervention, was notably underrepresented in the reviewed literature, with only one study reporting data on this dimension. This absence is not surprising, given that early phase studies typically involve high levels of researcher oversight and are rarely embedded within existing clinical workflows. Consequently, these studies are ill-equipped to generate insights into organisational readiness, staff training requirements, or institutional barriers to adoption.

Implementation

Implementation includes fidelity to the intervention protocol, as well as adaptations, resource demands, and contextual variables affecting delivery (Glasgow et al., 1999). While some studies included measures of fidelity or participant adherence (e.g., number of days the activity tracker was worn), few addressed implementation costs, staff burden, or required technological infrastructure. The systematic review concluded that reporting on Implementation was inconsistent and lacked sufficient detail for meaningful cross-study comparison.

Maintenance

Maintenance assesses whether intervention effects are sustained over time, both at the individual and organisational levels. This is perhaps the most difficult RE-AIM dimension to capture in early phase research due to time and funding limitations. Indeed, the systematic review found that only two studies provided any follow-up data beyond the immediate post-intervention period, and none examined long-term integration into routine care. Consequently, the capacity of these interventions to produce durable behaviour change or to be embedded in clinical practice remains unknown.

Lack of Qualitative Insight

A particularly salient limitation in the reviewed studies was the near complete absence of qualitative data. Qualitative methods are invaluable for exploring contextual factors that influence RE-AIM dimensions such as Adoption and Implementation. For example, interviews with healthcare staff can shed light on perceived barriers to integrating activity trackers into clinical workflows, while patient focus groups can uncover issues related to acceptability, usability, and equity. It was noted that only three of the included studies employed any form of qualitative data collection, and even these were narrowly focused on intervention usability or participant satisfaction. As a result, the review was unable to offer rich, context sensitive insights into how or why certain interventions succeeded or failed in their respective settings. This gap is significant, as qualitative data are often essential for interpreting quantitative outcomes and for guiding future implementation efforts (Greenhalgh, et al., 2017). Without it, the RE-AIM framework remains only partially operationalised, limiting its utility for informing real-world practice.

Implications for RE-AIM Application and Future Research

The limited reporting across key RE-AIM dimensions in the systematic review highlights a broader challenge in implementation science, such as the premature application of translational frameworks to studies that are not designed with implementation in mind. Although the use of RE-AIM was conceptually appropriate, its utility was constrained by the nature of the underlying evidence base. This mismatch calls for a more strategic alignment between research design and evaluation frameworks. Future studies should be explicitly designed to capture all dimensions of RE-AIM. This includes using mixed methods approaches, recruiting diverse and representative samples, engaging stakeholders during intervention design, and extending follow-up periods to capture sustainability outcomes. Furthermore, researchers should consider hybrid effectiveness and implementation trial designs, which allow simultaneous testing of clinical outcomes and implementation processes (Curran, Bauer, Mittman, Pyne, & Stetler, 2012).

Conclusion

The integrative systematic review provided a valuable contribution to the literature by attempting to evaluate the implementation potential of activity trackers in chronic disease care using the RE-AIM framework. However, the predominance of early phase trials among the included studies limited the feasibility of comprehensive RE-AIM reporting. In particular, the dimensions of Adoption, Implementation, and Maintenance were poorly represented, and qualitative methods, critical for understanding context and process, were largely absent. These limitations underscore the importance of aligning research design with evaluation frameworks and of using mixed methods approaches to fully realise the potential of tools like RE-AIM. Only by addressing these gaps can future research meaningfully inform the real-world adoption and sustainability of digital health interventions.

Justification and Critical Appraisal of the Inclusion of the Carrasco Study in the integrative systematic review

In the integrative systematic review the RE-AIM framework was employed to evaluate the use of wearable activity trackers in clinical care for adults with chronic diseases. Among the included studies was the observational study by Carrasco et al., 2019 which, while relevant in terms of intervention context, raises important questions regarding methodological suitability for RE-AIM evaluation, particularly in relation to the framework’s more structural dimensions such as Reach and Maintenance. Observational studies can offer valuable real world insights and are often instrumental in assessing the feasibility or acceptability of interventions outside controlled trial environments (Grimshaw, Campbell, Eccles, & Steen, 2000). The inclusion of Carrasco's study in this context is justified on the grounds that the RE-AIM framework does not necessitate randomised controlled trials alone; rather, it encourages pragmatic evaluations that can inform public health and clinical practice through diverse methodological approaches (Glasgow et al., 1999) (Glasgow et al., 2019). Observational designs, particularly those conducted in routine care settings, may therefore provide contextual information about user behaviour, technology uptake, or engagement trajectories that are relevant to dimensions like Implementation and Adoption.

However, despite this conceptual alignment, the capacity of Carrasco's observational design to meaningfully address the full RE-AIM framework appears limited in practice. For example, Reach, requires detailed denominator data and demographic profiling to determine who was excluded, declined participation, or was unreachable (Glasgow et al., 1999). In many observational studies, including Carrasco's, such data are either not available or are inconsistently reported. As a result, it becomes difficult to ascertain whether the intervention truly engaged a representative sample of the target population or disproportionately served certain subgroups, thus undermining the generalisability of findings. Similarly, Maintenance is challenging to evaluate in short term observational studies lacking longitudinal follow-up. Carrasco's study, while potentially informative regarding initial uptake and engagement, does not appear to have included sufficient follow-up to assess behavioural sustainability or structural embedding of the intervention within care processes. This is a critical omission, as Maintenance is central to the translation of pilot interventions into enduring practice (Glasgow et al., 2019) (Estabrooks et al., 2011).

Furthermore, observational designs may not systematically report on organisational adoption or the contextual adaptations required to implement technology within specific clinical environments, elements central to the Adoption and Implementation. The lack of structured reporting mechanisms in observational research further limits cross-study comparability and the aggregation of implementation evidence, which are core goals of systematic reviews applying RE-AIM (Kessler, et al., 2013).

Given these limitations, the inclusion of Carrasco's study in the review reflects a pragmatic compromise aimed at capturing a broader range of real world data, even if such data do not align neatly with every RE-AIM dimension. This approach is defensible to the extent that it broadens the evidence base and surfaces contextual factors often missed in controlled trials. Nonetheless, it is essential that such inclusions are critically appraised and clearly delineated within the synthesis, with transparency around the methodological constraints they introduce. Without such clarity, the risk emerges of over-interpreting or misapplying RE-AIM indicators to studies not designed to support their full operationalisation.
In summary, while observational studies like Carrasco's may yield valuable implementation-relevant insights, their methodological limitations, particularly regarding Reach and Maintenance, necessitate careful scrutiny in RE-AIM-based reviews. Future syntheses should consider not only the thematic relevance of such studies but also their capacity to contribute valid and reliable data across each RE-AIM domain.

Brief description of the RE-AIM data extraction tool used within Chapter 2

The RE-AIM extraction tool used in the integrative systematic review comprised of a series of predefined indicators for each of the five dimensions. The tool is suitable for use during systematic reviews or implementation evaluations to ensure consistency in data collection and facilitate comparability across studies. Each RE-AIM component is operationalised into specific sub-domains or items, which may be coded as reported, not reported, or partially reported. In more advanced applications, the degree or quality of reporting may also be scored on a numeric scale to assess the depth or rigour of each dimension's representation (Kessler et al., 2013; Harden et al., 2015).

Use of the RE-AIM extraction tool in systematic reviews helps standardise evaluation and illuminate reporting gaps across intervention studies. Such tools are thus essential for both documenting the quality of reporting and guiding future research to ensure more balanced and translationally useful evidence.

Chapter 3

Exploring the use of activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes: A qualitative interview study using the RE-AIM Framework.

Preface

Study 2 was a qualitative interview study with the aim of exploring the use of activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes. The author focused on a qualitative study as a result of the findings identified in the Study 1 systematic review, which indicated that qualitative methods were seldom used to evaluate the 5 main RE-AIM dimensions. Qualitative analysis offers rich, in-depth insights into human experiences and behaviors, allowing the author to explore and better understand the use of activity trackers by adults diagnosed with or at risk of type 2 diabetes. Having had previous experience of conducting qualitative analysis during previous studies and as a research assistant the author led this study throughout including its design, planning and implementation. This was supported through guidance from the authors PhD supervisors. An abductive thematic analysis approach was chosen by the author for this study due to its emphasis on the role of inference in data interpretation. The aim was to generate explanations that were grounded in the data collected but allow for analysis to be extended beyond the observed data and identify underlying patterns and relationships (Shorten & Smith, 2017). This was particularly important when extending the analysis and evaluation relationships into the RE-AIM framework dimensions. To fully explore the use and integration of activity trackers within routine type 2 diabetes clinical care the author aimed to recruit for interview both health care professionals and adults diagnosed with the condition. The author proceeded to undertake ethics approval, recruitment, development of a semi-structured interview schedule, all recorded interviews, transcription and abductive thematic analysis using the NVIVO platform. Identified themes and sub-themes were quality checked by the authors PhD supervisors. As within Study 1 the RE-AIM framework was used to evaluate the identified themes under each of the 5 main dimensions of Reach, Effectiveness, Adoption, Implementation and Maintenance (Glasgow, Vogt, & Boles, 1999). The rationale being that comparisons could be made across each individual study and overall within the PhD thesis. The results built on the findings within Study 1 which highlighted gaps within previous academic studies and identified recommendations for overcoming the shortfalls and integrating activity trackers into type 2 diabetes clinical care. The author compiled the final journal article and submitted this for publication in the Journal of Medical Internet Research Diabetes. After peer review Study 2 was accepted for publication.

Paper 2

Exploring the use of activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes: A qualitative interview study using the RE-AIM Framework

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Tables: 4

Figures: 1

This paper was after peer review accepted for publication in the Journal of Medical Internet Research Diabetes in December 2024. (Changes have been made to the original submitted document as a result of suggestions made during the VIVA examination).

Abstract

Background

The prevalence of type 2 diabetes in adults worldwide is increasing. Low levels of physical activity and sedentary behaviour are major risk factors of developing the disease. Physical activity interventions incorporating activity trackers can reduce blood glucose levels in adults diagnosed with type 2 diabetes. The My Diabetes My Way website is a support and educational platform for people diagnosed with diabetes and health care professionals. Users of the My Diabetes My Way website can upload their Fitbit activity data onto the system, but this is not presently being analysed and used routinely within clinical care. Developers of the My Diabetes My Way system are planning to allow different makes of activity trackers to be integrated with the platform.

Aim

The aim of this qualitative study was to explore (through the RE-AIM framework) views from adults diagnosed with type 2 diabetes and health care professionals on the integration of activity trackers into type 2 diabetes care.

Methods

Adults (n=12) diagnosed with type 2 diabetes and health care professionals (GP n=4, Consultant n=1, Diabetes Nurse n=2, Practice Nurse n=1, Physical Activity Advisor n=1) were recruited through social media and professional contacts. Semi-structured one to one interviews were conducted. Abductive thematic analysis was undertaken and main themes and sub-themes identified. The RE-AIM framework was used to evaluate the themes in respect of the wider use of activity trackers and the My Diabetes My Way platform within type 2 diabetes clinical care.

Results/Findings

Six main themes (awareness, access, cost, promotion, support, technology and data) and 20 sub-themes were identified. Evaluation using the 5 RE-AIM dimensions found that reach could be improved by raising awareness of the My Diabetes My Way platform and the ability to upload activity tracker data onto the system. Effectiveness could be improved by implementing appropriate personalised measures of health benefits and providing appropriate support for patients and health care staff. Adoption could be improved by better promotion of the intervention among stakeholders and development of joint procedures. Implementation could be improved through the development of an agreed protocol, staff training and introducing measurements of costs. Maintenance could be improved by supporting all patients for long term engagement and measuring improvements to patients health.

Conclusion

Using the RE-AIM framework allowed for the examine of improving the reach, effectiveness, adoption, implementation and maintenance of using activity trackers to increase physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes.

Keywords

Type 2 diabetes, physical activity, sedentary behaviour, Fitbit, activity tracker, adults, My Diabetes My Way, RE-AIM framework

Introduction

Type 2 diabetes mellitus is a non-communicable disease. Worldwide it is estimated that 483 million adults (20-79 years of age) are living with type 2 diabetes. By 2045 this number is estimated to rise to 705 million. Annually 6 million adults die prematurely due to type 2 diabetes (Sun, et al., 2022). In the UK 5 million adults have been diagnosed with type 2 diabetes and the care costs for the National Health Service (NHS) are approximately £12 billion each year (Diabetes UK, 2025). Major risk factors for developing type 2 diabetes include low levels of physical activity and sedentary behaviour (Deshpande, Harris-Hayes, & Schootman, 2008). Adults diagnosed with type 2 diabetes have been found to be less physically active and spend more time engaged in sedentary behaviour than those without the disease (Kennerly & Kirk, 2018). Physical activity even at low levels of intensity and reducing sedentary behaviour can lower blood glucose levels and improve several health outcomes in adults diagnosed with type 2 diabetes (Colberg, et al., 2016) (Delevatti, et al., 2019) (Sardinha, Magalhães, Santos, & Júdice, 2017).

Physical activity interventions involving the use of activity trackers have been shown to increase physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes (Chen, et al., 2015). Activity trackers are technological devices designed to measure the users steps, distance moved, physical activity intensity and sedentary behaviour (Franssen, Franssen, Spaas, Solmi, & Eijnde, 2020). Fitbit activity trackers for example have been shown to be moderately valid and reliable in measuring users physical activity and sedentary behaviour and it is estimated that there are about 37 million users globally (Ferguson, et al., 2022). Recent discussions have suggested that national physical activity guidelines should be formulated around activity tracker measured physical activity rather than self-reported data, which tends to over or underestimate the users activities (Gill, et al., 2023).

My Diabetes My Way is a web-based support and educational platform for diabetes patients and their health care professionals. The website allows users to access their patient records including prescribed medication and blood glucose measurements. The My Diabetes My Way website includes basic physical activity advice for patients though this element of the system is used less than other content (Cunningham, et al., 2019). Since 2019, patients have been able to upload their Fitbit activity data onto the My Diabetes My Way platform. The developers of this platform state that there is an appetite for the linking of further makes of activity trackers, mobile applications and online tools (Shields, Conway, Allardice, Wake, & Cunningham, 2023). Users of My Diabetes My Way have shown a desire for uploading physical activity data onto the system from alternative commercial activity trackers and mobile applications (Shields, Conway, Allardice, Wake, & Cunningham, 2023). However, very little is known about if and how patients and health care professionals use the activity trackers in combination with online systems like the My Diabetes My Way platform to support the patients physical activity and reduce their sedentary behaviour. Increasing our understanding of potential barriers and facilitators to the use of activity trackers and technology such as the My Diabetes My Way platform from both patients and health professionals will enable future improvement and development of digital health platforms and technologies to improve the clinical care of adults diagnosed with type 2 diabetes.

One way to evaluate the use of activity trackers is by using the RE-AIM framework. RE-AIM is a planning and evaluation framework used to improve adoption and sustainable implementation of a wide range of evidence-based interventions including health related interventions. The main RE-AIM dimensions are Reach, Effectiveness, Adoption, Implementation and Maintenance (Glasgow, Vogt, & Boles, 1999). Reach is defined as the absolute number, proportion and representativeness of individuals participating in a given initiative. Effectiveness is the impact of an intervention on outcomes, including potential negative effects, quality of life, and health components. Adoption is the proportion, representativeness and absolute number of organisational agents involved in the intervention. Implementation is set at an organisational level and how the program was delivered by staff. Maintenance is defined as the extent to which a program or policy becomes embedded in routine practice. At an individual level maintenance is a measure of the long-term impact of an intervention over 6-months (Glasgow, et al., RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review, 2019).

The aim of this qualitative study was to explore (through the RE-AIM framework) views from adults diagnosed with type 2 diabetes and health care professionals on the integration of activity trackers into type 2 diabetes care.

Method

This qualitative interview-based study was granted ethical approval by the relevant department University Ethics Committee (ethics approval 2021) (Appendix D). All participants provided written consent to take part and to ensure anonymity each was randomly allocated a unique four-digit identification number. A data management plan was prepared for this study (Appendix E).

Participants

Adults diagnosed with type 2 diabetes

Participants (n=12) were recruited through social media posts (via Facebook and Twitter). Recruitment inclusion criteria included adults aged 18+ years, diagnosed with type 2 diabetes, residing in the U.K and able to read and write in English. The study participant information sheet and consent form (Appendix F) was uploaded onto the secure Qualtrics survey system. A link to this form was emailed to participants and their consent recorded by indicating 'yes' on the Qualtrics consent form. Once consent was received participants were emailed a link to a baseline questionnaire on the Qualtrics system. This questionnaire gathered demographic, educational level, activity tracker use and who if anyone provides physical activity advice within the person's clinical care.

Health care professionals

Participants (n=9) were recruited through University contacts (via email) and through social media posts (via Facebook and Twitter). Recruitment criteria included adults aged 18 + years, residing in the UK and experience of type 2 diabetes health care or physical activity for health. The study participant information sheet and consent form (Appendix G) was uploaded onto the secure Qualtrics survey system. A link to this form was emailed to participants and their consent recorded. Once consent was received a link to a questionnaire on the Qualtrics survey system to collect information on demographic and job role characteristics was emailed to participants.

Procedure

A summary of the study procedures are provided in Figure 9.

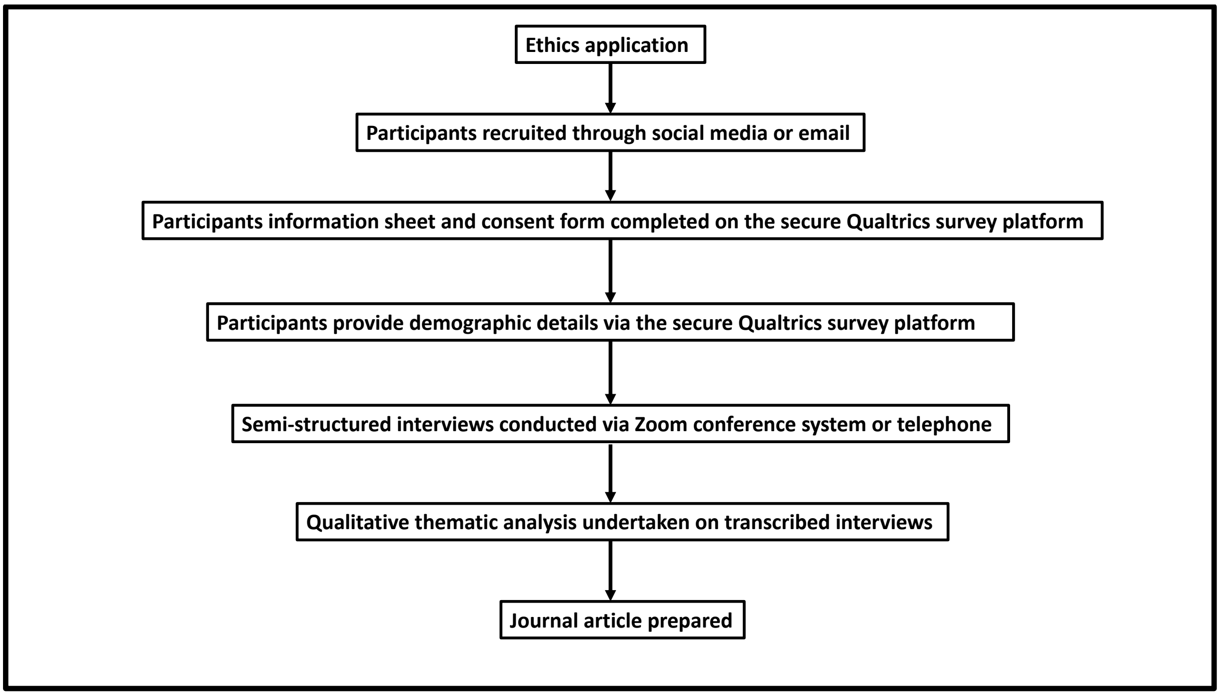

Figure 9: Flow diagram showing summary of study procedures.

Semi-structured interviews

One-to-one interviews were conducted with all participants. A semi-structured interview schedule was prepared focusing on the 5 RE-AIM dimensions of reach, effectiveness, adoption, implementation and maintenance (See Appendix H). Interviews were conducted either over telephone or via the secure Zoom conferencing platform. Each interview was recorded via a secure encrypted Dictaphone. An abductive interview technique was utilised which started with the main RE-AIM dimension and working down into the participants lived experiences in more detail (Shorten & Smith, 2017). Each interview was later transcribed verbatim from the Dictaphone recording.

Analysis

NVIVO – 12 software was used to manage the data and support the thematic analysis. All transcribed interviews were uploaded onto this platform. A thematic analysis plan was developed which incorporated the 6-stage process recommended by Braun and Clarke (Braun & Clarke, Using thematic analysis in psychology, 2006). The 6-stages are data familiarisation (repeated reading of the transcripts), initial coding (identification of words or sentences connected to the analysis), initial development of themes (combining of codes into themes), review of identified themes, naming and finalisation of themes and preparation of the final journal article. The thematic analysis was conducted by the lead author (WH) and cross checked by the three co-authors (A.K., M.L., and X.J.). Differences in thematic and code names or meanings were resolved via discussion between these three researchers and the lead author. Appendix I provides an example of the coding process and development of the sub-themes for the main theme Awareness. Alignment to the RE-AIM framework was not undertaken until the discussion section of this report. This allowed for the identification of main themes through thematic analysis to develop a more in depth understanding of the participants experiences. These main themes were then applied to the main RE-AIM dimensions.

Results

Participant demographics

Participant demographics are displayed in Table 13.

Table 13: Participants demographics.

	Adults diagnosed with type 2 diabetes (n=12)	Health care professionals (n=9)
Gender (female)	8	5
Mean age (years)	53.17 ± SD 11.18	52.57 ± SD 7.59
Mean years diagnosed with type 2 diabetes (years)	8.42 ± SD 6.76	N/A
Education		
Degree	5	8
Higher education	5	1
School qualifications	2	0
Ethnicity		
White	10	8
Black	2	0
Asian	0	1
Country of residence		
Scotland	10	8
England	2	1
Home setting		
Rural	2	4
Urban	10	5
Used an activity tracker before the study		
Fitbit	3	N/A
None	9	N/A
Physical activity advice in clinical care		
GP	2	N/A
Diabetes nurse	5	N/A
Practice nurse	1	N/A
Diabetes consultant	1	N/A
Cancer nurse	1	N/A
None	5	N/A
Role in clinical care		
GP	N/A	4
Consultant	N/A	1
Diabetes nurse	N/A	2
Practice nurse	N/A	1
Physical activity advisor	N/A	1

Findings

Abductive thematic analysis of interviews with adults with type 2 diabetes and health care professionals identified 6 main themes and 20 sub-themes. These are displayed in Table 14 and discussed in more detail below.

Table 14: Thematic analysis main themes and sub-themes.

Main Themes (n=6)	**Sub-themes (n=20)**
1. Awareness	1.1 My Diabetes My Way 1.2 Benefits of activity tracking 1.3 Benefits to health
2. Access	2.1 Activity trackers 2.2 Digital literacy barriers
3. Cost	3.1 Activity trackers 3.2 Internet access 3.3 Digital technology 3.4 Health care staff
4. Promotion	4.1 Signposting 4.2 Knowledge and credibility
5. Support	5.1 Advice 5.2 Gym referrals 5.3 Data interpretation 5.4 Educational packages
6. Technology and data	6.1 Feedback 6.2 Personalisation 6.3 Motivation 6.4 Data management 6.5 Fitbit functions

Awareness

The majority of adults diagnosed with type 2 diabetes stated that they were not aware of the My Diabetes My Way platform and that it had not been discussed during consultations with a health care professional. For those registered on the platform only one was aware of the ability to upload Fitbit data onto the system.

> *"I am not aware of this website…"* (T2D Male 61 years of age)

> *"I am registered but did not know you could upload your Fitbit activities."* (T2D Female 44 years of age)

Health care professionals (HCP) discussed awareness of the My Diabetes My Way platform and the ability to upload Fitbit data onto the system. The majority of health care professionals were aware of the platform but none knew that users could upload Fitbit data.

> *"I have limited knowledge of My Diabetes My Way and certainly did not know you could upload Fitbit data. This needs to be addressed by making staff aware."* (HCP (Diabetes Nurse) Female 57 years of age)

> *"I would say not aware. I have been using this system for a while and was not aware that Fitbit data could be uploaded."* (HCP (Practice Nurse) Female 61 years of age)

Awareness of the benefits of tracking physical activity through activity trackers was discussed. Adults diagnosed with type 2 diabetes suggested that these devices would provide the user and health care professionals with an accurate indication of an individual's physical activity.

"… monitoring a patients levels of activity. If these are low then they could be directed towards information on exercise or local classes." (T2D Male 37 years of age)

HCP discussed the benefits of using activity trackers in clinical care. The ability to monitor a patients physical activity and provide appropriate advice and support was identified as the main benefit.

"The first would be to see how active a patient is. After that advice can be given on appropriate exercise activities which can then be further monitored." (HCP (Consultant) Male 52 years of age)

"The activity tracker could form part of a physical activity intervention which would include advice and attending exercise classes." (HCP (GP) Male 43 years of age)

Awareness of the benefits of using activity trackers to improve the health of users was explored. Adults diagnosed with type 2 diabetes stated that these devices could increase users physical activity and reduce sedentary behaviour which would improve the health of the individual.

"It would give me a better understanding of how active I am and this may motivate me to do more physical activity and improve my overall health." (T2D Female 46 years of age)

HCP discussed the benefits to a patient's health if activity trackers were used in the clinical care of adults diagnosed with type 2 diabetes. Improved health was highlighted as the main benefit which would reduce the need for medical treatment.

> *"Long term this would benefit the patient's health with less reliance on medication and treatment for related health conditions."* (HCP (Consultant) Male 52 years of age)

Access

Adults diagnosed with type 2 diabetes discussed how clinical care providers could gain access to activity trackers. It was suggested that these devices could be prescribed by the health care provider and used as part of a patients treatment plan.

> *"The tracker could be prescribed on the NHS especially for those on low incomes."* (T2D Female 57 years of age)

HCP discussed how patients could access an activity tracker as part of their clinical care. It was suggested that these devices could be prescribed by a health care professional.

> *"Prescribing an activity tracker could help motivate a patient to be more active."* (HCP (Practice Nurse) Female 61 years of age)

Access to the My Diabetes My Way platform was discussed during interviews with adults diagnosed with type 2 diabetes. It was suggested that accessibility could be improved by a health care professional providing clear guidance and instructions on how to register for this service especially for people with limited information technology skills.

> *"I am not confident using computers and would need my GP or the practice nurse to provide me with support so I can register for this website."* (T2D Male 61 years of age)

HCP discussed the digital literacy barriers that may prevent a patient accessing and using information technology as part of their clinical care. It was suggested that those with limited digital skills and confidence using technology would need support and training.

> *"Some of my patients are uncomfortable using technology and would need support"* (HCP (GP) Male 43 years of age)

Cost

Adults diagnosed with type 2 diabetes discussed the costs in respect of purchasing an activity tracker. The majority of those interviewed said they would pay for a device if it was to form part of their type 2 diabetes care. If prescribed by a health care professional the cost would be covered by the NHS though some suggested that with stretched budgets this may not be possible.

> *"I would be happy to pay for the activity tracker though not everyone can afford them."* (T2D Female 72 years of age)

"Cuts in funding may prevent the NHS from giving these devices to patients" (T2D Female 46 years of age)

HCP discussed the cost of purchasing an activity tracker. It was suggested that those who can afford the device should pay for it. If bought by the health care provider in bulk the cost could be reduced for the patient. For those on a limited budget the activity tracker could be prescribed.

"Our resources are stretched and those who can afford a Fitbit should pay for it. We could prescribe the Fitbit if the patient is on a low income" (HCP (GP) Male 43 years of age)

Adults diagnosed with type 2 diabetes discussed the costs associated with internet access. Those interviewed stated that they had to pay an internet provider for home access and that would be required to access their activity tracker data and the My Diabetes My Way platform. It was suggested that those on low incomes may need financial support to access the internet at home.

"Costs could also include accessing the internet." (T2D Male 61 years of age)

"Not everyone can afford internet access so they may need help to pay for this" (T2D Female 44 years of age)

HCP discussed the cost implications accessing the internet. It was suggested that those on limited incomes may need support with the costs. Poor internet coverage in rural areas could also increase access costs and make it difficult for people in these locations to utilise technology in clinical care.

> *"Not all of my patients can afford internet access"* (HCP (GP) Male 43 years of age)

> *"Basic internet access is poor on the island. More efficient systems are expensive"* (HCP (Diabetes Nurse) Female 57 years of age)

Adults diagnosed with type 2 diabetes discussed the costs associated with purchasing digital technology. They indicated that either a smartphone or computer would be needed to access activity tracker data and the My Diabetes My Way website. For those on low incomes such devices could be prescribed by NHS.

> *"Another cost would be buying a mobile phone or laptop. I already have these but some may struggle to afford them."* (T2D Female 41 years of age)

HCP discussed the costs associated with purchasing digital technology. It was highlighted that for patients to upload activity tracker data onto the My Diabetes My Way platform they would need to have either a smartphone or computer. Patients on lower incomes may need support with the cost of these items.

> *"In addition to the activity tracker users would have to have a mobile phone or PC. Not all of my patients can afford these items."* (HCP (Practice Nurse) Female 61 years of age)

Adults diagnosed with type 2 diabetes discussed the cost implications in respect of health care staff if activity trackers are used as part of type 2 diabetes treatment. The main costs identified included staff training and staff time.

> *"This will be their time and training on how to use the activity tracker"* (T2D Female 72 years of age)

HCP discussed the costs associated with health care professionals. The main costs identified were staff time and training.

> *"The main costs for our practice would be our time and any training to improve or knowledge and understanding"* (HCP (GP) Male 53 years of age)

Promotion

Adults diagnosed with type 2 diabetes discussed promotion of the My Diabetes My Way platform and how this could be signposted. Awareness of the system was low and it was indicated that better signposting by health care professionals was required. Suggested methods of communication were face-to-face consultations, posters in health service clinics, leaflets, text messages, telephone calls and emails.

"During a face-to-face consultation with a medical practitioner." (T2D Female 57 years of age)

"Other methods of promotion could be a telephone call from my diabetes nurse or an information leaflet when I attend the clinic" (T2D Female 41 years of age)

HCP discussed the promotion of My Diabetes My Way and the ability to upload activity tracker data onto the system. It was suggested that signposting should be the responsibility of the health care provider and making all staff aware. Promotion should be undertaken during face-to-face consultations with between the patient and health care professional. Staff could be made aware during team meetings and work emails.

"I would prefer to promote these during my consultation with the patient" (HCP (GP) Male 42 years of age)

"I would make all our practice staff aware during team meetings or email" (HCP (Diabetes Nurse) Female 57 years of age)

Adults diagnosed with type 2 diabetes discussed the importance of the knowledge and credibility of health care staff when promoting the use of technology in clinical care. In recommending such technology the health care staff should understand how it works, the benefits and ability to fully support the patient.

> *"The health care professional promoting should fully understand how the technology works."* (T2D Male 37 years of age)

> *"The doctor or nurse should highlight the benefits of the technology during consultations with the patient"* (T2D Female 47 years of age)

HCP discussed the importance of health care professionals being credible and knowledgeable of any technology promoted. It was suggested that health care staff would need appropriate training to gain a full understanding before discussing and promoting information technology to a patient.

> *"I would need to ensure that we all had necessary training before discussing with a patient"* (HCP (GP) Male 42 years of age)

Support

Adults diagnosed with type 2 diabetes discussed the advice and support patients may require when using an activity tracker or the My Diabetes My Way platform. The main advice focused on individuals who possess low information technology skills and confidence in using such systems. Further advice in relation to exercise and physical activity was suggested.

> *"I am not confident using computers and would need plenty of advice on how to use them."* (T2D Female 72 years of age)

"More advice on exercise and weight which I have not received during my treatment." (T2D Female 57 years of age)

HCP discussed the advice patients may require to support them when using an activity tracker and the My Diabetes My Way platform as part of their type 2 diabetes treatment. The suggested advice included how best to access and use the technology.

"Probably like my gym work sitting down with the patient and talking them through the process, identifying their needs and encouraging them." (HCP (GP) Male 43 years of age)

"Many of my elderly patients would need advice to support them using these systems." (HCP (Practice Nurse) Female 62 years of age)

Adults diagnosed with type 2 diabetes discussed the additional support they would need to compliment the use of activity trackers as part of their type 2 diabetes care. The majority stated that being prescribed a gym referral would motivate them to be more physically active.

"It would be nice to get directed to specific exercise classes for those diagnosed with type 2 diabetes." (T2D Female 46 years of age)

HCP discussed the prescription of gym referrals to support the use of activity trackers in clinical care. The majority of health care professionals stated that prescribed gym referrals were already used to support adults diagnosed with type 2 diabetes. Some suggested that the gym referral through an exercise professional should incorporate an input about activity trackers.

> *"I already refer patients to the local gym. The fitness advisor would be the best person to show the patient how to use the activity tracker."* (HCP (Diabetes Nurse) Female 61 years of age)

Adults diagnosed with type 2 diabetes discussed the support patients may need to interpret the data collected on an activity tracker. It was suggested that health care professionals with knowledge of exercise and activity trackers should conduct the interpretation and communicate this to the patient.

> *"I would suggest a dedicated member of staff with knowledge of activity trackers and exercise. At the moment activity advice is limited and only occasionally discussed. The main focus is on medication and diet."* (T2D Female 56 years of age)

HCP discussed the support patients would need to interpret the data collected from the activity tracker. It was suggested that this support would be best delivered by a qualified health care professional with knowledge of physical activity and exercise.

> *"Ideally our health authority would employ fitness instructors."* (HCP (Consultant) Male 53 years of age)

Adults diagnosed with type 2 diabetes discussed support in the form of educational packages that could be developed and used to assist patients to use activity trackers and the My Diabetes My Way platform effectively. It was suggested that the packages could be delivered online or booklet or face-to-face educational class.

> *"Some type of educational support package would assist patients to use technology in an effective manner."* (T2D Male 37 years of age)

HCP discussed patient support in the form of educational packages. It was suggested that these packages could be self-read or delivered in a classroom setting.

> *"Additional support packages could be produced or we could run special classes to support the patient."* (HCP (Diabetes Nurse) Female 61 years of age)

Technology and data

Adults diagnosed with type 2 diabetes discussed how feedback from activity tracker data could be communicated and by who. The majority suggested the feedback should be delivered during a face-to-face consultation with a health care professional. Some proposed that when activity data was uploaded onto the My Diabetes My Way platform the system interpreted the information and provided immediate online feedback and advice.

> *"I would prefer my GP or the practice nurse to give me feedback from my activity data."* (T2D Female 57 years of age)

"I have uploaded my Fitbit data onto MY Diabetes My Way. It would be great if the system would give me advice when I do this" (T2D Female 41 years of age)

HCP discussed how best feedback from technology can be communicated to the patient. It was suggested that in the majority of cases this would be best served during face-to-face consultations. In respect of the My Diabetes My Way platform participants proposed that the system analysis the uploaded Fitbit data and feedback back direct to the patient.

"Most patients would prefer feedback delivered by a health care professional" (HCP (Practice Nurse) Female 62 years of age)

"Would it be possible for the website to feedback on the Fitbit information" (HCP Male (GP) 43 years of age)

Adults diagnosed with type 2 diabetes discussed how data collected from an activity tracker and interpreted should be personalised for the user during the feedback process. This should take into account the patients' medical history and understanding of physical activity.

"I would like any feedback to be personalised for my needs." (T2D Female 44 years of age)

HCP discussed the personalisation of data obtained through technology. It was suggested that as each patient has differing needs and goals the collected data should be personalised for the individual.

> *"After analysis I would personalise the feedback for the patient."* (HCP (Diabetes Nurse) Female 61 years of age)

Adults diagnosed with type 2 diabetes discussed the motivational aspect of using data from technology in clinical care. Some suggested that activity trackers could motivate users to be more physically active. Before there use participants said that user must be motivated to engage with the technology.

> *"My Fitbit has certainly motivated me to be more active."* (T2D Female 41 years of age)

> *"Before using an activity the user must be motivated to engage with it."* (T2D Male 61 years of age)

HCP discussed how activity trackers could act as a motivational tool for patients. For this to be effective it was highlighted that the patient would need to engage with the intervention for this to be successful.

"I can see these devices motivate some people to be more active. Saying that the patient always need to engage with any treatment plan" (HCP (Consultant) Male 52 years of age)

Adults diagnosed with type 2 diabetes discussed who should manage the data obtained from activity trackers and stored on the My Diabetes My Way platform. All suggested that a health care professional such as the patients doctor, practice nurse and diabetes nurse should have responsibility for managing the storage and use of the data.

"This would be my GP or the practice nurse" (T2D Male 37 years of age)

HCP discussed the management of any data collected from patients. It was suggested that this must follow national guidelines and policy for health care organisations. Such data should be managed by the local health authority.

"Any data collected from patients must be stored and managed as per NHS policy." (HCP Female (Diabetes Nurse) 61 years of age)

Adults diagnosed with type 2 diabetes discussed the available activity tracker functions. For those with knowledge of these devices the preferred functions were daily steps, distance moved, challenges and sleep.

> *"For me it is daily steps and distance travelled. Sleep is also interesting though I don't bother too much about it unless I have a poor night's sleep."* (T2D Female 61 years of age)

> *"I enjoy the challenges as these motivate me to keep going. I can do these with friends and family"* (T2D Female 57 years of age)

HCP discussed the main activity tracker functions that could be used to support patients. The main functions identified were steps, physical activity intensity, distance walked and stairs climbed.

> *"As a gym instructor I am aware of the useful functions. These would be steps taken, the level of physical activity, the distance moved and the height climbed"* (HCP (Physical Activity Advisor) Male 42 years of age)

Discussion

The aim of this qualitative study was to explore (through the RE-AIM framework) views from adults diagnosed with type 2 diabetes and health care professionals on the integration of activity trackers into type 2 diabetes care. The study themes are discussed in alignment to the 5 main RE-AIM dimensions (Reach, Effectiveness, Adoption, Implementation and Maintenance) (Glasgow, Vogt, & Boles, 1999). Some of the identified themes crossover more than one dimension. This evaluation seeks to identify how activity trackers can be implemented and effectively used by health care organisations to support long term maintenance of active lifestyles within type 2 diabetes care. Table 15 provides a summary of how the developed qualitative themes map to the RE-AIM dimensions.

Table 15: Summary of how the developed qualitative themes map to the RE-AIM dimensions

RE-AIM main dimension	**Mapped qualitative theme**
Reach	1. Awareness 2. Promotion
Effectiveness	1. Access 2. Support 3. Technology and data
Adoption	1. Awareness 2. Cost
Implementation	1. Awareness 2. Cost 3. Technology and data
Maintenance	1. Support 2. Technology and data

Reach

In Scotland 267,615 adults are diagnosed with type 2 diabetes yet only 32,000 (12%) are presently active users of the My Diabetes My Way platform (Scottish Government, 2020) (Shields, Conway, Allardice, Wake, & Cunningham, 2023). As reach is a measure of the proportion and representativeness of a health intervention the combined use of activity trackers together with the My Diabetes My Way platform should be made more visible and available to all adults diagnosed with type 2 diabetes (Holtrop, et al., 2021). This study has shown for example that awareness of the My Diabetes My Way platform was low among the adults diagnosed with type 2 diabetes though the majority of health care professionals did have knowledge of the system. We have also shown that there is low uptake and a lack of awareness of the ability to upload activity tracker data onto the My Diabetes My Way platform. Reach could be significantly improved through better promotion of the platform and what it does and what the benefits are if people upload their tracking data. Previous research has shown that the implementation of online physical activity interventions for adults at risk of developing type 2 diabetes has only reached a small proportion of eligible patients and was not representative of the target population. Improved engagement strategies have been recommended by others to increase the level of awareness and this study has shown this to be the case for both patients and professionals (Zigmont, et al., 2018).

Effectiveness

Effectiveness is a measure of the impact an intervention will have on important outcomes (Glasgow, Vogt, & Boles, 1999). Previous research has shown that individuals who have uploaded their Fitbit data on the My Diabetes My Way platform have lower Hb1Ac blood glucose readings, less likely to develop diabetes foot problems and less likely to have suffered a myocardial infraction (Shields, Conway, Allardice, Wake, & Cunningham, 2023). When the use of activity trackers is added as part of a type 2 diabetes physical activity intervention HbA1c levels have been shown to reduce, as have BMI and sedentary behaviour (Bender, Cooper, Park, Padash, & Arai, 2017). This study has shown that people are interested in and motivated by the perceived and actual benefits of activity tracking. It would be extremely beneficial therefore to create better ways to link activity tracker data to recorded health outcomes and to physical activity guidelines on platforms such as My

Diabetes My Way and make these features and their benefits much clearer to both patients and health care professionals (RE-AIM, 2024).

Previous research has shown that personalised feedback via device informed technology can increase levels of physical activity and reduce sedentary behaviour in adults (Barwais, Cuddihy, & Tomson, 2013). Our study also confirmed that physical activity feedback should be personalised for the individual patient. Our findings also indicate that to improve effectiveness of these interventions further we would recommend that additional support should be made available to patients including advice, data interpretation and educational packages. This level of personalisation with supporting educational packages to the user will help overcome individual barriers such as digital literacy and also improve understanding of physical activity and sedentary behaviour patterns to make interventions more inclusive and effective to a wider audience.

Adoption

Adoption is the absolute number, proportion, and representativeness of settings and intervention agents (people who deliver the program) who are willing to initiate a program (Glasgow, Vogt, & Boles, 1999). Our research identified that the integration of activity tracker data onto the My Diabetes My Way platform and use within type 2 diabetes clinical care was not being routinely adopted by health care providers. Research has shown that adoption can be enhanced through stakeholders working in close partnership (Estabrooks, et al., 2011). We identified the main stakeholders as the My Diabetes My Way website developer, National Health Service (UK), regional health boards, local diabetes clinics and local medical practices. In an effort to improve adoption of activity trackers into type 2 diabetes clinical care we recommend that stakeholders identify the added value of activity tracker use in terms of improved patient health and improve awareness for both patients and health care professionals. Furthermore there is a need to develop and manage the organisational capacity through providing training to improve health care professional knowledge and understanding of implementing activity tracking into clinical care.

Implementation

Implementation refers to the various stakeholders' commitment to all aspects of an intervention's protocol, including delivery consistency and the time and cost of the program. At an individual level implementation requires an understanding of how patients use the intervention (Glasgow, Vogt, & Boles, 1999). Our research found that a protocol should be developed focusing on the implementation of activity tracker data into type 2 diabetes clinical care. We recommend that a protocol be produced which pays particular attention to organisational implementation and the development of health care staff promoting and delivering an activity tracker programme. During the development of this protocol intervention testing should be undertaken through the use of pilot studies (Wray, et al., 2023).

Results in the current study also show that health care providers are presently working with limited financial budgets. When implementing an activity tracker intervention health care organisations need to balance the costs against the health benefits. Our analysis identified costs such as purchase of activity tracker, internet access, digital technology and health care staff training. Research has shown that providing adult patients with a free of cost wearable activity tracker in combination with supporting technology can increase levels of physical activity and reduce sedentary behaviour (McCormack, et al., 2022). It would be useful to explore partnerships with commercial organisations and the opportunity to provide activity trackers at reduced or no cost. We also recommend further research and evaluation to understand how patients and health care professionals use activity trackers, the impact on health in the short and long term and further work to explore cost savings by comparing the intervention costs against any reduced health care costs.

Maintenance

Maintenance is the extent to which a program or policy becomes routine practice within stakeholder organisations. At an individual level the measure of maintenance is a patients engagement with the intervention for 6 or more months (Glasgow, Vogt, & Boles, 1999). Research has shown that adults diagnosed with type 2 diabetes require long term support and monitoring to maintain an active lifestyle after taking part in a physical activity intervention (Casey, De Civita, & Dasgupta, 2010). Personalised feedback and peer support has been shown to improve patient engagement, physical activity levels and cardiorespiratory fitness of adults diagnosed with type 2 diabetes (Sazlina, Browning, & Yasin, 2015). Many studies fail to address and assess the RE-AIM dimension of maintenance and as such few interventions last more than 6-months and fail to become routine clinical care (Shelton, Chambers, & Glasgow, 2020). Our study identified support factors to maintain patient engagement in an activity tracker intervention with the aim of becoming routine type 2 diabetes care. It is recommended that support factors such as prescribed gym referrals, patient assistance in interpreting activity tracker data, personalised data interpretation and development of a personalised physical activity educational programme be routinely incorporated into patient care.

Table 16 provides a summary of the main recommendations under each of the 5 main RE-AIM dimensions.

Table 16: Summary of main recommendations under the 5 main RE-AIM dimensions.

RE-AIM Dimension	Main recommendations
Reach	1. Better promotion be undertaken through improved signposting. 2. Increase the knowledge and awareness of health care professionals.
Effectiveness	1. Personalise physical activity feedback for the individual patient. 2. Additional support should be made available to patients including advice, data interpretation and educational packages.
Adoption	1. Stakeholders should identify the added value of activity tracker use (improved health), improving awareness (patients and health care professionals) and organisational capacity (health care professional knowledge and potential training). 2. Development of joint procedures between stakeholders.
Implementation	1. Development of an agreed protocol, 2. Development of a staff training programme. 3. Introduce measurements of costs.
Maintenance	1. Support all patients for long term engagement. 2. Develop measures of improvements to patients health.

Strengths and limitations

Through abductive thematic analysis detailed main themes and sub-themes were identified. Further evaluation of the results through the RE-AIM framework helped develop a better understanding of how the intervention could be improved and become routine practice within type 2 diabetes care. The sample size for this study was relatively small with 12 adults diagnosed with type 2 diabetes and 9 health care professionals though it was apparent that data saturation had been reached with similar responses suggested by participants within each group.

Conclusion

This study set out to explore through qualitative analysis the use of activity trackers to support physical activity and reduce sedentary behaviour in adults with type 2 diabetes. Both adults with type 2 diabetes and health care professionals suggested that with amendments the use of activity tracker data could help support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and this study has concluded with recommendations aligned to the RE-AIM framework on how to improve current implementation.

Chapter 3 Sub-Section

Sample size within qualitative research

In qualitative research, determining sample size is not a matter of statistical power but of ensuring sufficient depth and relevance to address the study's objectives. Traditional approaches have often relied on the concept of data saturation, defined as the point at which no new themes or insights emerge (Guest, Bunce, & Johnson, 2006). However, this concept has been increasingly critiqued for its ambiguity and over-simplification of the complex, interpretative nature of qualitative analysis (Braun & Clarke, 2021). As an alternative, Malterud, Siersma, and Guassora (2016) proposed the concept of information power, which suggests that the adequacy of a sample is contingent upon the richness of the data in relation to the study's aim, the specificity of the sample, and the quality of dialogue obtained. Reflecting on the Chapter 3 qualitative interview study, which explored the use of activity trackers to support physical activity and reduce sedentary behaviour in adults with Type 2 Diabetes, the sample size can be considered adequate through the lens of information power. The participants were purposively selected for their direct experience with the intervention, aligning closely with the study's focus, and provided contextually rich accounts within a theoretically informed RE-AIM framework. Although the sample size was modest, the interviews generated detailed and relevant insights that informed each dimension of the framework, suggesting that the study achieved a high degree of information power. This reinforces a growing understanding within qualitative methodology that the quality, specificity, and purpose driven selection of participants can be more meaningful indicators of sufficiency than the pursuit of saturation or arbitrary numerical targets.

Abductive interview techniques

Abductive interview techniques have gained prominence in qualitative research as a flexible and iterative approach to data generation that seeks to balance inductive openness with theoretical sensitivity. Rooted in the philosophy of abduction, originally articulated by Charles Sanders Peirce, this logic of inquiry is concerned with generating plausible explanations for surprising or puzzling phenomena, rather than simply deducing from theory or inducing from data alone (Timmermans & Tavory, 2012). In the context of qualitative interviews, abduction involves moving back and forth between empirical observations and theoretical concepts in order to iteratively refine both the questions asked and the meanings derived from participant responses. Unlike purely inductive approaches that delay engagement with theory, abductive techniques assume that researchers bring provisional theoretical expectations to the field but remain open to modification or disruption by empirical findings (Timmermmans & Tavory, 2014). This approach is particularly well suited to semi-structured interviews, where the interview guide serves as a flexible scaffold rather than a rigid script. Researchers implementing abductive interviewing typically begin with open-ended questions aligned with broad thematic interests but adjust the focus of subsequent interviews and prompts in response to emerging insights. For example, if a participant introduces an unanticipated but theoretically salient issue, the interviewer may pursue that topic further in real-time and later integrate it into subsequent interview iterations (Age & Jonsson, 2017). This reflexive adaptation reflects a commitment to theoretical inference rather than mere data description, allowing for the co-production of meaning between researcher and participant. In this way, abductive interviewing facilitates the development of middle-range theories grounded in participants' lived experiences while remaining conceptually robust. As such, it offers a powerful method for generating nuanced, theory-informed qualitative insights without prematurely foreclosing the emergence of novel patterns.

Thematic analysis

Since their foundational publication in 2006, Braun and Clarke have significantly advanced the field of thematic analysis, evolving it from a broadly defined analytic method into a structured and differentiated set of approaches. Initially presented as a flexible tool suitable across a range of theoretical frameworks, Braun and Clarke's later work (2019; 2021) more clearly distinguishes between three distinct types of thematic analysis: reflexive thematic analysis, codebook thematic analysis, and coding reliability thematic analysis. These variations are differentiated by their epistemological assumptions, analytic procedures, and intended outcomes. Reflexive thematic analysis is grounded in interpretivist and constructionist paradigms, privileging the researcher's reflexive engagement with the data and notions of inter-rater reliability or fixed coding frames. In contrast, coding reliability thematic analysis draws on more positivist assumptions, often employing multiple coders, pre-defined codebooks, and inter-coder agreement to ensure consistency and reduce subjectivity. Sitting between these poles is codebook thematic analysis, which combines a structured coding framework, typically developed in advance or early in the analysis, with iterative development, allowing for a balance between flexibility and consistency, especially in applied or team-based research settings (Braun, Clarke, & Weate, 2016).

Given the applied nature and framework driven focus of study 2, the approach most aligned with the thematic analysis is codebook thematic analysis. The study utilised the RE-AIM framework to guide both data collection and analysis, meaning that some thematic structure was anticipated and conceptually informed from the outset. Codebook thematic analysis is particularly suited to such research, where themes are often mapped against pre-existing theoretical domains, in this case, Reach, Effectiveness, Adoption, Implementation, and Maintenance. This approach enables the systematic categorisation of qualitative data within a structured framework while retaining flexibility to capture emerging insights. Although the Study 2 paper did not explicitly label the method as codebook thematic analysis, the description of using a deductively informed, framework-based thematic analysis is consistent with Braun and Clarke's (2021) characterisation of this approach. It offers a pragmatic solution in health research contexts where analytic rigour, transparency, and alignment with implementation science frameworks are crucial. Thus, the study's methodological design reflects current best practices in thematic analysis, applying a structured yet adaptable strategy well suited to its translational aims.

Concepts of rigour and quality in qualitative research

The concepts of rigour and quality in qualitative research have evolved beyond procedural checklists and have instead come to embrace principles of transparency, reflexivity, and depth of engagement. Brett Smith (2017) offers a critical re-conceptualisation of qualitative rigour, advocating for a move away from mechanistic criteria such as member checking or inter-rater reliability, and towards a more holistic assessment of the coherence, richness, and resonance of the findings. Brett Smith (2017) emphasises the importance of demonstrating a “commitment to craft” through reflexive engagement with data, ethical sensitivity, and attentiveness to meaning making. Within this conceptual framework, Study 2 can be seen as exhibiting a strong sense of qualitative rigour. For example, the thesis author engaged in iterative discussions during the analytic phase, using the RE-AIM framework not as a rigid template but as a flexible guide that allowed for emergent insights. This reflexivity, although methodologically significant, was more clearly articulated during the VIVA than in the published account. Additionally, the thesis author’s responsiveness to unexpected findings, such as the nuanced barriers participants experienced in sustaining activity tracker use, reflected a depth of engagement and openness to complexity that aligns with Smith’s (2018) notion of quality. By foregrounding interpretive integrity and theoretical sensitivity, the study demonstrates how rigour can be embedded in the analytic process itself, even when such processes are not always made fully visible in written outputs.

Best reporting practices for qualitative research

The Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist is a rigorously developed instrument aimed at enhancing transparency and quality in reporting qualitative studies involving interviews and focus groups. It comprises 32 items, organised across three domains, each addressing crucial aspects of qualitative methodology (Tong, Sainsbury, & Craig, 2007).

Domain 1: Research Team & Reflexivity (Items 1–8)

- Personal characteristics: identification and disclosure of interviewer's credentials, occupation, gender, experience, and training—essential for assessing potential biases.
- Relationship with participants: details on whether pre-existing relationships exist, what participants knew about the interviewer, and any relevant assumptions or reasons, to contextualise data interpretation.

Domain 2: Study Design (Items 9–23)

- Theoretical framework: articulation of methodological orientation (e.g. grounded theory, phenomenology, ethnography, discourse/content analysis) guides the analytic lens.
- Participant selection: methods (purposive, convenience), approach, sample size, and reporting of non-participation or dropouts reinforce credibility.
- Setting: documentation of data collection environments, presence of others, and key participant characteristics (demographics, dates).
- Data collection: inclusion of interview guides, pilot testing, repeat interviews, recording methods, field notes, duration, saturation, and validation (e.g. returning transcripts to participants) ensures data integrity.

Domain 3: Analysis & Findings (Items 24–32)

- Data analysis: number of coders, coding tree description, derivation of themes (a priori vs emergent), software used, and potential participant feedback on findings.
- **Reporting**: illustration of themes with participant quotations (with identifiers), coherence between data and interpretations, and explicit description of major and minor themes—including deviant cases.

This comprehensive checklist serves as a standard for evaluating and strengthening qualitative research reporting, ensuring clarity, reflexivity, and methodological rigor (Tong, Sainsbury, & Craig, 2007).

Critical Analysis of Study 2 Using COREQ

Study overview

Study 2 explored stakeholders' views, 12 adults with type 2 diabetes and 9 healthcare professionals, on integrating activity trackers into type 2 diabetes care, framed via the RE-AIM framework. Semi-structured interviews with abductive thematic analysis was employed, identifying six core themes and 20 sub-themes.

Within study 2 the main methods which adhered to the COREQ checklist were:

1. Participant selection: The study provided a clear description of purposive recruitment via social media and professional contacts, with sample size detailed (12 patients, 9 professionals).
2. Data collection: Semi-structured one-on-one interviews were explicitly described; use of interview guides was indicated, though details on pilot testing remain unclear .

3. Analytic rigor: Abductive thematic analysis was declared, aligning with methodological orientation and clear derivation of themes .
4. Reporting clarity: Results include named themes and subthemes, though the article could have been more explicit whether participant quotes were systematically anchored to coded identifiers.

On reflection the following methods have been identified as not meeting the COREQ checklist and are identified as study limitations:

- Researcher reflexivity: The study does not report interviewer credentials, training, or reflexive positioning, as required in COREQ Domain 1.
- Interviewer-participant relationship: The study lacks clarity on pre-existing relationships, assumptions, or participant understanding of researchers, which is a key omission under Domain 1.
- Coding procedures: The number of analysts and the presence of a coding tree or audit trail aren't specified, potentially weakening rigor under Domain 3.
- Data saturation & participant checking: The study makes no explicit mention of saturation or returning transcripts to participants for validation, which leave COREQ items 22 and 23 remain unaddressed.

In respect of methodological alignment, COREQ emphasises systematic disclosure and reflexivity. Study 2 provides strong thematic and procedural transparency but falls short on reporting reflexive positionality and coder triangulation. The rigorous adoption of RE-AIM enhances conceptual clarity, yet COREQ would benefit from richer portrayal of analytic procedures (e.g. codebook evolution) and study reflexivity. Suggestions for strengthening the report so as to align with the COREQ checklist include:

- Include reflexivity statements: Outline interviewer backgrounds, training, assumptions, and relationships to participants.
- Detail analytic process: Specify number of coders, coding tree structure, and checking procedures (e.g. inter-coder reliability, participant validation).
- Report saturation: Define how and when theme saturation was judged.
- Anchor quotations: Present illustrative quotes with participant identifiers and source context.

In conclusion, the COREQ 32-item framework offers a valuable benchmark for enhancing transparency and rigor in qualitative reporting. While Study 2 demonstrate strength in thematic clarity, participant selection, and theoretical framing, the reporting would be strengthened by fuller adherence to COREQ's domains, especially reflexivity, coding transparency, and participant validation. Integrating these elements would improve credibility and reproducibility, producing deeper insight into how activity trackers may support type 2 diabetes self-management.

Chapter 4

Exploring the integration of consumer activity trackers into a community weight management intervention to support physical activity in adults at risk or with type 2 diabetes: A mixed methods study using the RE-AIM framework.

Preface

Study 3 allowed the author to explore the integration of consumer activity trackers into a community weight management intervention to support physical activity in adults at risk or with type 2 diabetes. This study allowed the author to implement and further explore the findings from Study 1 and 2 into a real life weight management behavioural change intervention. The author chose to undertake this through a mixed methods design (qualitative and quantitative analysis). By combining these 2 methods allowed for a more in depth understanding of activity tracker use and integration into type 2 diabetes clinical care. The study co-author David Kennedy was a co-ordinator for the Weigh to Go programme and he was also studying for an MRes under the supervision of Dr Alison Kirk. This relationship allowed the author to access this intervention and recruit participants. As with studies 1 and 2 the author took on the lead role with support from David Kennedy and the PhD supervisors. The author developed a comprehensive study protocol, obtained ethical approval, recruited participants with support from the Weigh to Go implementation team, set up baseline and end of study questionnaires, set up Fitbit accounts for participants, arranged for each participant to be provided with a Fitbit Charge 5 activity monitor, downloaded participants activity tracker data and conducted quantitative analysis, conducted semi-structured interviews with participants including health care professionals, transcribed recorded interviews, using abductive thematic analysis (as per Study 2) identified main themes and sub-themes and evaluated the findings using the RE-AIM framework (Glasgow, et al., RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review, 2019). The semi-structured interviews allowed the author to explore in depth the participants experiences of the intervention to better understand the integration of activity trackers into clinical care. Participants experiences could not be established through quantitative analysis alone. Initially the recruitment criteria included only adults diagnosed with type 2 diabetes but only a small number of participants consented to take part in the study. As the focus was integrating activity trackers into the weight management intervention the author expanded the recruitment criteria to include all adults registering on the Weigh to Go intervention. Another obstacle during the study was accessing the Fitbit accounts and some participants activity data. This occurred due to security measures applied by Google who own Fitbit (this is covered in more detail within paper 3). Though the author found solutions to accessing the activity tracker data it was not possible to download all participants data. This was valuable information for potential future studies which plan to use Fitbit devices. Again using the RE-AIM framework for evaluation allowed the author to maintain continuity between all 3 studies and identify recommendations for the integration of activity trackers into type 2 diabetes clinical care. At the submission of the PhD thesis the author has written up his findings in a journal article format (see below) but this has still to be submitted for peer review into the Journal of Medical Internet Research Diabetes.

Paper 3

Exploring the integration of consumer activity trackers into a community weight management intervention to support physical activity in adults at risk or with type 2 diabetes: A mixed methods study using the RE-AIM framework.

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Tables: 9

Figures: 5

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Abstract

Background

Globally 483 million adults are living with type 2 diabetes and, this number is increasing. It is estimated that annually 6 million people die prematurely from the disease. A major risk factor of developing type 2 diabetes are low levels of physical activity. Physical activity interventions can reduce the risk of developing type 2 diabetes and for those diagnosed with the disease improve metabolic health. Consumer activity trackers when combined with a behavioural change intervention have been shown to increase levels of physical activity in adults diagnosed with type 2 diabetes.

Aim

To explore the integration of consumer activity trackers into a community weight management intervention to support physical activity in adults at risk or with type 2 diabetes.

Methods

A mixed methods (quantitative and qualitative) approach used to allow for a more comprehensive analysis. Participants were recruited at registration for a community-based weight management intervention in Lanarkshire, Scotland, UK, called Weigh to Go. Health care professionals involved in the delivery of this intervention were recruited via email. Weigh to Go participants were provided with a Fitbit Charge 5 consumer activity tracker to record their physical activity data. The recorded activity data included daily steps and moderate and vigorous intensity physical activity. One to one semi-structured interviews were conducted with 10 Weigh to Go participants and 10 health care professionals. Qualitative thematic analysis was undertaken, and themes were identified. Quantitative statistical analysis was conducted on the participants recorded Fitbit data. The RE-AIM framework was used to interpret the data collected.

Results/Findings

Overall, participants' daily steps increased significantly ($p = .002$) between week 1 and week 7 (mean difference = 5345 steps, $F(3, 45) = 5.93$, $p = .002$, $n^2 = .19$). The qualitative findings revealed that: (i) Providing devices for free was considered important especially for increasing the reach of such interventions; (ii) Educational classes could be beneficial for increasing the effectiveness of such interventions – and should focus on how to use the tracker and how to interpret the data it produces; (iii) Staff would also benefit from understanding more how the devices work, are used and what the data means – this could lead to the wider adoption of the trackers within weight management interventions; (iv)

Management involved in the delivery of such interventions would benefit from developing a protocol which sets out in detail the introduction of activity trackers, their use, data analysis, measures of effectiveness and programme costs – this would ensure an effective and efficient implementation of activity trackers into weight management interventions; (v) Extending the compulsory attendance of participants to all weight management intervention classes was suggested – this could improve the long-term maintenance of such programmes.

Conclusion

Through this study we showed that it is possible to integrate consumer activity trackers into a community weight management intervention. By using the RE-AIM framework we have revealed that factors such as activity tracker provision and use, education, protocol development and compulsory attendance are likely to increase the success of the use of activity trackers in weight management interventions.

Keywords

Type 2 diabetes, physical activity, sedentary behaviour, Fitbit, activity tracker, adults, Weigh to Go, weight management, RE-AIM framework

Introduction

Type 2 diabetes mellitus is a chronic noncommunicable disease that occurs when the body cannot produce enough insulin, which facilitates the uptake of glucose into cells. This in turn raises blood glucose levels. If left untreated type 2 diabetes can lead to premature death. Complications of type 2 diabetes include a higher risk of developing cardiovascular disease, retinopathy, neuropathy and nephropathy (Deshpande, Harris-Hayes, & Schootman, 2008).

Globally it is estimated that 483 million adults (20-79 years of age) are living with type 2 diabetes and by 2045 this number is set to rise to 700 million (Sun, et al., 2022). In the UK 5 million adults have been diagnosed with type 2 diabetes and their treatment costs the National Health Service (NHS) £12 billion each year (Diabetes UK, 2025). Major risk factors for developing type 2 diabetes are physical inactivity, sedentary behaviour and being overweight or obese (Deshpande, Harris-Hayes, & Schootman, 2008). Adults diagnosed with type 2 diabetes have been shown to be less physically active and spend more time being sedentary when compared with those who do not have the disease (Kennerly & Kirk, 2018). The American Diabetes Association has stated that physical activity can help prevent adults developing type 2 diabetes and for those already diagnosed with the disease it can improve their diabetes and general health (Colberg, et al., 2016). Even low intensity physical activity and a reduction in sedentary behaviour can bring health benefits for adults diagnosed with type 2 diabetes by lowering their blood glucose levels and body mass index (BMI) (Delevatti, et al., 2019) (Sardinha, Magalhães, Santos, & Júdice, 2017).

Physical activity interventions can significantly reduce the blood glucose levels in adults diagnosed with type 2 diabetes (Delevatti, et al., 2019) (Sardinha, Magalhães, Santos, & Júdice, 2017) (Avery, Flynn, van Wersch, Sniehotta, & Trenell, 2012). Physical activity interventions which incorporate wearable technology such as consumer activity trackers and pedometers have been developed for adults diagnosed with chronic noncommunicable diseases including those living with type 2 diabetes (Franssen, Franssen, Spaas, Solmi, & Eijnde, 2020). Consumer activity trackers, including Fitbit models, have been shown to be valid and reliable devices for measuring users' daily steps and physical activity intensity (White, et al., 2024). Physical activity interventions which incorporate a consumer activity tracker have been shown to lower blood glucose levels, reduce BMI, increase activity and reduce sedentary time in adults living with type 2 diabetes (Bender, Cooper, Park, Padash, & Arai, 2017). Physical activity interventions which combine an activity tracker with either a behavioural change intervention or web-based platform can bring significant health improvements for type 2 diabetes patients (Lim, et al., 2016). In addition, consumer activity trackers have the potential to allow health care professionals to remotely monitor people's physical activity as part of their clinical care and for the person to self-manage their activity through feedback from the device (Shei, Holder, Oumsang, Paris, & Paris, 2022). Community based weight management interventions are one way to try and support the use of activity trackers by overweight adults and promote physical activity in this population (NHS Lanarkshire, 2024).

The aim of this study was to explore through a mixed methods study using the RE-AIM framework the integration of consumer activity trackers into a community weight management intervention to support physical activity in adults at risk or with type 2 diabetes.

Methods

This was a mixed methods study which was granted ethical approval by the relevant University of Strathclyde department University Ethics Committee (ethics approval number 2454) (Appendix J). All participants provided written consent to take part and to ensure anonymity each was assigned a unique four-digit identification number. A data management plan was prepared for this study (Appendix K).

The Study Context: Weigh to Go intervention

The Weigh to Go intervention is an established community-based weight management behavioural change programme based in Lanarkshire, Scotland. Sessions were held within 12 local community centres and sports centres. The intervention consists of a 15-week active phase and 15-week maintenance phase. In the active phase participants receive a 45-minute educational workshop and 45-minute circuit-based physical activity session each week. Each session has been developed to stand alone, and evidence-based content has been development by dieticians, nurses and psychologists (NHS Lanarkshire, 2024). Sessions include discussion and reflection on dietary educational content as well as activities to support positive and sustainable behaviour change through Motivation, Action, Prompts (MAP) informed health behaviour change strategies (Dixon & Johnston, 2020). In the Maintenance phase participants receive a short session with reflection on what was covered during the equivalent week in active phase alongside 45 minutes of physical activity. Attendance at the maintenance sessions is optional, however attendance at the active phase classes is expected. The standard physical activity component is circuit-based with adaptations to accommodate most levels of fitness and mobility. The intervention is free for participants and is delivered in local leisure centres and community facilities. The Weigh to Go intervention has the potential to be an effective community-based programme to support weight management and physical activity for adults with Type 2 diabetes and those at high risk of developing the disease. However, referral and adherence of adults with type 2 diabetes to the Weigh to Go intervention has been low and there has been limited evaluation, particularly of longer-term physical activity behaviour change. Health professionals also report limited follow up on the progress of people they have referred (NHS Lanarkshire, 2024).

Justification for the addition of activity trackers into the weigh to go programme

In weight management programmes like Weigh to Go, client referral and sustained adherence are crucial determinants of success. Yet, traditional interventions relying primarily on dietary advice and tracking, with limited assessment of physical activity and often face high dropout rates (Cheatham, Stull, Fantigrassi, & Motel, 2018) The Integration of wearable activity trackers could address these gaps and support self-monitoring of physical activity, behaviour change and ongoing engagement. Patients referred to weight management services frequently disengage early; lack of ongoing feedback contributes to this attrition (Ferguson, et al., 2022). Wearables provide continuous self-monitoring, one of the most effective behaviour change techniques, which has been shown to mediate weight loss. Moreover, users who consistently track physical activity lose significantly more weight than low adherers (Pourzanjani, Quisel, & Foschini, 2016).

Wearables deliver critical behaviour change strategies. Self-monitoring and goal setting can be achieved through step tracking and recording of active minutes, which enhances motivation and self-awareness (Sullivan & Lachman, 2017). Feedback and habit formation can be achieved through automated reminders to support long-term adherence (Ellingson, et al., 2019). Providing a professional oversight through consultations has been shown to significantly boost physical activity outcomes (Hodkinson, et al., 2021). Meta-analyses show wearables improve activity levels (~1,800 additional steps/day, 40 mins walking/day) and reduce body weight (~1 kg) across clinical populations (Ferguson, et al., 2022). In overweight adults, activity tracker inclusive interventions outperformed standard programmes over ≤6 months, particularly among middle-aged and older adults (Cheatham, Stull, Fantigrassi, &

Motel, 2018). Another meta-analysis reported moderate to large, standardised increases in daily steps (SMD 0.54) and moderate to vigorous physical activity (SMD 0.47), with meaningful reductions in weight and BMI (Dehghan Ghahfarokhi, Vosadi, Barzegar, & Saatchian, 2022).

The Weigh to Go programme typically secures referrals based on clinical or motivational criteria. However, post-referral, clients often lose momentum (NHS Lanarkshire, 2024). Embedding wearables at the referral point could potentially increase immediate engagement by giving clients tangible metrics and daily goals, produce early positive results for participants. This could also encourage long term adherence and provide continuous data to tailor individual support. Pairing trackers with professional guidance has the potential to create a multimodal intervention, diet, activity, technological feedback, and counselling, which yields better short-term outcomes than standard programmes alone (Cheatham, Stull, Fantigrassi, & Motel, 2018).

Incorporating physical activity trackers into the Weigh to Go programme has the potential to address critical gaps in referral and adherence. They operationalise evidence based behaviour strategies, self-monitoring, goal setting, feedback, supported by robust meta-analytic evidence. When paired with professional oversight, trackers enhance engagement, mitigate dropout, and drive measurable improvements in activity and weight loss. This tech-enhanced model not only aligns with best practices in behavioural medicine but also leverages scalable tools to boost programme effectiveness and sustainability.

Participants

Adults registered on the community Weigh to Go intervention

Participants were recruited via a study flyer at various venues hosting the registration stage of the Weigh to Go intervention. The initial inclusion criteria included adults aged 18+ years (no upper limit set), diagnosed with type 2 diabetes or at risk of developing the disease, residing in the U.K, access to internet services and able to read and write in English. Exclusion criteria included not having been diagnosed with type 2 diabetes or not at risk of developing the disease and had been advised by a health care professional not to undertake physical activity. Participants interested in taking part in the study were asked to email the research team. The study participant information sheet and consent form (Appendix L) were uploaded onto the secure Qualtrics survey system. A link to this form was emailed to interested participants and their consent recorded by indicating 'yes' on the Qualtrics consent form. Once consent was received participants were emailed a link to a baseline questionnaire on the Qualtrics system. This questionnaire gathered demographic details, educational level, present activity tracker use, and health conditions.

Health care professionals

Health care professionals (n=10) involved in the delivery and onboarding for the Weigh to Go intervention were recruited via an email from the research team. Recruitment criteria included adults aged 18 + years, residing in the UK and a health care professional (e.g. doctor, nurse, fitness instructor or Weigh to Go intervention administrator). The study participant information sheet and consent form (Appendix M) was uploaded onto the secure Qualtrics survey system. A link to this form was emailed to participants and their consent recorded. Once consent was received a link to a Qualtrics survey system questionnaire was emailed to the participant to gather information in respect of demographics, qualifications and job role characteristics.

Procedure

A summary of the study procedures for the Weigh to Go intervention participants are provided in Figure 10. A summary of the study procedures for the Weigh to Go health care professionals are provided in Figure 11.

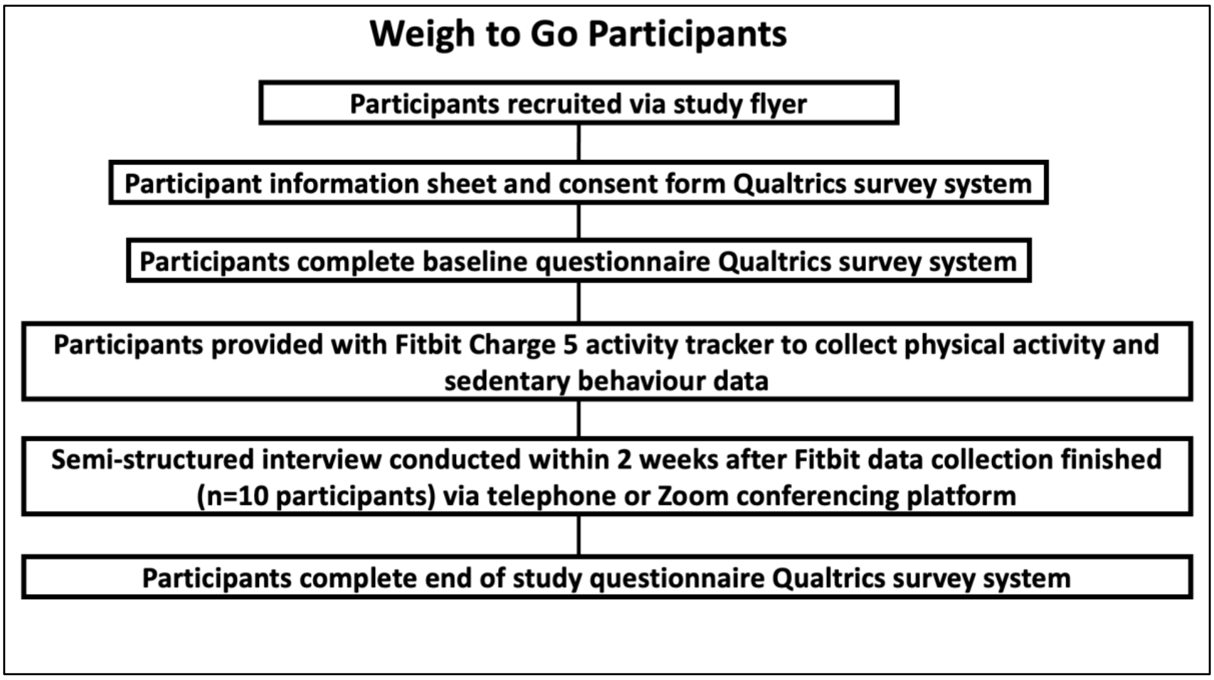

Figure 10: Flow diagram showing summary of study procedures for the Weigh to Go intervention participants.

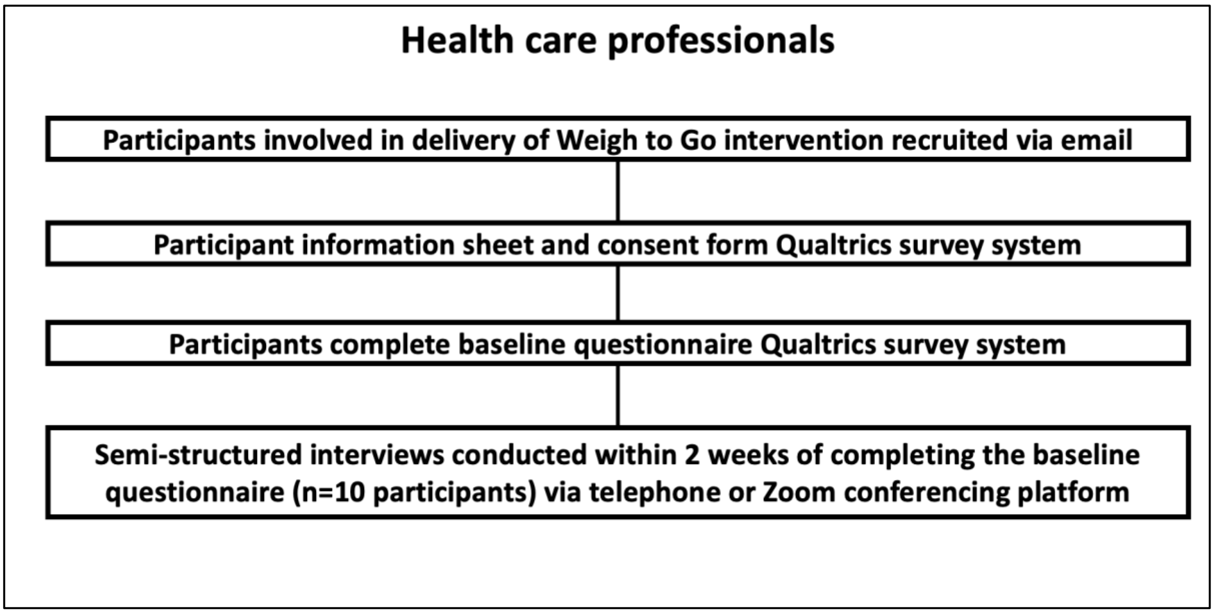

Figure 11: Flow diagram showing summary of study procedures for the Weigh to Go intervention health care professionals.

Data collection

Quantitative data collection

Once participants had consented and completed the study baseline survey, they were provided with a Fitbit Charge 5 device (provided free of charge by Fitbit UK), which they were allowed to keep at the conclusion of the study. The research team set up an individual Fitbit account for each participant (email address (Google Gmail) and password), to allow both the participant and study team to access the activity data from the Fitbit device. Instructions on how to access this account and set up the Fitbit device were emailed to each participant. Additional support was provided, if required, via email, telephone or face to face contact with the participants at the Weigh to Go venue. Participants were asked to use the Fitbit device over the period of time they attended the Weigh to Go intervention. Once each participant finished attending the Weigh to Go intervention, they were sent an email containing a link to the Qualtrics end of study questionnaire (Appendix N). The research team downloaded the participants Fitbit activity data from the Fitbit account. The downloaded data included daily steps and weekly minutes of moderate to vigorous intensity physical activity (Appendix O). The Fitbit and baseline/end of study questionnaire data were uploaded onto SPSS statistical software for analysis.

Qualitative data collection

This study adopted a qualitative design to explore experiences of Fitbit use and engagement with the Weigh to Go intervention. The methodological orientation was constructivist and interpretivist, recognising that knowledge is co-constructed through interaction and shaped by social and contextual factors (Lincoln & Guba, 1985) (Patton, 2015). Data were generated through semi-structured interviews and analysed using Braun and Clarke's (2006, 2019, 2021) reflexive thematic analysis. Reporting followed the COREQ 32-item checklist (Tong, Sainsbury, & Craig, 2007), ensuring transparency across domains of the author and reflexivity, study design, and analysis.

Study Design and Participants

One-to-one interviews were conducted with two groups:

- Ten Weigh to Go participants purposively sampled from those who provided Fitbit data, and
- Ten health care professionals drawn from the staff members involved in delivering the intervention.

Although participants were randomly selected within these eligible pools, the design was guided by a purposeful sampling logic, ensuring recruitment of individuals directly engaged with Fitbit use or intervention delivery (Patton, 2015). This approach balanced fairness in selection with the need for information rich accounts.

Sample size in qualitative research is not determined by statistical representativeness but by the adequacy of data to address research questions and generate meaningful insights (Malterud, Siersma, & Guassora, 2016; Saunders et al., 2018). The decision to recruit 20 participants in total was informed by methodological principles of *information power*, which suggests that smaller samples may be sufficient when study aims are specific, participants are closely aligned with the topic of inquiry, and the analysis is detailed (Malterud et al., 2016). Reflexive thematic analysis does not prescribe a fixed number of interviews; rather, it emphasises depth, variation, and interpretive engagement over numeric thresholds (Braun & Clarke, 2019). Empirical benchmarks indicate that major thematic patterns can often be captured with 12–15 interviews in relatively homogenous samples (Guest, Bunce, & Johnson, 2006; Hennink, Kaiser, & Marconi, 2017), although professional perspectives typically add diversity and nuance (Mason, 2010). Accordingly, this study adopted a pragmatic balance between analytic richness and feasibility, monitoring sufficiency throughout analysis and justifying the final sample size on grounds of analytic adequacy rather than saturation as a fixed endpoint (Braun & Clarke, 2019; Saunders et al., 2018).

Data Collection

A semi-structured interview schedule (Appendix P) was designed around the five RE-AIM dimensions, Reach, Effectiveness, Adoption, Implementation, and Maintenance (Glasgow et al. 2015). These dimensions provided a structured yet flexible scaffold for exploring experiences of intervention use and delivery.

An abductive interviewing approach was adopted (Shorten & Smith, 2017), enabling the author to attend to participants' lived experiences while actively probing surprising, contradictory, or unanticipated insights. This iterative, dialogical style supported the generation of richer explanations by moving fluidly between empirical data and sensitising theoretical concepts (Timmermans & Tavory, 2012).

Interviews were conducted via secure Zoom video conferencing or by telephone, based on participant preference. Each interview lasted between 45–90 minutes, was audio-recorded on an encrypted Dictaphone, and then transcribed verbatim. Transcripts were anonymised, checked for accuracy, and uploaded to NVivo-12 for data management.

Justification for Abductive Analysis

The study employed abductive analysis because neither purely inductive nor deductive logics were sufficient for the research aims.

- Inductive approaches, while useful for grounded, bottom-up coding, risk limiting interpretation to surface-level description without connecting findings to broader explanatory frames (Patton, 2015).
- Deductive approaches, by contrast, can over constrain interpretation through rigid application of pre-existing theories, missing novel or contextually embedded meanings (Timmermans & Tavory, 2012).

Abduction provided a middle ground: an iterative process of moving between empirical observations and theoretical frameworks (Peirce, 1998). In this study, abduction was particularly well-suited because:

1. Surprise and anomaly were expected. Weigh to Go participant and healthcare professional experiences with Fitbit use could not be fully anticipated, and abduction supported theorising around unexpected findings.
2. The RE-AIM framework informed but did not restrict analysis. Abduction enabled findings to dialogue with RE-AIM concepts, without being forced into them.
3. The goal was to generate plausible, explanatory insights. Abduction encourages researchers to adjudicate between rival explanations, ensuring that final themes represent the most coherent and plausible interpretations (Tavory & Timmermans, 2014).

Thus, abduction was methodologically congruent with reflexive thematic analysis, which views researcher subjectivity and theoretical engagement as analytic resources rather than sources of bias (Braun & Clarke, 2019).

Data analysis

The framework to guide analysis

The RE-AIM framework is a planning and evaluation tool used to improve the adoption and sustainable implementation of health-related interventions from research settings into real world working environments (Glasgow, Vogt, & Boles, 1999). The main RE-AIM dimensions are Reach, Effectiveness, Adoption, Implementation and Maintenance. Reach is defined as the absolute number, proportion and representativeness of individuals participating in each initiative. Effectiveness is the impact of an intervention on outcomes, including potential negative effects, quality of life, and health components. Adoption is the proportion, representativeness and absolute number of organisational agents involved in the intervention. Implementation is set at an organisational level and how the program was delivered by staff. Maintenance is defined as the extent to which a program or policy becomes embedded in routine practice (Glasgow, Vogt, & Boles, 1999). At an individual level maintenance is a measure of the long-term impact of an intervention over 6-months (Glasgow, et al., RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review, 2019).

Quantitative data analysis

Descriptive analysis and repeated measures one-way ANOVA tests were undertaken on the Fitbit data collected. One-way within-subjects ANOVA statistical tests were conducted to measure the effect of the participants use of the Fitbit Charge 5 activity tracker on their physical activity over a twenty-week period. Magnitude of change was measured between week 1, week 7, week 15 and week 20 in relation to daily steps taken (number taken) and weekly moderate to vigorous intensity physical activity (minutes). The dependent variables were (1) mean daily step count and (2) mean weekly minutes of MVPA.

The independent variable was time, with four repeated measures corresponding to week 1, week 7, week 15, and week 20. This design enabled assessment of within-subjects changes in physical activity across the intervention and immediate post-intervention phases.

Although the repeated-measures ANOVA assumes normally distributed data, inspection of residuals indicated that deviations from normality were minimal and within acceptable bounds for parametric testing. Given the moderate sample size, the ANOVA was considered robust to minor violations of normality. However, a non-parametric alternative (Friedman test) was also considered. In exploratory analyses, results from the Friedman test were consistent with the ANOVA findings, supporting the validity of the conclusions. Nonetheless, the parametric approach was retained as the primary method due to its greater interpretability and the ability to report effect sizes. The choice of time points (week 1, week 7, week 15, and week 20) was methodologically and practically driven. Week 1 acted as the initial reference point at the start of the intervention. Week 7 corresponded with the midpoint of the 15-week active phase, allowing assessment of early change and adherence. Week 15 marked the end of the active intervention phase, providing a natural point for evaluating intervention effects. Week 20 was included to assess whether physical activity behaviour was maintained after the active phase concluded, aligning with the RE-AIM framework's emphasis on maintenance. Data beyond week 20 (i.e., week 25 and 30) were too sparse for valid statistical analysis and could have risked compromising participant anonymity.

Qualitative data analysis

Data analysis followed Braun and Clarke's reflexive thematic analysis. NVivo-12 was used for organising codes and data extracts, but interpretation remained the authors responsibility. Analysis was iterative and abductive, proceeding through Braun and Clarke's six phases:

1. Familiarisation. The author immersed himself in transcripts and audio, producing reflexive memos that captured first impressions, contradictions, and anomalies.
2. Generating initial codes. Coding was conducted across the dataset at both semantic (descriptive) and latent (interpretive) levels. Abductive reasoning supported flexible refinement of codes when unexpected insights emerged.

3. Constructing candidate themes. Codes were collated into candidate themes representing shared patterns of meaning relevant to the research question. Rival candidate structures were considered and abductively evaluated for explanatory power.
4. Reviewing and refining themes. Candidate themes were tested against data extracts and the dataset as a whole. Incoherent or redundant themes were reworked, merged, or discarded. Negative cases were actively sought to challenge emerging interpretations.
5. Defining and naming themes. Each theme was clearly defined with a central organising concept and explanatory warrant. For example, the theme Fitbit as accountability partner captured both motivational and burdensome aspects of device use.
6. Producing the report. Themes were written into an analytic narrative, weaving data extracts with interpretation to build plausible explanations that extended beyond description. Quotations were included as analytic evidence, not mere illustrations (Braun & Clarke, 2019).

Reflexivity and Rigour

In line with COREQ principles (Tong et al., 2007), reflexivity was integral throughout. Regular supervisory meetings provided reflexive dialogue and guarding against premature closure of analysis. Trustworthiness was addressed using strategies congruent with reflexive thematic analysis (Nowell, Norris, White, & Moules, Thematic analysis: Striving to meet the trustworthiness criteria, 2017) (Tracy, 2010):

- Credibility through prolonged engagement with data, reflexive memoing, and analytic dialogue.
- Dependability via a transparent audit trail documenting coding iterations and theme refinements.
- Confirmability by explicitly acknowledging researcher subjectivity as a resource in interpretation.
- Resonance and contribution by producing findings with conceptual and practical utility for digital health intervention design.

Results

Weigh to Go participants recruitment and retention

Details of the Weigh to Go participants recruitment and retention are displayed in Figure 12.

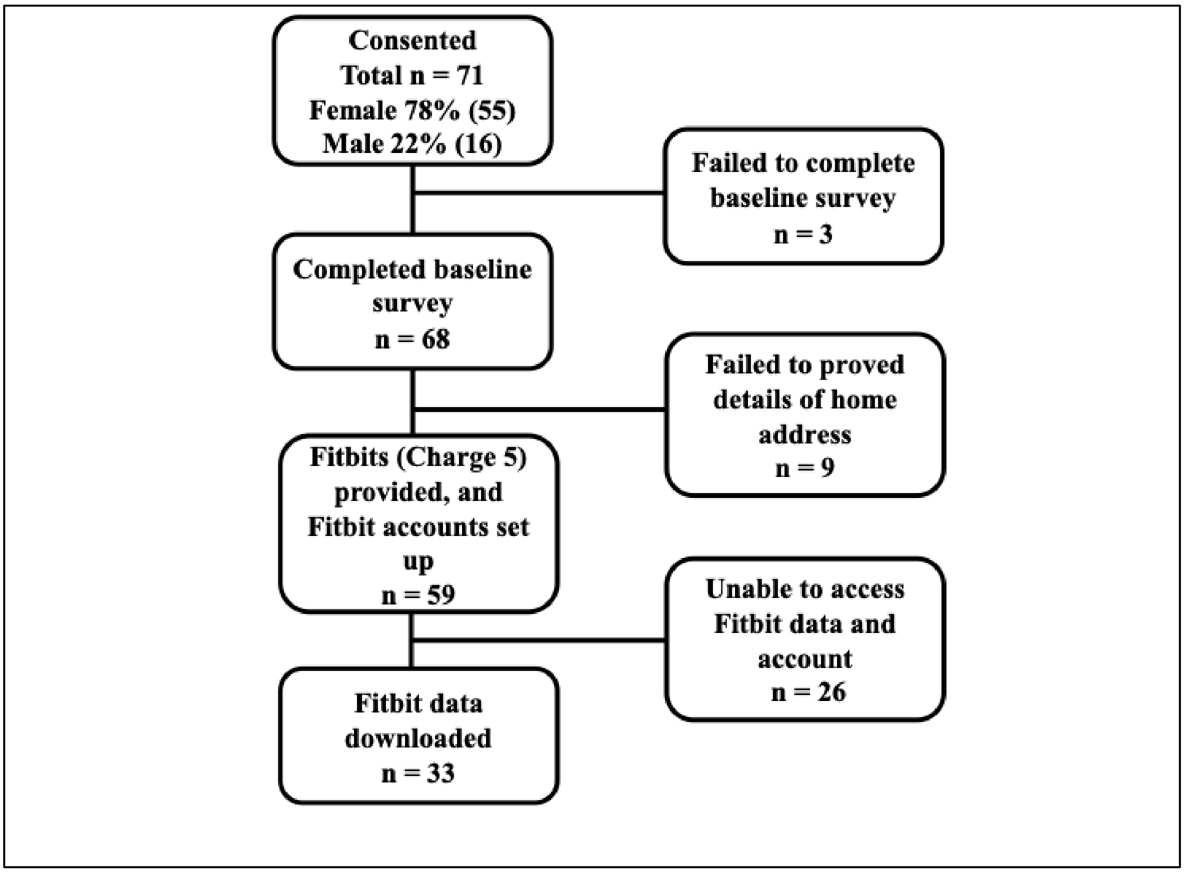

Figure 12: Weigh to Go participants recruitment and retention.

Explanation of Fitbit Data Loss and Its Implications

In research involving digital health technologies, data integrity is paramount. Wearable activity trackers such as Fitbits offer researchers valuable opportunities to collect continuous, real-world data on physical activity. However, technological and procedural challenges can hinder data acquisition, leading to significant data loss. This was observed in the present study, where Fitbit data loss affected both the completeness of analyses and the generalisability of findings.

Figure 12 illustrates participant recruitment and retention throughout the Weigh to Go intervention. Although participants were provided with Fitbit devices and accounts were set up by the research team, unexpected changes to Google's security protocols during the study period caused substantial disruption. Specifically, midway through data collection, Google introduced additional two-step verification processes for Fitbit accounts. This required participants to authorise access to their Fitbit data via a smartphone code linked to their Fitbit mobile application. Consequently, the research team could no longer directly access the accounts to download data.

To mitigate this, the team attempted to schedule telephone authorisations with participants during the download process. However, many participants (n=26) failed to respond to emails or were otherwise unavailable, which prevented access to their data. This issue ultimately resulted in the loss of approximately 44% of participant Fitbit datasets, thereby contributing to the attrition shown in Figure 12.

Participants demographics

Weigh to Go participants demographics are displayed in Table 17. Health care professional participants demographics are displayed in Table 18.

Table 17: Weigh to Go participants demographics.

	Percentage (n)	**Mean (SD)**
Age (years)		54.6 (12.24)
Sex		
Male	18% (6)	
Female	82% (27)	
Educational qualifications		
Degree	27% (9)	
SVQ	27% (9)	
School qualifications	18% (6)	
Higher education	21% (7)	

Other qualifications	7% (2)	
Ethnicity		
White	100% (33)	
Area of residence		
Rural	9% (3)	
Urban	91% (30)	
Health conditions		
Type 2 diabetes	52% (17)	
Arthritis	27% (9)	
Mental health	15% (5)	
Asthma	9% (3)	
COPD	3% (1)	
Stroke	3% (1)	
Heart disease	3% (1)	
Learning difficulties	3% (1)	
Previous use of an activity tracker		
Yes	6% (2)	
No	94% (31)	

Table 18: Health care professional participants demographics.

	Percentage (n)	**Mean (SD)**
Age (years)		51.3 (9.7)
Sex		
Male	30% (3)	
Female	70% (7)	
Educational qualifications		
Degree	70% (7)	
SVQ	30% (3)	
Ethnicity		
White	90% (9)	
Asian	10% (1)	

Quantitative data analysis

Results are presented under the appropriate RE-AIM main dimensions (reach, effectiveness, adoption, implementation and maintenance).

Reach

Seventy-one adults consented to take part in the study between July 2023 and January 2024. Of those who consented 55 (78%) were female and 16 (22%) were male. All 71 participants were white. We were unable to calculate the total number of Weigh to Go participants approached to take part in this study as this was not recorded by the intervention staff. In total 705 participants attended the Weigh to Go session venues targeted for this study (10% of these consented to take part). The average number of participants attending each venue was 10.

Effectiveness

Weigh to Go participants Fitbit daily steps (number taken)

A test of normality was carried out and the assumption was met. Mauchly's test of sphericity produced a non-significant result ($p = .620$). Reporting Sphericity Assumed there was a significant large effect of Fitbit use on daily steps $F(3, 45) = 5.93$, $p = .002$, $n^2 = .19$. Post hoc comparisons using the Bonferroni correction for multiple comparisons were carried out. There was a significant increase in daily steps between week 1 and week 7 ($p= .008$) with participants in week 7 walking on average 5345 more steps. There was no statistically significant difference in steps between any of the other weeks. Participants daily steps at week 1, week 7, week 15 and week 20 are displayed in Figure 13.

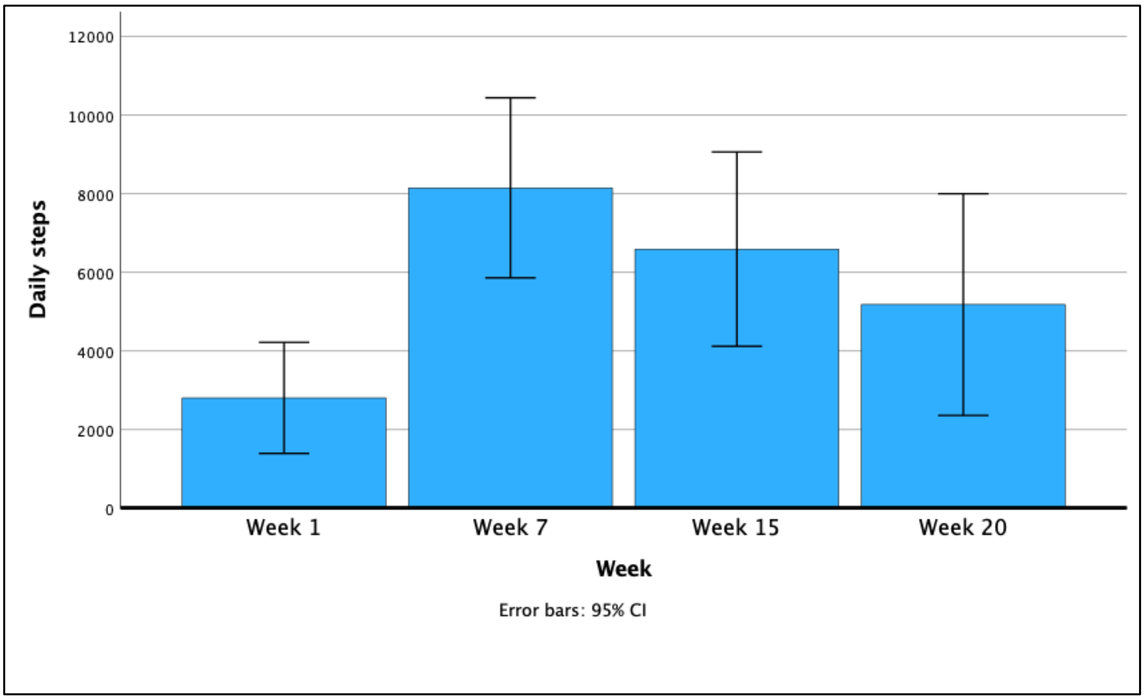

Figure 13: Participants mean daily steps at week 1, week 7, week 15 and week 20

Weigh to Go participants Fitbit weekly minutes of moderate to vigorous intensity physical activity

A test of normality was carried out and the assumption was met. Mauchly's test of sphericity produced a significant result (p = .038). Reporting Greenhouse-Geisser showed that there was no significant effect of Fitbit use on weekly minutes of moderate to vigorous intensity physical activity $F(1.68, 13.45) = 0.65$, $p = .511$, $n^2 = .07$. Figure 14 shows participants weekly minutes of moderate to vigorous intensity physical activity at week 1, week 7, week 15 and week 20.

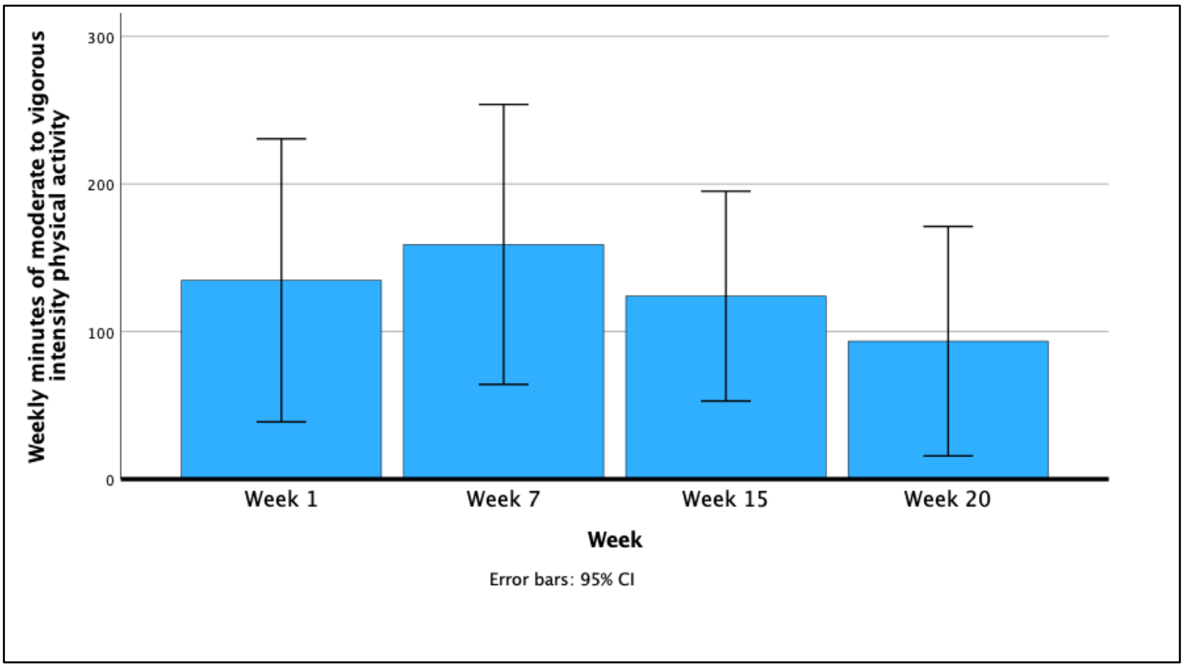

Figure 14: Participants weekly minutes of moderate to vigorous intensity physical activity at week 1, week 7, week 15 and week 20.

Adoption

The total number of staff involved in the delivery of the Weigh to Go intervention are displayed in Table 19. The total number of staff involved in the delivery of this study are displayed in Table 20.

Table 19: Total number of staff involved in the delivery of the Weigh to Go intervention.

Role	Number
Intervention instructor	22
Project manager	8
Administration support	5

Table 20: Total number of staff involved in the delivery of this study.

Role	**Number**
Intervention instructor	22
Researchers	5

The types and number of venues used for the delivery of the Weigh to Go intervention and total number available throughout the 2 local councils are displayed in Table 21.

Table 21: Types of venues used to deliver the Weigh to Go intervention.

Venue type	**Number used**	**Total number available**
Community centre	8	108
Community fitness centre	4	29
Total	12	137

Implementation

Signposting for the Weigh to Go intervention used by the study Weigh to Go participants are displayed in Table 22.

Table 22: Weigh to Go intervention signposting.

Diabetes nurse	5
Practice nurse	5
Local gym	5
GP	3
Local community centre	5
Website	4
Work email	1
Word of mouth	2
Facebook	2
Carer centre	1

The cost of delivering the Weigh to Go intervention are displayed in Table 23.

Table 23: Cost of delivering the Weigh to Go intervention.

Session cost per 15 weeks	£672.00
Session cost per 30 weeks	£1,344.00
Venue cost per year	£2,016.00
Annual cost	£60,480.00
Average cost per participant per the 15-week active phase	£67.20
Average cost per participant per the 30-week active and maintenance phase	£134.40

Though all Fitbit devices were supplied free of charge for this study the retail cost of purchasing these devices are displayed in Table 24.

Table 24: Retail cost of Fitbit Charge 5 devices.

Individual retail cost for each Fitbit Charge 5	£101.52
Total study cost	£5,989.68

The mean number of sessions Weigh to Go participants attended during the 15-week active phase of the Weigh to Go intervention was 11.35 $\pm$ 3.63 sessions.

Maintenance

The mean number of sessions all Weigh to Go participants attended during the maintenance phase of the Weigh to Go intervention was 1.91 $\pm$ 2.57. Only one participant attended the full 15-weeks of the active and maintenance phases of the intervention.

Only 5 Weigh to Go participants provided Fitbit data beyond 20-weeks. The mean number of maintenance sessions attended by these 5 participants was 12.2 $\pm$ 3.47.

Qualitative findings

Abductive thematic analysis of interviews conducted with the Weigh to Go participants (n=10) and health care professionals (n=10) involved in the delivery and onboarding of the Weigh to Go intervention identified 6 main themes and 11 sub-themes. The themes are displayed in Table 25 and discussed in more detail below.

Table 25: Study main themes and sub-themes.

Main themes (n=6)	**Sub-themes (11)**
1. Fitbit use	1.1 Barriers 1.2 Enablers
2. Promotion	2.1 Health care 2.2 Weigh to Go intervention
3. Clinical care	3.1 Benefits of activity tracker use 3.2 Use by health care staff
4. Finance	4.1 Costs (patient and health care provider) 4.2 Health care monetary savings
5. Fitbit functions	5.1 Preferences 5.2 Interpretation
6. Effectiveness	6.1 Physical activity 6.2 Goal setting

Fitbit Use

Participants described several barriers that limited their ability or willingness to use activity trackers. A central issue was low motivation to engage in physical activity, which diminished the perceived utility of the device. One participant reflected:

“I am not interested in exercising even though I know it is good for me. I just don’t have the drive to exercise” (Female participant, 62 years).

Such accounts illustrate that, while Fitbits can support behaviour change, they are unlikely to generate motivation where this is fundamentally absent.

A further barrier related to digital literacy, particularly among older adults. As one healthcare professional noted,

“I think some of the older participants will struggle using activity trackers as they have poorer technology skills compared with the younger generation” (Female professional, 38 years).

This concern highlights the persistence of a digital divide that risks excluding certain groups unless targeted support is provided.

Financial constraints also emerged as a significant limitation. One professional commented:

“I know that some of those taking part in the Weigh to Go programme have little money and could not afford a Fitbit and do not own a mobile phone because of the cost” (Female professional, 47 years).

This illustrates that cost-related barriers extend beyond the device itself to include the ownership of compatible technologies and ongoing data costs.

For others, health conditions imposed practical limitations on activity tracker use. A participant with multiple chronic conditions explained:

“I have underlying health conditions such as arthritis and type 2 diabetes. These make it difficult to exercise and my mobility is poor” (Female participant, 76 years).

In such cases, the issue is not a lack of awareness or willingness, but the incompatibility of technological prompts with physical capacity.

Finally, participants reported that self-efficacy shaped their willingness to use a Fitbit. One male participant expressed:

> *"My confidence is very low due to my weight problems. This not only stops me exercising in public but it impacts other areas of my life like learning new skills"* (Male participant, 58 years).

This suggests that psychological and social barriers, such as low confidence and fear of judgement, can limit both physical activity and engagement with new technologies.

Despite these barriers, participants identified several factors that could encourage uptake. Provision of a free device was repeatedly highlighted as a strong motivator:

> *"Normally I would not have bought a Fitbit but having had the device provided free has helped motivate me to be more active"* (Female participant, 56 years).

Device provision at registration was seen as a way to reduce cost-related inequalities and promote engagement from the outset.

Participants also emphasised the importance of education and support. One explained:

> *"I wasn't sure how best to use the Fitbit. I think a class dedicated on how best to use the Fitbit would have been very useful"* (Female participant, 54 years).

Similarly, healthcare professionals highlighted the value of hands-on assistance:

> *"A number of your study participants needed support to set up the Fitbit device… I could help participants set up their trackers if required"* (Male professional, 34 years).

These accounts underscore the importance of embedding structured technical support into interventions.

Goal setting was another key enabler. A professional suggested:

> *"As part of the Weigh to Go programme we could speak to each participant and set them physical activity goals over the 15 weeks"* (Female professional, 41 years).

This reflects established evidence that personalised and incremental goal-setting strategies can enhance motivation and sustain behaviour change.

Promotion

Healthcare professionals and participants proposed several mechanisms for promoting Fitbit use within clinical settings. The most direct approach was integration into consultations:

> *"This could be promoted through our practice or during a consultation"* (Female professional, 41 years).

Others suggested passive promotion through printed materials displayed in clinical environments:

> *"The NHS could produce posters, leaflets and handout documents within their premises or other public buildings"* (Male professional, 34 years).

Finally, national level campaigns were seen as potentially effective for awareness raising, with one participant proposing:

> *"A national campaign in local newspapers informing patients of this service might work"* (Male participant, 41 years).

Within the Weigh to Go programme the promotion at the point of registration was viewed as crucial:

> *"I was informed of this study when I first registered for the Weigh to Go programme. A friend of mine attended a different venue but was not told of this. I think promoting this at each venue would be a good idea"* (Female participant, 69 years).

Beyond clinical settings, community spaces were highlighted as useful sites for engagement:

> *"I attend a companion group at my local community centre each week… This would be a good place to promote the Fitbit"* (Female participant, 66 years).

Such suggestions reflect the importance of both formal and informal networks in raising awareness.

Clinical Care

Participants emphasised the potential for Fitbits to contribute to clinical care. A healthcare professional highlighted:

> *"Using an activity tracker could form part of a patient's care and if properly managed could improve their physical activity levels and improve their health"* (Male professional, 34 years).

This was reinforced by participants who valued the potential for professional monitoring:

> *"The Fitbit could be used by doctor or nurse to monitor my activity and give me advice and exercise support if required"* (Female participant, 30 years).

Healthcare professionals also considered the possibility of prescribing Fitbits, akin to medication or medical equipment:

"Activity trackers could be prescribed by say my doctor…" (Female participant, 56 years).

Remote monitoring was seen as particularly advantageous:

"These pieces of technology would allow for the remote monitoring of a patient through their activity data and subsequently provide appropriate advice and support" (Female professional, 51 years).

Referral pathways were also considered, with one professional suggesting:

"If a patient is not undertaking enough exercise through analysis of their Fitbit information we could refer them to a local gym" (Male professional, 34 years).

Finance

Participants highlighted potential costs for both patients and providers. For patients, the primary expense was the purchase of the Fitbit itself:

"For me the main cost would be purchasing the Fitbit device" (Female participant, 48 years).

Others noted that the use of Fitbits necessitated additional costs such as smartphones and internet access:

"To use the Fitbit I would need to pay for internet access and to download the Fitbit app have a mobile phone" (Female participant, 60 years).

For healthcare providers, resource implications extended beyond devices to include staff training and time:

"The main costs for the health care provider beyond the price of the Fitbit would be staff training and staff time" (Female professional, 47 years).

Conversely, participants suggested that investment in activity trackers could generate long-term savings through improved health outcomes. One professional explained:

> *"If patients increase their physical activity and reduce their sedentary behaviour the knock-on effect will be improved health and a reduction in the risk of developing future illnesses"* (Male professional, 34 years).

Another emphasised reduced reliance on costly treatments:

> *"The healthier patients are then they will need less medications and expensive treatments"* (Female professional, 51 years).

Fitbit Functions

Step counting was the most commonly used and valued feature, as one participant explained:

> *"I tended to only use the step function on the Fitbit as I found this easiest to understand"* (Female participant, 56 years).

Other participants valued the ability to track weight:

> *"My Weigh to Go instructor told me how to type my weight into the Fitbit. This allowed me to monitor it while I was on the course"* (Female participant, 30 years).

However, several participants described difficulties interpreting the full range of data provided by the device. One commented:

> *"I found the Fitbit motivational but other than steps I did not understand much of the information on the app"* (Female participant, 76 years).

This was seen as a missed opportunity, with others suggesting that staff-led educational sessions could bridge this gap:

"I would have found it useful if our Weigh to Go class instructor had delivered a session explaining how best to use the Fitbit and how to interpret the information recorded" (Male participant, 41 years).

Effectiveness

Participants generally perceived Fitbits as effective in increasing awareness of their physical activity levels and progress. For example:

"I enjoyed using the Fitbit. It helped me see any improvements in my activity levels" (Female participant, 48 years).

The device also acted as a motivational prompt:

"I found the Fitbit motivated me to be more active and encourage me to do something on days when I felt tired" (Female participant, 60 years).

Healthcare professionals suggested that activity trackers could be integrated into structured goal-setting strategies within interventions such as Weigh to Go. As one professional argued:

"These devices could certainly be incorporated into the Weigh to Go programme and be used as an effective goal setting tool" (Male professional, 34 years).

Summary

Overall, the findings highlight both the opportunities and challenges associated with incorporating Fitbits into weight management and clinical care. While barriers such as cost, digital literacy, and health conditions were evident, enablers including device provision, education, and personalised goal setting enhanced engagement. Promotion strategies at both clinical and community levels were proposed, and participants recognised the potential for activity trackers to support both behaviour change and clinical monitoring. However, realising these benefits will require attention to structural inequalities and adequate resourcing to ensure equitable access and effective integration.

Discussion

This discussion reports a pragmatic evaluation of integrating a consumer activity tracker (Fitbit Charge 5) into Weigh to Go, a community weight-management programme delivered across Lanarkshire, Scotland. The purpose was not to test the effectiveness of Fitbits per se, but to examine feasibility, acceptability, and implementation issues in a real-world service using the RE-AIM framework; Reach, Effectiveness, Adoption, Implementation, and Maintenance (Glasgow, Vogt, & Boles, 1999; Glasgow et al., 2019). Quantitative (Fitbit steps and MVPA minutes) and qualitative (semi-structured interviews with Weigh to Go participants and healthcare professionals) data were integrated abductively to illuminate why the observed patterns occurred and what they imply for future scale-up (Braun & Clarke, 2006, 2019, 2021; Patton, 2015; Timmermans & Tavory, 2012).

Reach

Consistent with RE-AIM, Reach concerns the absolute number, proportion, and representativeness of individuals who participate (Glasgow et al., 1999). Seventy-one adults consented between July 2023 and January 2024; 59 were enrolled, and 33 contributed analysable device data, with participants predominantly female and white and with a mean age in the mid-50s. Although 705 people attended the targeted Weigh to Go venues during the recruitment window, the programme did not record how many were approached, constraining precise calculation of recruitment rate and representativeness. Based on venue attendance, a conservative, estimate suggests that ~10% of potentially eligible attendees consented (i.e., 71/705), but this cannot be taken as a true denominator because approach rates were not logged. Future evaluations should prospectively track the recruitment path and report reasons for non-participation and attrition, in line with RE-AIM and CONSORT-style flow logic adapted for pragmatic studies (Glasgow et al., 2019).

Qualitatively, participants and healthcare professionals emphasised that providing devices at no cost enhanced reach, particularly among people facing financial constraints and among men and ethnic minority groups, who are often underrepresented in weight-management services (Cheatham, Stull, Fantigrassi, & Motel, 2018) (Ferguson, et al., 2022). However, digital access and digital literacy remained barriers for some older adults and those with limited technology confidence, echoing persistent "digital divide" concerns in community interventions (Mercer, Li, Giangregorio, Burns, & Grindrod, 2016).

Effectiveness

Within RE-AIM, Effectiveness refers to impact on key outcomes, including potential harms. The within-subject analyses indicated a significant increase in daily steps between Week 1 and Week 7 (Bonferroni-adjusted $p = .008$), with an average change of +5,345 steps (reporting group means), whereas no statistically significant differences were observed for the other pairwise comparisons of steps or for weekly MVPA minutes over the same period. These results are presented cautiously as the study design does not permit causal attribution to the tracker or to any single component of Weigh to Go. Step count increases could reflect early engagement with the programme as a whole, seasonal/contextual influences, or novelty effects (Ledger & McCaffrey, 2014), not necessarily the addition of a Fitbit.

There was a difference between recorded change in steps and MVPA. However step counts often increase through additional light-intensity walking and incidental movement (e.g., breaks in sedentary time), whereas MVPA requires higher-intensity bouts of physical activity (Tudor-Locke, et al., 2011) (Colberg, et al., 2016). In our qualitative data, participants described finding steps easy to understand and act upon, while feeling unsure how to interpret intensity metrics, suggesting an opportunity for education sessions focused on translating device feedback (active minutes, heart-rate zones) into actionable weekly plans. Importantly, the Fitbit served simultaneously as an intervention component and measurement tool, a limitation we acknowledge below, given concerns about construct overlap and potential reactivity (Evenson, Goto, & Furberg, 2015) (White, et al., 2024).

To improve interpretability in future phases, it is recommended that a single family of follow-up contrasts either (a) stepwise (Week 1 to 7; 7 to 15; 15 to 20) or (b) baseline-referenced (Week 1 vs. 7, 15, 20) with appropriate multiplicity control (e.g., Bonferroni or Holm). In this evaluation the baseline referenced approach was chosen to avoid mixing strategies, and Weeks 1, 7, 15, and 20 were selected a priori to represent early engagement (Week 1), mid-active phase (Week 7), end of active phase (Week 15), and early maintenance (Week 20), aligning with the programme's delivery structure.

Adoption

Adoption addresses the proportion and representativeness of settings and staff willing to initiate the intervention (Glasgow et al., 1999). Across the service, 22 instructors and additional managers/administrators are engaged in Weigh to Go delivery, with 12 community venues used during the study period (community centres and fitness centres). Staff interviews revealed high conceptual openness to tracker integration but practical uncertainties regarding what exactly to do with device data, how to interpret dashboards meaningfully, and how to troubleshoot common issues (e.g., syncing, account management). Although Fitbits are consumer friendly, clinical/community adoption requires confidence in data interpretation, behaviour change coaching with device metrics, and pathways for acting on data (e.g., tailoring targets, referrals to supervised activity). This aligns with prior literature: wearables can support self-monitoring and feedback, but do not drive behaviour change in isolation; professional guidance and integration into a behavioural programme are essential (Patel, Asch, & Volpp, 2015) (Cadmus-Bertram, Marcus, Patterson, Parker, & Morey, 2019) (Lim, et al., 2016).

At the organisational level, adoption is more likely where there is a protocol specifying eligibility, onboarding, data governance, coaching scripts, troubleshooting trees, and criteria for progression and referral (e.g., to gym-based supervision). The interviewees explicitly requested such a protocol, which would also facilitate staff training and quality assurance across venues.

Implementation

Implementation refers to fidelity, adaptations, costs, and practicalities (Glasgow et al., 1999). The programme delivered a 15-week active phase (education and exercise) followed by an optional 15-week maintenance phase. In practice, attendance during the active phase averaged 11.35 ± 3.63 sessions, while maintenance attendance averaged 1.91 ± 2.57 sessions. Only one participant attended all 30 sessions across active and maintenance phases; five submitted Fitbit data beyond 20 weeks. Interviews pointed to competing life demands, waning novelty, device/app literacy challenges, and variable goal-setting support as proximate reasons for drift. These reasons mirror broader evidence that self-monitoring adherence decays without ongoing reinforcement, social support, and personally meaningful goal setting (Hermsen, Moons, Kerkhof, Wiekens, & De Groot, 2016) (Cadmus-Bertram, Marcus, Patterson, Parker, & Morey, 2019) (Sniehotta, Scholz, & Schwarzer, 2014).

From an economic standpoint, Weigh to Go's reported average delivery cost was £67.20 per participant for the 15-week active phase and £134.40 for 30 weeks (active and maintenance), exclusive of devices. The retail cost of a Fitbit Charge 5 was £101.52 during the study. A simple per-participant estimate for an activity tracker enabled 15-week programme is therefore ~£168.72 (programme delivery + device), rising with staff training and technical support. Venue costs were £2,016 per venue annually. Scaling to 125 venues at current venue costs implies ~£252,000/year for venues alone, plus session delivery (e.g., £1,344 per 30-week cycle per venue), devices, training, and support infrastructure. Given low maintenance attendance and data incompleteness, such scaling is unlikely to be cost-effective unless adherence can be substantially improved and unit costs reduced (e.g., negotiated device pricing, shared equipment pools, or bring your own device models with equity safeguards). Prior work suggests that digital components can be cost-effective at scale only when engagement is sustained (Wang & al, 2015) (Dombrowski, Knittle, Avenell, Araujo-Soares, & Sniehotta, 2016).

Two further implementation issues require explicit acknowledgement.

First, measurement/intervention confounding arises when the Fitbit is used simultaneously as both the behavioural intervention component (i.e., providing feedback, reminders, or activity prompts) and the outcome assessor (i.e., recording steps, activity minutes, or heart rate). This dual role introduces a risk of reactivity, whereby participants may alter their behaviour simply because they know their activity is being monitored by the device, rather than due to the intended intervention mechanisms. In addition, relying on a single tool for both intervention delivery and measurement raises **common method bias concerns**, as the observed changes in outcomes may partly reflect the measurement method itself rather than genuine behavioural change (Evenson, Goto, & Furberg, 2015). Consequently, improvements recorded in physical activity metrics could be artificially inflated, undermining the ability to disentangle whether changes are attributable to the intervention's efficacy, participants' awareness of being monitored, or inherent limitations in the measurement device. Second, data loss. Missing device data arose primarily from account and syncing errors (Google/Fitbit credential issues, intermittent app–phone connectivity), compounded by irregular wear. These problems were exacerbated by external vendor driven changes, such as Google/Fitbit account migration, which caused unexpected authentication barriers. Syncing failures meant that even when devices were worn, data often did not upload consistently, while irregular wear patterns, charging lapses, and user disengagement further inflated missingness. Such losses created a disproportionate burden on staff, who had to provide troubleshooting, technical support, and device replacements, increasing hidden resource demands. Beyond logistical challenges, these gaps undermined analytic validity data were systematically missing from lower engagement participants, limiting statistical power and biasing outcome estimates. Together, these issues highlight that consumer devices, while seemingly low cost, introduce significant risks to data completeness, programme fidelity, and equity unless robust technical and contractual safeguards are in place.

Maintenance

Maintenance concerns sustained individual behaviour change and the institutionalisation of the programme (Glasgow et al., 2019). At the individual level, the sharp fall-off after the active phase indicates that behavioural maintenance was weak. Interviews suggest that goal-progression, habit formation, and social accountability mechanisms were insufficiently embedded. Evidence indicates that maintenance benefits from graduated goals, implementation intentions, prompted self-regulation, and structured social support (Sniehotta, Scholz, & Schwarzer, 2014) (Sullivan & Lachman, 2017) (Avery, Flynn, van Wersch, Sniehotta, & Trenell, 2012). At the organisational level, maintenance would require a codified protocol, staff capability for data-guided coaching, and routine use of trackers in referral pathways (e.g., to condition-appropriate activity prescriptions, remote monitoring, or peer groups), as suggested by both participants and healthcare professionals and supported by remote-monitoring literature (Shei, Holder, Oumsang, Paris, & Paris, 2022).

Consideration of Participant with Learning Difficulties

During the study, one Weigh to Go participant was identified as having learning difficulties through the demographics Qualtrics survey. Ethical and methodological considerations were taken into account to ensure that their inclusion in the research was appropriate, respectful, and did not compromise the quality of the data collected.

For this participant, support was offered and a member of the research team was available to provide clarification and to check comprehension at each stage.

Data collection procedures were also adjusted to accommodate the participant's needs. Instructions for the use of the activity tracker were delivered slowly, repeated where necessary, and supplemented with practical demonstrations from venue staff. Written guidance was supported by verbal explanations. Regular check-ins were conducted to ensure that the device was being worn correctly and that data were being recorded as intended.

Ethically it is important to reflect on the implications of including a participant with learning difficulties. Their participation demonstrates the inclusivity of the study design and highlights the feasibility of using wearable technologies across a broader range of populations, including those with additional support needs. It also underlines the importance of tailoring recruitment and data collection procedures to individual capabilities to maximise both participant experience and data quality.

Future research should more systematically address accessibility and inclusivity, ensuring that interventions involving wearable technologies are designed with flexibility to accommodate individuals with varying levels of literacy, cognitive capacity, and health literacy. By doing so, activity tracker interventions can be made more equitable and representative of real-world populations.

In summary, the study accounted for the needs of a participant with learning difficulties by providing adapted materials, additional support during consent and data collection, and regular check-ins to ensure compliance. Reflection on this inclusion highlights the importance of designing interventions and research methodologies that are accessible to diverse populations, an area for future development in this field.

Strengths and Limitations

A key strength of this study is its pragmatic design, which examined the integration of a consumer activity tracker into an existing community-based weight management programme (Weigh to Go) under real-world service conditions. By embedding the evaluation within a routine community intervention, findings reflect implementation realities, enhancing ecological validity and the relevance of recommendations for service delivery (Glasgow et al., 2019). The use of the RE-AIM framework further strengthened the study by structuring the analysis across Reach, Effectiveness, Adoption, Implementation, and Maintenance domains, facilitating a comprehensive evaluation of both individual and system-level outcomes (Glasgow, Vogt, & Boles, 1999).

Another strength lies in the mixed methods approach, which combined quantitative Fitbit data with qualitative interviews from both Weigh to Go participants and healthcare professionals. This methodological triangulation provided richer insight into not only whether physical activity increased but also how and why adoption and engagement occurred (Patton, 2015). The abductive analytic strategy enabled nuanced interpretation that linked empirical findings with theoretical concepts, capturing unanticipated patterns such as the divergence between step count improvements and minimal changes in moderate to vigorous physical activity (Braun & Clarke, 2019) (Timmermans & Tavory, 2012).

The study also benefited from the inclusion of multiple stakeholders, with perspectives gathered from Weigh to Go participants and healthcare professionals involved in programme delivery. This broadened the analysis beyond individual behaviour change to include service delivery challenges, data governance considerations, and resource implications, critical elements for informing scale-up (Cadmus-Bertram et al., 2019). Furthermore, the provision of free Fitbit devices increased participation among individuals who might otherwise face financial barriers, supporting equity of access and contributing to insights around reach (Cheatham et al., 2018).

Despite these strengths, several limitations must be acknowledged. First, the non-controlled design precludes causal inference. Increases in daily step counts, particularly between Week 1 and Week 7, cannot be attributed solely to Fitbit use, as changes may also reflect general engagement with the Weigh to Go programme, seasonal influences, or novelty effects (Ledger & McCaffrey, 2014). Second, the Fitbit device functioned both as an intervention and as the primary measurement tool, raising concerns about measurement reactivity, construct overlap, and reliance on proprietary algorithms (Evenson, Goto, & Furberg, 2015) (White et al., 2024).

Third, data completeness and quality issues emerged, with missing Fitbit records due to syncing errors, account access problems, and irregular device wear. Such missingness may bias estimates and reduced the statistical power to detect changes. Fourth, maintenance engagement was low, with very few participants providing data beyond 20 weeks and only one completing the full 30-week programme. This point was not explored during the qualitative interviews and in particular with the one participant who completed the full 30-week programme. Overall these limit conclusions regarding long-term sustainability, which is critical for population level type 2 diabetes prevention (Sniehotta, Scholz, & Schwarzer, 2014).

Fifth, the sample lacked socio-demographic diversity. The participant group was predominantly White, female, and middle-aged, reducing the representativeness of findings and limiting generalisability to more diverse populations, including men, younger adults, and ethnic minority groups. Given evidence of disparities in both type 2 diabetes prevalence and digital health engagement (Mercer et al., 2016), future studies should prioritise targeted recruitment and culturally tailored strategies.

Finally, while the study provided illustrative economic estimates, these relied on assumptions regarding device costs, staff time, and venue use. A full economic evaluation incorporating cost-effectiveness modelling and sensitivity analyses is needed to assess scalability and sustainability (Dombrowski et al., 2016) (Wang et al., 2015).

In summary, this study provides valuable real-world evidence on the integration of consumer activity trackers into a community weight management programme, highlighting both opportunities and challenges. Its strengths lie in its pragmatic, mixed-methods design and stakeholder inclusion, while its limitations include design constraints, data loss, limited diversity, and uncertain long-term outcomes. These considerations should inform future controlled evaluations, independent measurement strategies, and implementation planning.

Implications and Conclusions

Within a real world community programme, integrating an activity tracker is feasible and perceived as acceptable by many participants and staff. However, sustained engagement is the principal challenge and a determinant of value for money. The quantitative signal of increased steps early in the active phase, without corresponding MVPA change, is consistent with light-intensity activity displacement rather than structured intensity gains; education on interpreting intensity metrics, goal-progression, and coaching appear necessary to shift MVPA. To support Adoption and Implementation at scale, the service should develop a formal protocol (onboarding, data governance, coaching scripts, referral triggers), deliver role-specific training for staff (data interpretation, troubleshooting, behaviour-change techniques), and strengthen Maintenance via scheduled check-ins, social/peer support, graduated goals, and remote prompts/feedback. Economically, large-scale roll-out (e.g., 125 venues) will remain fragile unless adherence improves and unit costs (notably device and support) are reduced through procurement and design efficiencies.

Reframed as a pragmatic evaluation rather than an efficacy test, this study contributes evidence on how and under what conditions activity trackers can be integrated into community weight-management services for adults at risk of or living with type 2 diabetes.

Future research should include comparative designs (e.g., stepped wedge or cluster randomised control trial's), independent activity assessment (accelerometery), and economic evaluation, coupled with qualitative process evaluations grounded in reflexive thematic analysis to explain mechanisms and context. Only with stronger maintenance supports and clear operational protocols is tracker-enabled scale-up likely to achieve meaningful population health.

Chapter 5

Discussion of thesis

Overview and synthesis

This thesis used a staged programme of research; an integrative systematic review (Study 1), a qualitative study with people living with type 2 diabetes and healthcare professionals (Study 2), and a pragmatic mixed methods study to examine whether and how consumer activity trackers can be integrated into routine clinical and community care to promote physical activity and reduce sedentary behaviour. The RE-AIM framework (Reach, Effectiveness, Adoption, Implementation, Maintenance) was used across all three studies to interpret findings not only in terms of short term behavioural change but also organisational translational potential (Glasgow et al., 1999).

The staged design enabled iterative learning. Study 1 identified consistent under reporting of Adoption and Maintenance in the literature; Study 2 explored stakeholder perspectives to explain those gaps; and Study 3 tested the feasibility of recommended mitigations in real service settings. This section discusses findings by RE-AIM domain, followed by broader methodological considerations, strengths and limitations, and future recommendations.

Reach

Across the thesis, Reach emerged as a complex, equity sensitive construct. The systematic review found limited and inconsistent reporting of who interventions reached, with few studies documenting approach and eligibility denominators (Hodgson et al., 2023). In Study 3, recruitment was undertaken through Weigh to Go venues, but approach counts were not prospectively recorded. This omission prevented calculation of a true response rate and made it difficult to judge representativeness, a notable gap given the skew of participants towards white, middle-aged women.

Qualitative data provided greater depth. Participants and healthcare professionals described financial barriers (activity tracker and data costs), constraints linked to phone ownership, and digital literacy limitations as inhibitors of reach (Studies 2 and 3). Even when devices were provided free of charge (Study 3), access issues (such as connectivity and phone compatibility) and use of technology confidence gaps meant that provision alone did not guarantee equitable participation. These findings suggest that successful Reach strategies must combine free device provision with targeted outreach, accessible messaging, and digital inclusion support (for example, connectivity subsidies and in-person onboarding).

Effectiveness

The most consistent quantitative finding in Study 3 was an early and significant increase in daily step counts during the active phase of the Weigh to Go programme, while weekly minutes of moderate to vigorous physical activity (MVPA) did not significantly change across measured time points (weeks 1, 7, 15, 20). This pattern reflects findings from wider research literature showing that activity trackers encourage incidental movement and reductions in sedentary behaviour, but do not necessarily lead to structured MVPA without additional support (Colberg, et al., 2016) (Tudor-Locke, et al., 2011).

Qualitative data from Study 3 provide an explanation in that participants found step counts simple, immediate, and actionable, whereas other physical activity constructs were harder to interpret and translate into weekly plans without professional guidance. From a behaviour change perspective, this suggests that trackers enhance opportunity and motivation for incidental activity (COM-B model) but do not improve capability for structured exercise unless paired with coaching, progression planning, and self-regulatory techniques (Michie et al., 2011) (Sniehotta, Scholz, & Schwarzer, 2014). Future interventions therefore need to deliberately connect tracker feedback to graded goal setting, brief action planning, and clinician or physical activity expert review.

Adoption

Study 1 showed that Adoption was poorly reported in published studies (Hodgson et al., 2023), and Study 2 interviews echoed this, with healthcare professionals highlighting three conditions for adoption: (1) a clear value proposition (how activity tracker data would enhance care), (2) role clarity (who is responsible for monitoring and acting on the data), and (3) workable resource models (time, training, device procurement). Study 3 operationalised some of these conditions with devices being provided, staff were given onboarding information, and costs were calculated. Nevertheless, staff still expressed uncertainty about data interpretation pathways and where activity tracker review should sit within existing workflows (routine checks versus behaviour change consultations). Adoption therefore appears contingent on clarity about clinical roles, alongside sustained resourcing.

Implementation

Study 3 revealed practical fragilities in Implementation. Account setup issues, vendor authentication changes (e.g., Google/Fitbit account migrations), syncing failures, and inconsistent device wear reduced analysable data and weakened Implementation fidelity.

These experiences highlight that the apparent low cost of consumer trackers conceals hidden resource demands, including staff time, IT support, and replacement devices. Operational lessons documented in this thesis point to the need for technical and contractual mitigations such as service level data sharing agreements, dedicated technical support, and contingency procedures for activity tracker manufacturer driven changes. Without such safeguards, reliability and fidelity of tracker based programmes are at risk.

Maintenance

Maintenance emerged as the most challenging RE-AIM domain. Study 1 showed that maintenance was rarely reported in published literature. Study 3 observed low maintenance attendance (mean ≈1.9 sessions) and very limited data beyond 20 weeks. Qualitative interviews suggested that novelty effects wore off once structured support ended. Financial modelling also showed that sustainment carries ongoing costs (venues, staff, devices). Maintenance therefore needs to be designed in from the outset, with planned booster sessions, peer support mechanisms, device replacement budgets, and automated reminders. Without these, both individual and organisational sustainment are unlikely.

Data governance, trust, and clinical integration

Stakeholders across Studies 2 and 3 expressed a preference for NHS anchored stewardship of activity tracker data, noting that clinical utility depended on trust and clarity about data storage and responsibility. Participants wanted clinician friendly dashboards with personalised feedback rather than raw data streams. These findings reinforce the need for interoperable data standards, co-designed visualisations, and clear governance frameworks. Without them, activity tracker data risk being underused by both patients and clinicians.

Measurement and methodological considerations

The validity and reliability of consumer activity trackers are critical to interpreting findings. Activity trackers such as Fitbit provide reasonably accurate step counts in free living conditions, typically within 5–10% error compared to research grade accelerometers (Evenson, Goto, & Furberg, 2015) (Feehan, et al., 2018). However, estimates of MVPA and energy expenditure are less reliable, with systematic over and underestimation observed (Ferguson, et al., 2022) (Tully, McBride, Heron, & Hunter, 2014). Reliability of step based measures is generally acceptable, but syncing failures, firmware changes, and inconsistent wear reduce longitudinal stability (Henriksen, et al., 2018). These weaknesses were mirrored in Study 3, where data loss and syncing failures reduced analytic power.

Another concern is measurement intervention overlap, because trackers were both the intervention and the outcome measure in Study 3, participants may have altered behaviour simply because they could see their data, confounding causal inference (Duncan, Wunderlich, Zhao, & Faulkner, 2017). Future research should therefore combine consumer trackers for ecological relevance with research grade accelerometers in a validation subsample. Pre-defined wear rules, pre-registered analysis plans, and risk registers anticipating vendor changes should be built into study protocols to protect against bias and data loss.

Consideration of Cost and Economic Evaluation

Inclusion of Early-Stage Studies and Scope of Evidence

In Study 1 many of the included studies were early-phase feasibility or pilot trials. These studies primarily evaluated acceptability, usability, and initial behavioural engagement, rather than clinical or economic outcomes. This distinction is crucial for accurate interpretation. The inclusion of such early-stage research aligns with the aims of this thesis and with the RE-AIM framework (Reach, Effectiveness, Adoption, Implementation, Maintenance) (Glasgow et al., 2019), which supports the examination of interventions across various translational stages. However, the predominance of formative studies inevitably limits external validity and certainty of the conclusions. Study 1 demonstrates that activity trackers are feasible and acceptable tools for supporting physical activity in people with or at risk of type 2 diabetes, but evidence of sustained clinical benefit and cost-effectiveness remains limited. Furthermore, the lack of cost data in Study 1 reflects the developmental nature of included trials rather than a universal gap in the type 2 diabetes literature. Indeed, recent systematic reviews show substantial progress in assessing cost-effectiveness of diabetes prevention interventions (Li et al., 2020) (Palmer et al., 2020). These findings underscore the need to interpret Study 1 as providing foundational, early translational evidence that can guide subsequent large scale trials.

Study 2: Stakeholder Insights and Refinement of Interpretations

Study 2 (qualitative exploration of stakeholder perspectives) offered important insights into how wearable technology could be integrated into diabetes care delivery. It highlighted perceived benefits such as enhanced patient motivation, improved clinician feedback, and opportunities for personalised behaviour change. However, the study also revealed significant barriers, including variability in technology literacy, resource constraints, and uncertainty about long-term patient engagement.

Findings from Study 2 should not be interpreted as conclusive evidence of stakeholder readiness or universal support for digital health adoption. Instead, they represent context-specific perspectives drawn from a limited sample of healthcare professionals and patients within a defined service model. This discussion now positions Study 2 as providing exploratory evidence of the conditions necessary for successful adoption, such as clinician training, patient co-design, cost, and interoperability across health systems, rather than as evidence of widespread feasibility. These insights are vital for implementation planning but should be considered preliminary, requiring validation in broader, more diverse populations. Moreover, reflections from Study 2 inform the later recommendations on stakeholder engagement and joint protocols, ensuring that future implementation strategies directly address the structural and organisational barriers identified here.

Study 3: Cost, Implementation, and Certainty of Findings

Study 3 (mixed-methods evaluation of the "Weigh to Go" programme) concluded that "costs of research interventions are seldom if ever reported." This statement has been reviewed to reflect a more accurate position within the type 2 diabetes literature. While this particular study did not include a full economic evaluation, systematic review-level evidence demonstrates that lifestyle based and digital interventions for diabetes prevention and management can be cost-effective under real world conditions (Li et al., 2020) (Palmer et al., 2020).

The absence of cost data in Study 3 is a reflection of its implementation phase and funding context, rather than an indicator of a broader lack of cost evidence in the field. Indeed, feasibility trials like Weigh to Go typically prioritise recruitment, engagement, and acceptability measures rather than economic analysis (Hernandez-Villafuerte, 2019). This discussion reframes the finding ("costs of research interventions are seldom if ever reported.") as highlighting a methodological limitation rather than a definitive statement about the literature.

Findings from Study 3 should be interpreted as preliminary evidence of intervention feasibility and behavioural impact rather than as confirmation of clinical or economic efficacy. The observed increases in physical activity and engagement provide a basis for future implementation–effectiveness hybrid trials (Curran, Bauer, Mittman, Pyne, & Stetler, 2012) that can simultaneously evaluate health outcomes, cost-effectiveness, and equity impacts.

Cross-Study Synthesis and Evidence Certainty

Taken together, the three studies present complementary perspectives on the integration of wearable supported interventions into type 2 diabetes care. The combined findings suggest that such interventions are feasible, acceptable, and potentially cost-effective when implemented at scale, but current evidence remains at an emergent stage.

Adopting the GRADE approach to evidence assessment (Schünemann, Brożek, Guyatt, & Oxman, 2019), the overall certainty across studies can be summarised as follows:

- **Moderate certainty** for feasibility and user acceptability (Studies 1 and 2);

- **Low-to-moderate certainty** for short-term behavioural outcomes (Studies 1 and 3);
- **Low certainty** for sustained clinical and cost-effectiveness outcomes (Studies 1 and 3).

This discussion avoids overstatement of effectiveness and positions these findings as indicative, not conclusive. This calibrated interpretation ensures alignment between the methodological design of each study and the strength of the claims drawn from them.

Cost Implications for Future Research

Based on these findings, future research should:

1. Transition from small-scale feasibility studies to hybrid effectiveness–implementation designs that integrate clinical and economic endpoints (Curran, Bauer, Mittman, Pyne, & Stetler, 2012).
2. Include standardised cost-reporting frameworks from the outset, capturing device costs, training, maintenance, and digital infrastructure (Hernandez-Villafuerte, 2019).
3. Expand stakeholder diversity and co-production models to ensure equity and sustainability in implementation (Greenhalgh, et al., 2017).
4. Strengthen longitudinal evaluation to determine sustained behavioural, clinical, and cost outcomes (Li et al., 2020) (Palmer et al., 2020).

These strategies will help translate the findings from this thesis into scalable, sustainable, and economically viable models of digital support for type 2 diabetes prevention and management.

Behaviour Change Theory, Education, and Digital Prompts

This section integrates findings from Studies 1–3 with the updated literature review on behaviour change theory and digital health interventions, addressing how educational components, reminders, and digital coaching align with contemporary evidence about what drives sustainable behavioural change. The purpose is to contextualise participant suggestions within a theoretically grounded framework and ensure alignment between the thesis findings and current published evidence (Albarracín, Fayaz-Farkhad, & Samayoa, 2024).

Education as a Behaviour Change Mechanism

During interviews in Study 2, participants frequently proposed that effectiveness could be enhanced if users attended a specific educational class on how to use the activity tracker and analyse the data collected. While this insight reflects a practical barrier, namely, the need for adequate onboarding and data literacy support, it must be evaluated in light of evidence showing that education alone is typically insufficient to sustain behavioural change.

Recent meta-analytic evidence from (Albarracín, Fayaz-Farkhad, & Samayoa, 2024) demonstrates that “knowledge and education” rank among the least effective standalone targets for behaviour change interventions, whereas self-regulation, habit formation, feedback, and environmental restructuring are considerably more powerful levers. Similarly, Araújo-Soares et al. (2018) argue that interventions focusing purely on information provision tend to generate short-term awareness rather than long-term behaviour adoption.

This evidence reframes the qualitative suggestion in Study 2 that participants' desire for an educational class likely reflects a perceived gap in confidence and competence when interpreting tracker data, rather than a belief that education itself produces change. Within the Capability–Opportunity–Motivation–Behaviour (COM-B) model (Michie, van Stralen, & West, 2011), education enhances psychological capability, but sustainable change also requires motivational and contextual supports. Therefore, education should be conceptualised as an enabling mechanism rather than a primary driver of behaviour change.

In Study 1, few interventions described formal educational components, and those that did often lacked detail on behavioural change content. This omission reflects a broader trend in digital health research, where training is often operationalised as device orientation rather than structured behaviour change education (El Kirat et al., 2024). Similarly, Study 3 (the Weigh to Go programme) provided limited educational content, focusing primarily on data capture and automated summaries. Participants who struggled with device use or interpretation may have disengaged sooner, supporting the need for minimal onboarding that increases self-efficacy but does not substitute for deeper behavioural scaffolding. Consequently, this thesis positions education as a necessary but insufficient component: useful to reduce early attrition and enhance capability, yet requiring integration with evidence based mechanisms such as goal-setting, self-monitoring, and feedback (Michie et al., 2011) (Albarracín et al., 2024). Educational elements should be concise, practical, and linked to ongoing prompts and feedback loops.

Digital Prompts, Reminders, and Virtual Coaching

A second theme across Studies 2 and 3 involved participants' enthusiasm for automated reminders, motivational prompts, or virtual health coaches within future tracker designs. Such requests align with growing recognition in behavioural science that environmental cues, feedback, and digital nudges are among the most effective levers for sustained activity change (Albarracín et al., 2024) (Gardner, 2023).

Evidence from systematic reviews of digital interventions suggests that goal setting, action planning, feedback, and reminders, rather than passive education, drive adherence and physical-activity increases (El Kirat et al., 2024). Within the context of Self Determination Theory, these digital prompts can support autonomous motivation if designed to encourage self-efficacy and personal relevance (Alberts, Lyngs, & Lukoff, 2024). Conversely, excessively controlling or intrusive prompts can diminish intrinsic motivation, leading to disengagement. Therefore, behaviourally informed tracker designs must strike a balance between supportive structure and user autonomy.

Empirical data from this thesis echo these theoretical principles:

- In Study 2, several participants described wanting alerts when activity levels dropped below targets, suggesting that timely cues could reinforce self-monitoring.
- In Study 3, adherence declined after the initial weeks, indicating that the absence of interactive prompts may have contributed to waning engagement.
- Study 1 revealed that very few published interventions incorporated adaptive feedback mechanisms or context-aware prompts, representing a persistent implementation gap.

By situating these findings within the broader literature, it becomes clear that the addition of behaviourally intelligent features, such as adaptive reminders, goal-progress notifications, and virtual coaching avatars, represents a theoretically grounded extension rather than speculative innovation. These components directly target empirically supported determinants of behaviour, such as self-monitoring, reinforcement, and habit formation (Gardner, 2023) (El Kirat et al., 2024). Nevertheless, the thesis maintains epistemic caution. While prompts and digital coaching appear promising, their effectiveness among individuals with type 2 diabetes has yet to be established in long-term pragmatic trials. Future studies should therefore test adaptive intervention designs (e.g., Sequential Multiple Assignment Randomised Trials, or SMARTs) to evaluate when and for whom prompts are most effective (Curran, Bauer, Mittman, Pyne, & Stetler, 2012).

Integrating Education and Behavioural Support

Synthesising across the three studies, the optimal approach likely lies in integration rather than substitution. A brief educational session can establish foundational digital literacy and self-efficacy, while behavioural supports, reminders, prompts, feedback loops, and coaching, drive sustained engagement. Theoretically, this integration maps onto both COM-B and RE-AIM frameworks: education builds capability, prompts sustain motivation, and structured systems enable maintenance (Glasgow, Harden, Gaglio, Rabin, Smith, Porter, & Estabrooks, 2019). As such, future interventions should adopt multi-component designs that layer these elements rather than privileging any single mechanism.

In conclusion, participant recommendations for education and prompts are consistent with established behaviour-change frameworks when appropriately contextualised. Education plays an enabling role, while prompts and digital coaching address the active determinants of sustained behaviour change. Future implementation research should experimentally test how these mechanisms interact to enhance adherence, health outcomes, and cost-effectiveness within type 2 diabetes care.

Insights from Physical Activity Data: Implications for the Prevention and Management of Type 2 Diabetes

The Expanding Value of Wearable-Derived Data

Wearable activity trackers have transformed the ability of researchers and clinicians to monitor physical activity behaviour continuously, objectively, and in naturalistic contexts. Unlike self-report instruments, which are prone to recall and social-desirability bias, accelerometer-based devices provide minute-to-minute records of activity intensity, duration, frequency, and variability (Evenson, Goto, & Furberg, 2015) (Ferguson, Rowlands, Olds, & Maher, 2022). When aggregated across large cohorts, such data generate a rich digital phenotype of habitual movement patterns, sedentary behaviour, and sleep variables intricately linked with metabolic health and diabetes risk (Strain, Wijndaele, Pearce, & Brage, 2022).

These continuous data streams extend beyond measurement to knowledge generation. Analysis of large-scale physical activity datasets enables identification of behavioural signatures associated with glycaemic control, insulin sensitivity, and cardiometabolic outcomes. In turn, this can inform novel, data-driven strategies for the prevention and management of type 2 diabetes.

Understanding Behavioural Patterns and Glycaemic Variability

Detailed accelerometery permits fine-grained analysis of activity patterns, including timing, frequency, and fragmentation of movement bouts, that influence post-prandial glucose regulation. For example, emerging evidence indicates that interrupting prolonged sedentary periods with short bouts of light activity can significantly reduce glucose excursions and insulin demand (Dempsey et al., 2018). By examining within-day variation, wearable data can uncover behavioural signatures, such as high evening sedentariness or inconsistent day-to-day activity, that may signal impaired metabolic flexibility. Researchers can apply machine-learning techniques to integrate accelerometer, dietary, and glucose-monitoring data, identifying clusters of behavioural phenotypes predictive of HbA1c trajectories or incident diabetes (Chen, Zhang, & Li, 2022). Such analysis moves beyond simplistic “step count” metrics to a nuanced understanding of how, when, and in what patterns movement confers protection.

Personalised Feedback and Adaptive Interventions

Continuous physical activity monitoring facilitates personalised diabetes management by enabling adaptive feedback loops. Algorithms can detect deviations from individual baselines and deliver tailored prompts or exercise recommendations. For instance, a patient whose activity data show reduced moderate to vigorous activity during workdays could receive context-specific suggestions for brief walking breaks or standing intervals.

When integrated with continuous glucose monitoring systems, activity data allow temporal linkage between movement and glycaemic response, revealing which activity patterns most effectively stabilise glucose levels for a given individual (Rawlings, Sharrett, & Young, 2019). This fusion of behavioural and physiological analytics underpins next generation precision-health models, enabling clinicians to prescribe personalised activity prescriptions optimised for metabolic response.

Population-Level Insights and Prevention Strategies

At the population level, aggregated wearable datasets can support epidemiological modelling and risk stratification. By linking anonymised activity profiles to health record outcomes, researchers can identify thresholds of activity or sedentary exposure associated with type 2 diabetes onset. For example, large scale analyses of accelerometer data from the UK Biobank have already demonstrated non-linear dose–response relationships between daily moderate intensity physical activity and diabetes risk reduction (Yates, Smith, Henson, Rowlands, & Davies, 2023).

These findings refine public health recommendations, moving from one-size-fits-all guidelines toward data-derived, context-sensitive targets, for instance, recognising that short, frequent activity bouts may offer similar metabolic benefit as longer sessions. Furthermore, real-time population surveillance using consumer wearable data could help policymakers monitor behavioural shifts and evaluate the effectiveness of national physical activity campaigns in near real time (Strain et al., 2022).

Identifying New Pathways for Diabetes Management and Research

The analytical potential of physical activity data extends to discovering novel behavioural biomarkers and treatment pathways:

1. **Behavioural Biomarkers** – Patterns of diurnal movement, circadian rhythm, and sedentary clustering may serve as early indicators of metabolic dysfunction, enabling proactive intervention before clinical onset.
2. **Comorbidity Insights** – Physical activity data can reveal relationships between activity variability and comorbid conditions such as depression, sleep disorders, or cardiovascular disease, informing integrated care models.
3. **Predictive Modelling** – Combining Physical activity metrics with demographic, genetic, and biochemical data enables the creation of predictive algorithms for diabetes progression and complication risk (Chen et al., 2022).
4. **Intervention Optimisation** – Analyses of adherence curves and engagement metrics can identify when and why individuals disengage from activity programmes, guiding refinement of digital health interventions to sustain long-term participation (King, Glasgow, & Leeman, 2020).

Through these applications, wearable derived physical activity data become not merely a monitoring tool but a scientific discovery resource, informing both mechanistic understanding and applied intervention design.

Ethical and Practical Considerations

While the analytical promise of wearable data is substantial, its realisation depends on addressing ethical, technical, and governance challenges. Data accuracy, interoperability, privacy protection, and equitable access must be ensured to avoid reinforcing health disparities (Greenhalgh et al., 2017). Moreover, translating large scale analytics into clinical practice requires multidisciplinary collaboration between clinicians, behavioural scientists, data analysts, and policy stakeholders.

The integration of behavioural informatics into diabetes care thus represents both an opportunity and a responsibility, to harness data ethically, interpret findings contextually, and convert digital insights into meaningful health outcomes.

Summary

In summary, analysis of physical activity data from wearable devices provides a powerful means to identify new pathways for managing and preventing type 2 diabetes. Through granular pattern recognition, linkage with metabolic markers, and large-scale predictive modelling, researchers can uncover how specific activity behaviours influence glycaemic control and disease progression. These insights enable personalised management, inform population guidelines, and advance understanding of diabetes aetiology. As digital-health infrastructure matures, the capacity to translate such data into actionable clinical intelligence will define the next frontier of precision diabetes prevention.

Evaluation Frameworks

Context and Purpose

Within this thesis, reference has been made to other evaluation frameworks alongside the RE-AIM model. The RE-AIM framework is one of several complementary frameworks available for evaluating health interventions, particularly those involving complex, multi-component, or technology enabled programmes such as wearable supported physical activity promotion for type 2 diabetes.

This section clarifies which frameworks were considered, how they differ conceptually, and why RE-AIM was ultimately prioritised as the core evaluative lens for the current research.

Alternative and Complementary Frameworks

A number of alternative frameworks are widely used within implementation science and public health evaluation, each offering distinct emphases:

1. **The Consolidated Framework for Implementation Research (CFIR)**

   The CFIR (Damschroder, et al., 2009) provides a comprehensive taxonomy of constructs across five domains: intervention characteristics, outer setting, inner setting, characteristics of individuals, and process. It is particularly useful for identifying contextual factors influencing adoption and sustainability. CFIR guided parts of the qualitative design in *Study 2*, particularly when exploring organisational readiness, leadership support, and contextual barriers to tracker integration.

2. **The Medical Research Council (MRC) Framework for Complex Interventions**

   The MRC framework (Skivington, et al., 2021) outlines sequential stages for developing, piloting, evaluating, and implementing complex interventions. Its emphasis on theory development and iterative refinement aligns with early phase research. Study 1 drew conceptually on this approach by mapping the evidence base and identifying mechanisms to inform later pilot work.

3. **The PRECEDE–PROCEED Model**

   Developed by Green and Kreuter (2005), this model structures evaluation from a socio-ecological perspective, linking behavioural, environmental, and policy determinants to health outcomes. While broader in scope, it shares RE-AIM's concern with multilevel influences and was reviewed for relevance when considering community-level implementation of wearable interventions.

4. **The Normalization Process Theory (NPT)**

   The Normalization Process Theory (May, et al., 2018) focuses on the social processes through which new interventions become routinely embedded in practice, examining coherence, cognitive participation, collective action, and reflexive monitoring. This theoretical lens was considered particularly relevant to interpreting stakeholder narratives in Study 2 about integrating trackers into clinical routines.

5. **The Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) Framework**

   While RE-AIM served as the principal analytical structure in this thesis, it also draws conceptually from these complementary approaches. Its strength lies in operationalising evaluation across both individual level and organisational level domains (Glasgow, Harden, Gaglio, Rabin, Smith, Porter, & Estabrooks, 2019). RE-AIM's pragmatic emphasis on real world applicability made it particularly well suited for a thesis positioned at the intersection of feasibility, behaviour change, and implementation science.

Integration and Justification

The decision to employ RE-AIM as the primary evaluative framework was guided by the thesis's translational aims, to understand not only whether wearable interventions work, but how they can be feasibly embedded within NHS diabetes care pathways.

However, elements from other frameworks could improve interpretation:

- CFIR constructs contextualise organisational and policy influences of adoption (e.g., data governance, clinical workflow).
- NPT concepts illuminate the social work of integrating tracker use into everyday professional practice.
- The MRC framework could inform study sequencing and iterative learning across phases.

Summary

In summary, the other evaluation frameworks cited in this thesis include **CFIR**, **MRC Complex Interventions**, **PRECEDE–PROCEED**, and **NPT**. These were not applied in this thesis but could inform specific aspects of study design and interpretation. The RE-AIM framework remained central due to its suitability for evaluating both implementation and population level impact within pragmatic healthcare settings. If situating RE-AIM among these complementary frameworks, the thesis acknowledges the pluralistic nature of implementation science and demonstrates methodological breadth.

Overall Strengths and Limitations of the Thesis

Overall Strengths

A key strength of this thesis lies in its integrated mixed-methods design, combining a systematic review, qualitative exploration, and pragmatic implementation research to examine the use of wearable activity trackers in type 2 diabetes prevention and management. Collectively, these studies address a continuum of translational inquiry, from evidence synthesis to stakeholder insight and real-world evaluation, offering a comprehensive and contextually grounded contribution to the field.

First, the thesis advances knowledge by bridging the gap between theoretical promise and implementation reality. While many prior studies evaluated efficacy under controlled conditions, this research situates wearable use within everyday healthcare contexts, thereby producing insights relevant to NHS service delivery. The integration of the RE-AIM framework throughout ensures conceptual coherence and provides a pragmatic lens for assessing Reach, Adoption, Implementation, and Maintenance (Glasgow et al., 2019).

Second, the work demonstrates a multi-stakeholder perspective, encompassing evidence from patients, clinicians, and health service managers. This holistic viewpoint supports translational relevance and highlights system level enablers and barriers, an aspect frequently absent in narrowly focused intervention studies (Greenhalgh, Jackson, Shaw, & Janamian, 2017).

Third, the thesis contributes methodological innovation by combining qualitative and quantitative data to inform real-world implementation design. The use of naturalistic data, alongside iterative stakeholder feedback, strengthens ecological validity and provides a foundation for future hybrid effectiveness, implementation trials (Curran, Bauer, Mittman, Pyne, & Stetler, 2012).

Finally, the thesis adds strategic value to digital-health policy. By contextualising wearable integration within NHS infrastructure and highlighting requirements for governance, interoperability, and cost measurement, it offers actionable insights for service commissioners and technology developers. The recommendations extend beyond individual behaviour change to system level reform, an important hallmark of applied public-health research.

Overall Limitations

Despite these strengths, the thesis has several overarching limitations that temper the breadth and certainty of its contribution. These limitations do not detract from its value but rather delineate the scope and boundaries of the claims that can be made.

First, the thesis represents early-stage translational research, focused on feasibility and implementation readiness rather than definitive clinical or cost-effectiveness outcomes. While this positioning is consistent with the thesis aims, it limits the extent to which findings can generalise to large-scale health system impact.

Second, although the research employs mixed methods, it was conducted largely within **a** single national context (Scotland). As a result, contextual factors such as local infrastructure, digital-maturity levels, and socio-demographic patterns may constrain transferability to other healthcare systems or populations.

Third, while participant numbers were appropriate and justified within each study's methodological framework, the thesis as a whole remains exploratory in evidential power. The synthesis draws together diverse data sources, yet conclusions regarding sustained behavioural change, long-term clinical improvement, or economic efficiency remain provisional and would require future large-scale pragmatic or hybrid trials (Li et al., 2020).

Fourth, there are technological and temporal limitations. Rapid evolution in wearable-device accuracy, data-sharing protocols, and privacy standards means that some implementation insights may date quickly. The thesis provides a snapshot of technological and organisational conditions during the research period rather than an enduring statement on future capabilities.

Finally, as this work was undertaken within the constraints of doctoral research, it necessarily prioritised depth over breadth. Certain aspects, such as quantitative evaluation of behavioural determinants or economic modelling, were beyond feasible scope. Consequently, while the thesis identifies important implementation gaps, it could not empirically quantify all cost or behavioural mediators.

Overall, these limitations frame the thesis as a formative, translational contribution, advancing understanding of wearable integration within health systems, but not yet establishing definitive evidence of large-scale effectiveness or cost-benefit. The thesis therefore contributes a strong platform for subsequent applied research, including hybrid effectiveness–implementation trials and economic evaluation studies.

Future Recommendations

Stakeholder Engagement

Effective promotion and adoption of wearable supported interventions require a multi-level stakeholder approach. Key stakeholders include patients, primary-care clinicians, diabetes specialist nurses, general practitioners, local health-board managers, digital-health vendors, and public-health policy makers. Each group contributes a distinct role:

- **Clinicians** should integrate tracker feedback into routine consultations and use automated summary dashboards to facilitate patient-centred goal setting (Cadmus-Bertram et al., 2019).
- **Health-board managers** and **commissioners** should embed tracker supported physical activity promotion into chronic disease pathways and allocate budget lines for device procurement, replacement, and data management contracts (King et al., 2020).
- **Digital vendors** must collaborate with the NHS to ensure data interoperability, privacy compliance under GDPR, and sustainability of cloud based infrastructure (Strain et al., 2022).
- **Patients** should be engaged as co-design partners in interface development to ensure usability, accessibility, and cultural relevance (Greenhalgh et al., 2017).

Establishing a national stakeholder consortium, comprising clinicians, informaticians, patient representatives, and policymakers, would improve communication, promote consistent governance standards, and facilitate knowledge exchange across regions (Shelton, Chambers, & Glasgow, 2020).

Development of Joint Protocols

Joint protocols should be established between clinical services, local authorities, and technology providers to streamline operational delivery. Protocols must define:

1. **Data flow procedures** outlining responsibilities for collection, storage, and access;
2. **Clinical response pathways** for abnormal readings (e.g., sustained inactivity or elevated glucose indicators); and
3. **Standard operating procedures** for device setup, troubleshooting, and replacement.

Jointly developed protocols can reduce duplication, prevent data silos, and ensure equity in service delivery across geographic areas (Glasgow et al., 2019). Inter-organisational protocols should also mandate interoperable data standards so that patient generated activity data integrate seamlessly with electronic health records, enhancing continuity of care and facilitating evaluation (Evenson, Goto, & Furberg, 2015).

Patient Support and Long-Term Engagement

To sustain engagement beyond initial novelty effects, multi-component support is required. Recommended actions include:

- **Personalised feedback loops** combining automated tracker summaries with clinician interpreted insights to reinforce behaviour change (Michie et al., 2011);
- **Structured booster sessions** at 3, 6, and 12-month intervals incorporating motivational interviewing and peer-support groups;
- **Digital literacy training** delivered through community health hubs, particularly for older adults and socio-economically deprived populations; and
- **Accessible support channels** (helplines, chatbots, or drop-in clinics) to resolve technical issues swiftly, maintaining device fidelity (Henriksen et al., 2018).

Embedding these elements into diabetes care pathways can transform episodic participation into sustained self-management. Long-term engagement is enhanced when patients perceive tangible feedback on health outcomes and when activity data inform personalised care plans (Cheatham et al., 2018).

Measurement of Health Improvement

Evaluation of success must extend beyond step counts. Recommended multi-level metrics include:

1. **Physiological indicators** – HbA1c, fasting glucose, BMI, and blood pressure (Ferguson et al., 2022);
2. **Behavioural metrics** – weekly minutes of moderate to vigorous physical activity, sedentary time reduction, and adherence rates (Tully et al., 2014);
3. **Psychosocial outcomes** – self-efficacy, quality of life, and perceived behavioural control (Bandura, 2004); and
4. **Implementation outcomes** – adoption, fidelity, and maintenance consistent with the RE-AIM framework (Glasgow et al., 1999).

Measurement should employ a hybrid design using both consumer grade trackers for ecological validity and research grade accelerometers in a validation subsample (Troiano et al., 2014). Data should be collected by trained healthcare professionals, automatically synced to secure NHS servers, and analysed quarterly by regional data-analytics teams. Results must feed back into quality improvement cycles, informing service adjustments, staff training, and national benchmarking dashboards. Regular dissemination to clinicians and patients can strengthen trust and transparency in data use (Wake et al., 2016).

Utilisation of Measurement Data

Measurement data should be used for three inter-related purposes:

1. **Individual Care Optimisation:** Clinicians use real time dashboards to tailor exercise prescriptions and review progress during consultations.
2. **Programme Evaluation:** Aggregated data are analysed to assess cost effectiveness, engagement trends, and equity of reach across demographic groups (King et al., 2020).
3. **Policy and Research:** De-identified datasets contribute to public health surveillance, informing national physical activity targets and diabetes prevention strategies (Strain et al., 2022).

Governance frameworks must ensure ethical secondary use, with transparent consent processes and patient control over data sharing (Greenhalgh et al., 2017). Continuous audit and public reporting would reinforce accountability and stimulate system-wide learning.

Summary

Future research in this field needs to take both methodological and practical lessons from this thesis. From a research perspective, studies should adopt designs that allow both Effectiveness and Implementation to be tested at the same time, such as hybrid or stepped-wedge trials. Where consumer activity trackers are used, a subsample of participants should also wear research grade accelerometers so that the accuracy of step and activity data can be checked. Study protocols should include clear rules for minimum wear time, pre-registered analysis plans, and risk registers that anticipate problems such as manufacturer driven software changes, which disrupted Study 3. Larger and more diverse samples will be important to test whether these approaches are equitable across different demographic groups, and future trials should be powered to allow subgroup analysis. Longer follow-up, ideally over twelve to twenty-four months, will also be essential to understand whether the effects of trackers can be maintained once the initial novelty wears off.

For services, the findings point towards several priorities. Onboarding support, including co-designed tutorials and troubleshooting assistance, is essential if activity trackers are to be used equitably. Clinicians need simple dashboards that integrate activity tracker data into existing workflows, and services will have to plan for ongoing costs such as device replacement, booster sessions, and technical support. Efforts to recruit participants should focus on inclusivity, such as lending devices to those who cannot afford them and tailoring communication to different cultural groups.

Trust and data governance also need to be central. Participants and healthcare professionals alike expressed a preference for NHS anchored data stewardship, and any large scale rollout will require secure agreements with manufacturers and the co-design of dashboards that balance clarity, usefulness, and privacy. Finally, there is a strong case for building in formal cost effectiveness analysis from the beginning, including both direct delivery costs and longer term health outcomes, so that funders and organisation management can make confident decisions about investment.

Taken together, these recommendations provide a practical roadmap. In the short term, services could pilot improved onboarding processes and clinician dashboards. In the medium term, trials that are more rigorous and diverse should be launched, with validation subsamples and planned risk management. Over the longer term, sustained large scale evaluations with 12 to 24 month follow-up and cost effectiveness modelling will be needed to demonstrate whether activity tracker enabled care is viable and sustainable as part of routine diabetes prevention and management.

Conclusion

This thesis shows that consumer activity trackers can be integrated into community and clinical programmes and can produce rapid increases in ambulatory behaviour. However, they are only partial solutions. Sustained benefit requires an ecosystem of supports including adoption pathways, staff training, onboarding and technical assistance, governance frameworks, and maintenance activities.

The findings also highlight methodological limits. Trackers are valid and reliable for step counts but less so for MVPA and energy expenditure, and their reliability in real world programmes is undermined by syncing failures, firmware changes, and incomplete wear. Data loss and the dual role of trackers as both intervention and outcome tool complicate causal inference.

The challenge, therefore, is not whether trackers can change behaviour but how services can adopt and sustain them equitably and reliably while addressing these methodological and operational constraints. If the recommendations set out in this thesis are followed, including independent validation subsamples, explicit equity measures, vendor risk planning, and cost effectiveness modelling, activity tracker enabled care can move from fragile pilots towards routine, durable contributions to type 2 diabetes prevention and management.

Researcher Development and Skill Acquisition

Over the course of the PhD, the author progressed from practitioner researcher to independent academic investigator. The multidisciplinary nature of this programme, integrating behavioural science, clinical implementation, and digital health analytics, necessitated the development of a diverse skill set.

Methodologically, the author gained competence in systematic review methods, qualitative interviewing, mixed-methods design, and implementation science evaluation. The systematic review phase (Study 1) refined abilities in critical appraisal, database searching, and data synthesis, while the qualitative phase (Study 2) enhanced skills in thematic analysis, reflexive interviewing, and participant engagement. The mixed-methods study (Study 3) provided hands-on experience in intervention implementation, project coordination across clinical settings, and quantitative data interpretation.

The doctoral journey also strengthened transferable competencies, academic writing, research ethics, data governance, and stakeholder collaboration. Exposure to the RE-AIM and COM-B frameworks deepened theoretical literacy in behaviour change and implementation science (Michie, van Stralen, & West, 2011) (Glasgow et al., 2019). Through iterative application, these frameworks became both analytical tools and professional learning scaffolds, cultivating the ability to translate theory into practice.

Reflexive Awareness and Decision-Making

Early in the programme, the author approached digital health evaluation primarily through a behavioural science lens. Over time, reflexive engagement with the literature and stakeholder feedback broadened this perspective to include system-level determinants, such as data infrastructure and organisational readiness (Greenhalgh, Jackson, Shaw, & Janamian, 2017). This shift from individual level to system level thinking reflects a maturation of research identity, from micro-behavioural analysis to macro-implementation understanding.

Reflexive journaling and supervision discussions were used throughout to document reasoning behind methodological decisions, aligning with recommendations for reflexive transparency in qualitative and mixed-methods research (Nowell, Norris, White, & Moules, 2017). These records became valuable during the analysis of stakeholder perspectives, helping the author recognise potential interpretive bias shaped by prior clinical experience.

Self-Critique and Lessons Learned

The viva examination prompted critical reconsideration of certain design choices, particularly within Study 3. While the mixed-methods approach provided rich, contextual insight, in retrospect, the author acknowledges that an adaptive or hybrid design (Curran, Bauer, Mittman, Pyne, & Stetler, 2012) could have strengthened inferential power and enabled iterative intervention refinement. A Sequential Multiple Assignment Randomised Trial (SMART) or Hybrid Type II implementation-effectiveness design might have allowed real time adjustment of feedback mechanisms or prompt delivery, offering more robust evidence of causal relationships between behavioural prompts and adherence.

Another reflective observation concerns data integration timing. Greater concurrent analysis between qualitative and quantitative components could have enhanced triangulation, aligning with recommendations for interactive mixed-methods synthesis (Fetters & Freshwater, 2015). For instance, emerging qualitative insights regarding user motivation could have been incorporated mid-study to modify engagement strategies. Ethical and logistical considerations also shaped decisions that, in hindsight, constrained scope. The author initially opted for a single national implementation site to ensure feasibility and governance compliance. While this decision facilitated depth, it limited geographical diversity and generalisability. A multi-site approach, though more complex, might have yielded broader contextual insight.

Personal and Professional Transformation

The process of conducting this research facilitated substantial growth in scientific resilience, critical reasoning, and professional identity. Managing participant recruitment challenges, ethical amendments, and data-management complexities demanded adaptability and perseverance. These experiences cultivated confidence in handling ambiguity, an essential skill for implementation research, where contextual uncertainty is inherent (Chambers, Norton, & Glasgow, 2021).

Equally transformative was the shift in understanding of the researcher's positionality. Initially viewing the role as that of a neutral evaluator, the author came to recognise the inherently co-constructive nature of digital-health research, in which investigators shape, and are shaped by, the social systems under study (Berger, 2015). This awareness informed a more collaborative, participatory approach during later stakeholder interactions.

Looking Forward

If repeating the research, the author would adopt a more iterative, participatory, and data-adaptive methodology. Early engagement with patients and clinicians as co-design partners would be prioritised to ensure greater contextual fit and sustainability. Future research would also embed economic and behavioural analytics components from inception, addressing the cost-evaluation limitations identified in this thesis (Li et al., 2020).

Beyond specific methodological changes, the doctoral process has reinforced a commitment to interdisciplinary collaboration and translational impact, bridging behavioural science, clinical practice, and data analytics to improve chronic-disease management. The author recognises that doctoral research is less a conclusion than a foundation for continued scholarly contribution.

Summary

In summary, this reflective account demonstrates the author's evolution from novice researcher to independent scholar capable of critically integrating behavioural, implementation, and digital-health sciences. It acknowledges both strengths, methodological versatility, theoretical integration, stakeholder engagement, and limitations, notably the opportunity for more adaptive design in Study 3. Most importantly, it illustrates the researcher's deepened reflexive awareness and commitment to rigorous, ethically grounded, and co-produced public-health research.

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Appendices

Appendix A: Study 1 systematic review protocol

An integrative, systematic review exploring the reach, effectiveness, adoption, implementation and maintenance of using activity trackers in clinical care to support physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases

William Hodgson, Alison Kirk, Marilyn Lennon, Xanne Janssen

Citation
William Hodgson, Alison Kirk, Marilyn Lennon, Xanne Janssen. An integrative, systematic review exploring the reach, effectiveness, adoption, implementation and maintenance of using activity trackers in clinical care to support physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases.

Review question
The overall aim of this integrative systematic review is to comprehensively explore the reach, effectiveness, adoption, implementation and maintenance of using activity trackers in clinical care to support physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases.

This will be achieved by conducting a systematic search of published quantitative and qualitative research exploring the use of activity trackers in clinical care to support physical activity or reduce sedentary behaviour in adults diagnosed with chronic diseases and identifying the 5 main RE-AIM elements (primary objective) and 28 RE-AIM sub-elements that can evaluate their effectiveness with the aim to improve the sustainable adoption and implementation of effective evidence-based interventions.

This comprehensive analysis of evidence will enhance the practicality of findings and inform future clinical decisions and interventions.

PICOS Statement (Quantitative):
Population: adults (18 + years of age) with a diagnosed chronic disease (as per World Health Organization definition 19 November 2021 https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases)
Intervention/Exposure: individual or combined use of an activity tracker within clinical care.
Comparisons: all control/comparison groups.
Outcomes: reach, effectiveness, adoption, implementation and maintenance of using an activity tracker within clinical care.
Study: interventional/experimental and observational.

SPIDER Statement (Qualitative):

Sample: adults (18 + years of age) with a diagnosed a chronic disease (as per World Health Organization definition 19 November 2021 https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases) and adult (18 + years of age) health care professionals working within a clinical capacity.
Phenomenon of Interest: experiences of using an activity tracker within clinical care.
Design: qualitative and mixed methods.
Evaluation: reach, effectiveness, adoption, implementation and maintenance of using an activity tracker within clinical care.
Research Type: qualitative and mixed methods (qualitative and quantitative).

Searches

- A University of Strathclyde subject specialist will assist in developing the search strategy.
- An electronic literature search will be conducted between January 2022 and March 2022 (estimated) on 6 databases (Web of Science (Core Collection), MEDLINE (ProQuest), MEDLINE (Ovid, Embase and Embase Classic), ACM (Digital Library), APA PsycINFO (EBSCO), Cochrane Library.
- Grey Literature (e.g. Thesis and Dissertations, Conference and Trials) will be sought by searching OpenGrey and Open Access Thesis and Dissertations.

Types of study to be included
This review will consider quantitative, qualitative and mixed methods studies. Mixed method studies will only be considered if data from the quantitative or qualitative components can be clearly extracted. All published articles in English between 2015 and 2022 will be included.

Quantitative:
Inclusion criteria:

- Any experimental/interventional studies (e.g. randomised and non-randomised) and any non-experimental/observational studies (e.g. cross sectional/prevalence, cohort/longitudinal, case control/case reference) and mixed method studies providing quantitative data can be clearly extracted.
- Articles written in English.

Exclusion criteria:

- Commentaries, reviews, editorials, meta-analysis, diagnostic studies.
- Articles written in any language except English.

Qualitative:
Inclusion criteria:

- Any qualitative studies (e.g. ethnography (e.g. observation of cultures), phenomenology (e.g. lived experiences), grounded theory (e.g. development of theory), narrative inquiry (e.g. how individuals make sense of their experiences through narrative), case study and visual and participatory methodologies) and mixed method studies providing qualitative data can be clearly extracted.
- Articles written in English.

Exclusion criteria:

- Articles written in any language except English.

Condition or domain being studied
Chronic diseases are the main cause of death for 15 million adults, globally, each year. Physical inactivity and sedentary behaviour are major risk factors of developing chronic diseases (World Health Organization, 2021).

Activity trackers when used within a clinical care setting have been shown to increase levels of physical activity and reduce sedentary behaviour in adults diagnosed with chronic diseases (Franssen et al. 2020)

The RE-AIM (Reach, Effectiveness, Adoption, Implementation and Maintenance) integrated framework was developed to improve the long-term adoption and implementation of effective knowledge-based interventions within healthcare/clinical care. This is achieved by focusing the attention of healthcare professionals and researchers around the 5 main elements of the framework and the external validity of the intervention (Glasgow et al. 1999).

Participants/population
Quantitative:
Inclusion criteria:
- Adults (18 + years of age) diagnosed with a chronic, all genders, all ethnicities, all socioeconomic backgrounds and all chronic disease durations.

Exclusion criteria:
- Any other type of disease not listed in the inclusion criteria. Any people aged out with the defined age bracket.

Qualitative:
Inclusion criteria:
- Adults (18 + years of age) diagnosed with a chronic disease, adult (18 + years of age) health care professionals working within clinical care, all genders, all ethnicities, all socioeconomic backgrounds and all chronic disease durations.

Exclusion criteria:
- Any other type of disease not listed in the inclusion criteria. Any people aged out with the defined age bracket.

Intervention(s), exposure(s)
Inclusion criteria:
- Any individual or combined use of activity trackers within clinical care by people diagnosed with a chronic disease.
    - Activity trackers: all commercially available activity trackers capable of measuring at least one of the following elements: steps, physical activity intensity, distanced moved horizontally or vertically, energy expenditure and sedentary behaviour.
    - Clinical care: the provision of patient healthcare by a healthcare professional either in a clinical environment or community setting.
    - Chronic disease: any human disease that is long lasting and non-infectious.
    - Exclusion criteria:

- Any intervention/exposure out with the defined inclusion criteria.
    - Activity tracker: any non-commercial research graded activity tracker, pedometer or accelerometer not for use by the general public (e.g. ActivPal and Actigraph).
    - Clinical care: any healthcare provision provided for in-patient treatment.
    - Chronic disease: any non-chronic diseases.

Comparator(s)/control
Inclusion criteria:
- All adult (18+ years of age) control/comparison groups.

Context
There are no restrictions on the context in which data has been gathered.

Main outcome(s)
Primary:
- The primary outcomes are percentage of reporting across the 5 main elements of the RE-AIM integrated framework (Reach, Effectiveness, Adoption, Implementation and Maintenance) and possibly for the following age categories:
    - 18 – 30-year-olds
    - 31 – 50-year-olds
    - 51 – 64-year-olds
    - 65 + year-olds
- The secondary outcomes are percentage of reporting across the 28 sub-elements contained within the 5 main elements of the RE-AIM integrated framework and possibly for the age categories 18 – 30, 31 – 50, 51 – 64 and 65 + year-olds;
    - Reach
        - Method to identify target population.
        - Inclusion criteria.
        - Exclusion criteria.
        - Sample size.
        - Participation rate.
        - Use of qualitative methods to understand reach.
        - Characteristics of participants Vs non-participants.
    - Effectiveness
        - Measurement/results at shortest assessment.
        - Imputation procedures (created data).
        - Quality of life measurement.
        - Effects at longest assessment (extra follow-up)
        - Use of qualitative methods to understand outcomes.
        - Percentage attrition rate (dropout rate)
    - Adoption
        - Method to identify target delivery agent.
        - Level of expertise of delivery agent.
        - Inclusion/Exclusion.
        - Use of qualitative methods to understand adoption at setting.

- Rate of adoption.
- Characteristics of setting and participants of adoption Vs non-adoption.
- Measure of cost.

- Implementation
  - Intervention type and intensity.
  - Extent protocol delivered as intended (protocol reported).
  - Use of qualitative methods to understand implementation.
  - Measure of cost within protocol.
- Maintenance
  - Assessment 6 months following completion of intervention.
  - Is the program still in place.
  - Use of qualitative methods.
  - Was the program modified.

Measures of effect
Any effect measure.

Data extraction (selection and coding)
All identified citations will be compiled into Rayyan (www.rayyan.ai) software to manage and remove duplicate references. The stages of data extraction are as follows:

Stage 1: title and abstract screening
Titles and abstracts identified via the electronic database search will be screened by three reviewers. Initially 100 citations will be reviewed by all three reviewers together, which will ensure that each fully understands the inclusion/exclusion criteria and screening process. The lead reviewer will review 100% of the remaining citations, while the other two reviewers will review 50% each. This will ensure that each citation is reviewed by two reviewers so as to eliminate any bias. Reviews will be undertaken blindly on the Rayyan system. Any disagreements will be discussed until a unified decision is made. If a consensus cannot be reached on the inclusion of a reference, a fourth reviewer will be consulted.

Stage 2: full text screening
Full texts will be independently blindly screened by two reviewers to confirm eligibility through completing inclusion/exclusion checklists. After full text screening are complete any disagreements will be discussed until a unified decision is made. If a consensus cannot be reached on the inclusion of a reference, a third reviewer will be consulted.

Stage 3: data extraction
Data extraction will be informed by the Cochrane Handbook (http://handbook.cochrane.org/) and compiled onto an Excel document. One reviewer will complete data extraction. Data to be extracted includes relevant article bibliographic information, setting and study design, sample characteristics, intervention/exposure description (quantitative) and outcome measurements/outcomes relevant to qualitative objectives.

Risk of bias (quality) assessment

Risk of bias (quality) assessment will be assessed by one reviewer.

Risk of bias for interventional/experimental studies will be guided by the Cochrane handbook (http://handbook.cochrane.org/). Observational studies and qualitative studies quality assessment will be evaluated using the Critical Appraisal Skills Programme (CASP). No studies will be excluded based on the risk of bias (quality) assessment score but will be taken into consideration during the reporting, analytical and discussion phases.

Strategy for data synthesis

After the search element of the systematic review identified journal articles will be screened and data identified and extracted in relation to the 5 elements (Reach, Effectiveness, Adoption, Implementation and Maintenance) of the RE-AIM integrated framework. The data will be extracted using a combination of two validated RE-AIM coding sheets (https://re-aim.org/resources-and-tools/measures-and-checklists/). The combination of the two sheets facilitated in the coding of information across all five dimensions of the RE-AIM framework, looking at 28 individual indicators from each intervention. The alignment of these indicators to each dimension of the RE-AIM framework is:

Reach

The items from the extraction tool that facilitate in reporting on the potential reach of an intervention include the following: the method used to identify the target population, inclusion criteria and exclusion criteria, use of qualitative methods to understand reach or recruitment, sample size, participation rate, and sample representatives. The participation rate will be calculated based on the reported number of participants, divided by the number of eligible participants exposed to recruitment. The sample representativeness information will be extracted if an intervention reports the demographics of both the participants and eligible non-participants.

Efficacy/Effectiveness

The efficacy and effectiveness items include the following: assessment of the effect on outcomes at shortest assessment point, imputation procedures reported, the presence of quality of life measure, effects at longest follow-up, use of qualitative methods to understand outcomes, and percent attrition or dropout rate. If the attrition rate is not directly reported, it will be calculated based on the participant numbers at randomisation, as compared to the participant numbers at shortest assessment point.

Adoption

The items that will be extracted for adoption relate to both the setting and participants. Specifically, the extent to which a study reports; the method of identifying target agent—an agent should be identified regardless of the type of intervention; level of expertise of delivery agents (e.g., was specific training or level of understanding or influence reported for different intervention agents); inclusion and exclusion criteria for target agent; the adoption rate; comparison of settings/participants of adoption vs. non-adoption settings (e.g., demographic or environmental differences between adoption of program/intervention vs. non-adoption);

and use of qualitative methods to understand either adoption at setting level and staff participation.

Implementation
Information relating to the implementation that will be extracted and reported on. Specifically, the intervention type and measure of physical activity. Further items will include the following: the extent the protocol was delivered as intended (e.g., did the intervention achieve its intended implementation goal or did the protocol need to be adapted); a measure of cost (e.g., monetary or time commitment); and use of qualitative methods to understand the implementation of the study.

Maintenance
Maintenance will be assessed using the following three items: was an individual's behaviour assessed at least six months following the completion of the intervention; is the program still in place, was the program modified, and use of qualitative methods to understand long-term effects.

All of the relevant information will be extracted and coded in an excel spreadsheet by one reviewer. Upon the completion of the extraction, each of the 28 items will be colour coded green if the information is presented, or red if the information is not presented.

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Type and method of review
Systematic review based around the RE-AIM integrated framework

Anticipated or actual start date
18 March 2022

Anticipated completion date
01 October 2022

Funding sources/sponsors
Review Funder: The University of Strathclyde
State the funder, grant or award number and the date of award

Award: University Student Excellence Award (SEA) Studentship
Date of Award: 18th May 2021

Conflicts of interest Language

English

Country
Scotland

Stage of review
Review Ongoing

Subject index terms
Activity Tracker; Noncommunicable Disease; Adult; RE-AIM; Reach; Effectiveness; Adoption; Implementation; Maintenance; External Validity

Stage	**Started**	**Completed**
Preliminary searches	No	No
Piloting of the study selection process	No	No
Formal screening of search results against eligibility criteria	No	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

PROSPERO Registration - CRD42022319635 23 March 2022

Versions
18 March 2022 Draft V4

Appendix B: Study 1 search strategy

Web of Science – Core Collection (all editions)

Summary of Keywords and Combinations Used for each Topic Search (TS)

1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Topic search (TS) of Web of Science core collection (all editions) 01/01/2015 to 21/02/2022

- #1 TS=(“adult*”) (819,238 results)
- #2 TS=("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”) (2,182,962 results)
- #3 TS=("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) (53,606 results)
- #4 TS=("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "outpatient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”) (2,661,019 results)
- #5 TS=(“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) (2,753,372 results)
- #6 TS=(“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”) (44,930 results)
- #7 TS=(“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”) (6,296,718 results)

- #8 #1 AND #2 (231,165 results)
- #9 #3 AND #4 (16,441 results)
- #10 #5 OR #6 (2,769,060 results)
- #11 #7 AND #10 (1,037,132 results)
- #12 #8 AND #9 AND #11 (718)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

MEDLINE (ProQuest)

Summary of Keywords and Combinations Used for each Anywhere Except Full Text search (NOFT)

1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Anywhere Except Full Text search (NOFT) of MEDLINE (ProQuest) 01/01/2015 to 22/02/2022

- #1 noft((“adult*”)) (1,696,473 results)
- #2 noft(("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) (2,148,392 results)
- #3 noft(("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”)) (40,275 results)
- #4 noft(("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) (3,236,733 results)
- #5 noft((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”)) (1,671,955 results)
- #6 noft((“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) (35,839 results)
- #7 noft((“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)) (2,989,629 results)
- #8 #1 AND #2 (586,359 results)
- #9 #3 AND #4 (28,969 results)
- #10 #5 OR #6 (1,682,586 results)
- #11 #7 AND #10 (702,370 results)
- #12 #8 AND #9 AND #11 (2,516 results)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence”

OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

ACM (Digital Library)

Summary of Keywords and Combinations Used for each Full Text search [Full Text:]

1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Full Text search [Full Text:] of ACM Guide to Computing Literature (Digital Library) January 2015 to February 2022

- #1 [Full Text: “adult*”] (10,971 results)
- #2 [Full Text: "chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”] (34,889 results)
- #3 [Full Text: "activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”] (3,145 results)
- #4 [Full Text: "clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”] (5,624 results)
- #5 [Full Text: “physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”] (203,990 results)
- #6 [Full Text: “sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”] (12,055 results)
- #7 [Full Text: “validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach”

OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”] (11,560 results)

- #8 #1 AND #2 (2,639 results)
- #9 #3 AND #4 (3,145 results)
- #10 #5 OR #6 (203,744 results)
- #11 #7 AND #10 (194,468 results)
- #12 #8 AND #9 AND #11 (194 results)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

APA PsycINFO (EBSCO)

Summary of Keywords and Combinations Used for each Search (no field selected)

1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of APA PsycINFO (EBSCO) (all editions) January 2015 to February 2022

- #1 (“adult*”) (2,269,459 results)
- #2 ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”) (2,028,042 results)
- #3 ("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) (60,327 results)
- #4 ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”) (5,992,636 results)
- #5 (“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) (4,257,388 results)
- #6 (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”) (179,289 results)
- #7 (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”) (13,280,371 results)
- #8 #1 AND #2 (310,435 results)
- #9 #3 AND #4 (19,828 results)
- #10 #5 OR #6 (4,393,388 results)
- #11 #7 AND #10 (1,389,688 results)
- #12 #8 AND #9 AND #11 (521)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

Cochrane Library

Summary of Keywords and Combinations Used for each Search (title, abstract, keyword)

1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of Cochrane Library January 2015 to February 2022

- #1 (“adult*”) (Cochrane reviews = 2,055, Cochrane protocols = 319, Trials = 402.303)
- #2 ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”) (Cochrane reviews = 2,597, Cochrane protocols = 318, Trials = 363,910)
- #3 ("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) (Cochrane reviews = 28, Cochrane protocols = 4, Trials = 8,840)
- #4 ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”) (Cochrane reviews = 3,925, Cochrane protocols = 268, Trials = 661,887)
- #5 (“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) (Cochrane reviews = 3,211, Cochrane protocols = 1,183, Trials = 508,552)
- #6 (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR

“deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”) (Cochrane reviews = 96, Cochrane protocols = 2, Trials = 15,967)

- #7 (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”) (Cochrane reviews = 4,339, Cochrane protocols = 1,006, Trials = 935,033)
- #8 #1 AND #2 (Cochrane reviews = 1,323, Cochrane protocols = 56, Trials = 157,789)
- #9 #3 AND #4 (Cochrane reviews = 28, Cochrane protocols = 0, Trials = 6,578)
- #10 #5 OR #6 (Cochrane reviews = 3,229, Cochrane protocols = 1,183, Trials = 510,641)
- #11 #7 AND #10 (Cochrane reviews = 3,194, Cochrane protocols = 887, Trials = 478,131)
- #12 #8 AND #9 AND #11 (Cochrane reviews = 9, Cochrane protocols = 0, Trials = 1,206) (1,215 results)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

MEDLINE (Ovid, Embase, Embase Classic)

Summary of Keywords and Combinations Used for each Search (title, abstract, keyword)

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1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour

7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of MEDLINE (Ovid, Embase, Embase classic) 2015 to 2022

- #1 (adult*) (5,429,955 results)
- #2 (chronic disease* OR chronic illness* OR noncommunicable disease* OR non-communicable OR noncommunicable OR chronic OR illness OR disease) (5,377,196 results)
- #3 (activity track* OR activity monitor* OR wearable* technolog* OR wearable device* OR eHealth OR mHealth OR fitness tracker* OR fitness monitor* OR fitness device* OR digital intervention* OR digital tracker* OR digital monitor* OR digital device* OR wearable activity tracker* OR pedometer OR accelerometer OR step counter) (61,299 results)
- #4 (clinical care OR health care OR healthcare OR primary care OR outpatient OR out patient OR out-patient OR clinical practice OR public health OR clinical OR care OR health promotion) (7,702,687 results)
- #5 (physical activity OR active lifestyle* OR physical fitness OR fitness OR physical health OR active* OR intervention OR activity OR exercise) (4,041,469 results)
- #6 (sedentary behav* OR sedentary OR sedentary time OR sitting OR sitting time OR sitting behav* OR screen time OR screen based OR chair based OR deskbound OR physical inactivity OR inactive lifestyle OR lack of activity) (81,309 results)
- #7 (validity OR external validity OR behaviour change OR policy change OR community change OR participation OR quality of life OR reach OR influence OR effectiveness OR success OR usefulness OR efficacy OR adoption OR acceptance OR maintenance OR preservation OR acceptability OR rate OR appraise OR analyses OR implement* OR implementation OR deliver) (6,926,942 results)
- #8 #1 AND #2 (2,220,987 results)
- #9 #3 AND #4 (36,464 results)
- #10 #5 OR #6 (4,067,354 results)
- #11 #7 AND #10 (1,686,931 results)
- #12 #8 AND #9 AND #11 (455 results)

((adult*) AND (chronic disease* OR chronic illness* OR noncommunicable disease* OR non-communicable OR noncommunicable OR chronic OR illness OR disease)) AND ((activity track* OR activity monitor* OR wearable* technolog* OR wearable device* OR eHealth OR mHealth OR fitness tracker* OR fitness monitor* OR fitness device* OR digital intervention* OR digital tracker* OR digital monitor* OR digital device* OR wearable activity tracker* OR pedometer OR accelerometer OR step counter) AND (clinical care OR health care OR healthcare OR primary care OR outpatient OR out patient OR out-patient OR clinical practice OR public health OR clinical OR care OR health promotion)) AND ((physical activity OR active lifestyle* OR physical fitness OR fitness OR physical health OR active* OR intervention OR activity OR exercise) OR (sedentary behav* OR sedentary OR sedentary time OR sitting OR sitting time OR sitting behav* OR screen time OR screen based OR chair based OR deskbound OR physical inactivity OR inactive lifestyle OR lack of activity)) AND (validity OR external validity OR behaviour change OR policy change OR community change OR participation OR quality of life OR reach OR influence OR effectiveness OR success OR usefulness OR efficacy OR adoption OR acceptance OR maintenance OR preservation OR acceptability OR rate OR appraise OR analyses OR implement* OR implementation OR deliver)

Grey Literature

GreyNet

Summary of Keywords and Combinations Used for each Search

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1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of GreyNet (2015 to 2022)

- #1 (adult*) (2,982 results)
- #2 (chronic disease* OR chronic illness* OR noncommunicable disease* OR non-communicable OR noncommunicable OR chronic OR illness OR disease) (3,485 results)
- #3 (activity track* OR activity monitor* OR wearable* technolog* OR wearable device* OR eHealth OR mHealth OR fitness tracker* OR fitness monitor* OR fitness device* OR digital intervention* OR digital tracker* OR digital monitor* OR digital device* OR wearable activity tracker* OR pedometer OR accelerometer OR step counter) (13,626 results)
- #4 (clinical care OR health care OR healthcare OR primary care OR outpatient OR out patient OR out-patient OR clinical practice OR public health OR clinical OR care OR health promotion) (74,334 results)

- #5 (physical activity OR active lifestyle* OR physical fitness OR fitness OR physical health OR active* OR intervention OR activity OR exercise) (10,938 results)
- #6 (sedentary behav* OR sedentary OR sedentary time OR sitting OR sitting time OR sitting behav* OR screen time OR screen based OR chair based OR deskbound OR physical inactivity OR inactive lifestyle OR lack of activity) (153,416 results)
- #7 (validity OR external validity OR behaviour change OR policy change OR community change OR participation OR quality of life OR reach OR influence OR effectiveness OR success OR usefulness OR efficacy OR adoption OR acceptance OR maintenance OR preservation OR acceptability OR rate OR appraise OR analyses OR implement* OR implementation OR deliver) (153,753 results)
- #8 #1 AND #2 (303 results)
- #9 #3 AND #4 (3,192 results)
- #10 #5 OR #6 (153,559 results)
- #11 #7 AND #10 (152,724 results)
- #12 #8 AND #9 AND #11 (31 results) (o extracted)

((adult*) AND (chronic disease* OR chronic illness* OR noncommunicable disease* OR non-communicable OR noncommunicable OR chronic OR illness OR disease)) AND ((activity track* OR activity monitor* OR wearable* technolog* OR wearable device* OR eHealth OR mHealth OR fitness tracker* OR fitness monitor* OR fitness device* OR digital intervention* OR digital tracker* OR digital monitor* OR digital device* OR wearable activity tracker* OR pedometer OR accelerometer OR step counter) AND (clinical care OR health care OR healthcare OR primary care OR outpatient OR out patient OR out-patient OR clinical practice OR public health OR clinical OR care OR health promotion)) AND ((physical activity OR active lifestyle* OR physical fitness OR fitness OR physical health OR active* OR intervention OR activity OR exercise) OR (sedentary behav* OR sedentary OR sedentary time OR sitting OR sitting time OR sitting behav* OR screen time OR screen based OR chair based OR deskbound OR physical inactivity OR inactive lifestyle OR lack of activity)) AND (validity OR external validity OR behaviour change OR policy change OR community change OR participation OR quality of life OR reach OR influence OR effectiveness OR success OR usefulness OR efficacy OR adoption OR acceptance OR maintenance OR preservation OR acceptability OR rate OR appraise OR analyses OR implement* OR implementation OR deliver)

CORE

Summary of Keywords and Combinations Used for each Search

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1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)

9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of CORE (2015 to 2021)

- #1 (“adult*”) (942,014 results)
- #2 ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”) (2,329,297 results)
- #3 ("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) (9,464 results)
- #4 ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”) (435,060 results)
- #5 (“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) (1,628,392 results)
- #6 (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”) (6,671 results)
- #7 (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”) (879,836 results)
- #8 #1 AND #2 (0 results)
- #9 #3 AND #4 (5,546 results)
- #10 #5 OR #6 (1,628,460 results)
- #11 #7 AND #10 (468,773 results)
- #12 #8 AND #9 AND #11 (0 results)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

OAlster and WorldCat.org

Summary of Keywords and Combinations Used for each Search

1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)
8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of OAlster and WorldCat.org (2015 to 2022) (Title and Abstract)

- #1 (“adult*”) (494 results)
- #2 ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”) (399 results)
- #3 ("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) (0 results)
- #4 ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”) (34 results)
- #5 (“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) (1,029 results)

- #6 (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”) (0 results)
- #7 (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”) (4,664 results)
- #8 #1 AND #2 (5 results)
- #9 #3 AND #4 (0 results)
- #10 #5 OR #6 (1,029 results)
- #11 #7 AND #10 (67 results)
- #12 #8 AND #9 AND #11 (0 results)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

Open Access Theses and Dissertations (OATD)

Summary of Keywords and Combinations Used for each Search

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1. Population - Adult.
2. Sample - Chronic disease
3. Intervention - Activity tracker
4. Exposure - Clinical care
5. Outcome – Physical activity
6. Outcome – Sedentary behaviour
7. Outcome – Reach, effectiveness/efficacy, adoption, implementation, maintenance (RE-AIM outcomes)

8. 1 and 2 (population and sample)
9. 3 and 4 (intervention and exposure)
10. 5 or 6 (physical activity/sedentary behaviour outcome)
11. 7 and 10 (all outcomes)
12. 8 and 9 and 11 (final result)

Search of OATD (2015 to 2022) (Title, Abstract and Keywords)

- #1 (“adult*”) (68,157 results)
- #2 ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”) (266,582 results)
- #3 ("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) (4,292,216 results)
- #4 ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”) (629,724 results)
- #5 (“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) (788,047 results)
- #6 (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”) (4,789,302 results)
- #7 (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”) (4,787,498 results)
- #8 #1 AND #2 (0 results)
- #9 #3 AND #4 (72,747 results)
- #10 #5 OR #6 (4,777,939 results)
- #11 #7 AND #10 (4,735,263 results)
- #12 #8 AND #9 AND #11 (0 results)

((“adult*”) AND ("chronic disease*" OR "chronic illness*" OR "noncommunicable disease*" OR "non-communicable" OR "noncommunicable" OR “chronic” OR “illness” OR “disease”)) AND (("activity track*" OR "activity monitor*" OR "wearable* technolog*" OR "wearable device*" OR "eHealth" OR "mHealth" OR "fitness tracker*" OR "fitness monitor*" OR "fitness device*" OR "digital intervention*" OR "digital tracker*" OR "digital monitor*" OR "digital device*" OR “wearable activity tracker*” OR “pedometer” OR “accelerometer” OR “step counter”) AND ("clinical care" OR "health care" OR "healthcare" OR "primary care" OR "outpatient" OR "out patient" OR "out-patient" OR "clinical practice" OR "public health" OR “clinical” OR “care” OR “health promotion”)) AND ((“physical activity” OR "active lifestyle*" OR "physical fitness" OR "fitness" OR "physical health" OR "active*" OR "intervention" OR “activity” OR “exercise”) OR (“sedentary behav*” OR “sedentary” OR “sedentary time” OR “sitting” OR “sitting time” OR “sitting behav*” OR “screen time” OR “screen based” OR “chair based” OR “deskbound” OR “physical inactivity” OR “inactive lifestyle” OR “lack of activity”)) AND (“validity” OR “external validity” OR “behaviour change” OR “policy change” OR “community change” OR “participation” OR “quality of life” OR “reach” OR “influence” OR “effectiveness” OR “success” OR “usefulness” OR “efficacy” OR “adoption” OR “acceptance” OR “maintenance” OR “preservation” OR “acceptability” OR “rate” OR “appraise” OR “analyses” OR “implement*” OR “implementation” OR “deliver”)

Text Words

Original Term	**Broader Terms**
Activity trackers	1. Activity monitor 2. Wearable technology 3. Wearable device 4. eHealth 5. mHealth 6. Fitness tracker 7. Fitness monitor 8. Fitness device 9. Digital intervention 10. Digital tracker 11. Digital monitor 12. Digital device 13. Wearable activity tracker 14. Pedometer 15. Accelerometer 16. Step counter
Clinical care	1. Health care 2. Healthcare 3. Primary care 4. Outpatient 5. Out patient 6. Out-patient 7. Clinical practice 8. Public health 9. Clinical 10. Care 11. Health promotion
Physical activity	1. Physical fitness 2. Active lifestyles 3. Fitness 4. Physical health

	5. Activity 6. Exercise 7. Intervention
Sedentary behaviour	1. Sedentary 2. Sedentary time 3. Sitting 4. Sitting time 5. Sitting behaviour 6. Screen time 7. Screen based 8. Chair based 9. Deskbound 10. Physical inactivity 11. Inactive lifestyle 12. Lack of activity
Adults	
Chronic diseases	1. Chronic illness 2. Noncommunicable disease 3. Noncommunicable 4. Non-communicable 5. Chronic disease 6. Chronic 7. Illness 8. Disease
RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance)	1. Validity 2. External validity 3. Behaviour change 4. Policy change 5. Community change 6. Participation 7. Quality of life 8. Reach 9. Influence 10. Effectiveness 11. Success 12. Usefulness 13. Efficacy 14. Adoption 15. Acceptance 16. Maintenance 17. Preservation 18. Acceptability 19. Rate 20. Appraise 21. Analyses 22. Implement* 23. Implementation

	24. Deliver

PROSPERO Registration - CRD42022319635 (23/03/2022)

Final Results

Total – 5,619
Rayyan duplicates – 1,034
Final number for screening in Rayyan – 4,585

Title and Abstract Screening Rayyan
Include – 63
Excluded – 4,522

Full Text Screening
Include – 15
Excluded – 48

Appendix C: Link to RE-AIM data extraction document (Study 1)

https://strath-
my.sharepoint.com/:x:/r/personal/ckb16145_uni_strath_ac_uk/Documents/Bill%20Hodgso
n%20PhD%20Folder/Thesis/Thesis%20Appendix/RE-
AIM%20Data%20Extraction%20V1%201%20Sept%2022.xlsx?d=wed2e0ef0d3e843f2932cacf
46d375e7c&csf=1&web=1&e=HGwTlu

Appendix D: Study 2 ethics application

Title of research:
Evaluating the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website using the RE-AIM framework: A mixed methods Study.

Study Aim
Evaluate the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website using the RE-AIM Framework

How will participants be recruited?
Qualitative
Adults (18 + years of age) diagnosed with type 2 diabetes (n = 10) and health care professionals (n = 10) (Consultants, GP's, Diabetes nurses and Practice nurses) will be recruited through involvement in previous studies by the research team (email), University contacts (email) and social media (Twitter and Facebook). If participants wish to take part in this study they will be asked to follow a link contained in the recruitment document to the secure online Qualtrics study participant information sheet, consent form and demographic data collection form.

What will the participants be told about the proposed research study? Either upload or include a copy of the briefing notes issued to participants. In particular this should include details of yourself, the context of the study and an overview of the data that you plan to collect, your supervisor, and contact details for the Departmental Ethics Committee.

Participants will be provided with a link to an online Qualtrics participant information sheet, consent form and data collection form. The participant information sheet will explain:
- The scope/aim of the study.
- Roles of participants involved.
- The time commitment asked of participants and broad timeline of the project.

The participant information sheets, consent form and demographics form for both health care professionals and adults with type 2 diabetes are attached to this application.

This study is the year 2 element of the applicants PhD and supervised by Dr Alison Kirk, Dr Marilyn Lennon and Dr Xanne Janssen. They have granted approval for this ethics application to be submitted.

How will consent be demonstrated? Either upload or include here a copy of the consent form/instructions issued to participants. It is particularly important that you make the rights of the participants to freely withdraw from the study at any point (if they begin to feel stressed for example), nor feel under any pressure or obligation to complete the study, answer any particular question, or undertake any particular task. Their rights regarding associated data collected should also be made explicit.

Those interested in taking part in this study will be asked within the recruitment document to follow a link to the secure online Qualtrics participant information sheet, consent form and demographics data form. If participants agree to take part in this study they will confirm this on the Qualtrics consent form. Consent forms will be downloaded from Qualtrics in Microsoft Word format and stored securely on the University OneDrive system.

The participant information sheets and consent forms for both the health care professionals and adults with type 2 diabetes are attached to this application.

What will participants be expected to do? Either upload or include a copy of the instructions issued to participants along with a copy of or link to the survey, interview script or task description you intend to carry out. Please also confirm (where appropriate) that your supervisor has seen and approved both your planned study and this associated ethics application.

Once participants have consented to take part in this study (by marking the Qualtrics online I agree to participate section within the consent form) they will be emailed to arrange a one-to-one interview. Each participant will be provided with a unique identification number which will be used throughout this study. The identification of all participants will remain anonymous beyond the initial recruitment and consent process. Participants will be informed that they can withdraw from the study at any stage. Prior to analysis of any data participants will have the option to exclude any information they provide.

A semi-structured interview schedule will be developed. Participants will be invited to take part in one-to-one interviews online via the secure University Zoom system. These interviews will be recorded via the Zoom recording function.. Each interview will last about 45 minutes. Once each interview has finished the Zoom recording will be transcribed verbatim and uploaded onto the secure NVIVO thematic analysis system. Qualitative thematic analysis will be conducted to identify themes relating to the study. All Zoom recordings will be deleted once transcription has been completed.

What data will be collected and how will it be captured and stored? In particular indicate how adherence to the Data Protection Act and the General Data Protection Regulation (GDPR) will be guaranteed and how participant confidentiality will be handled.

The data will be:
Qualitative
The research team will collect qualitative interview data via recorded Zoom sessions with participants. The Zoom recordings will be transcribed verbatim onto a Microsoft Word document and uploaded onto the secure NVIVO thematic analysis system. Qualitative thematic analysis will be conducted to identify themes relating to the study. All Zoom recordings will be deleted once transcription has been completed.

Following University protocols, we will ensure data collected are treated securely at all times and ensure that consent forms are stored separately to any data collected. Once the study is complete (September 2023) all data will be removed from the Qualtrics system and stored within Strathcloud folders for longer term secure storage.

Participants will be informed that information they provide may appear in published reports but will remain anonymised at all times.

How will the data be processed? (e.g. analysed, reported, visualised, integrated with other data, etc.) Please pay particular attention to describing how personal or sensitive data will be handled and how GDPR regulations will be met.
Analyses will be conducted by the research team based at the University of Strathclyde. Reports and visuals will be produced for scientific publication (e.g. using NVIVO, SPSS and Standard Microsoft Programmes). Top level summaries will be shared with study partners but we will not refer to participants by name in any publications or reports.

How and when will data be disposed of? Either upload a copy of your data management plan or describe how data will be disposed.
PDF File: (max 10MB)
After the study: Meeting notes and questionnaire data will be stored securely for 10 years according to University of Strathclyde policy. Our Qualtrics online data will be removed 6 months after the study concludes- but will be retained in the Strathcloud servers/PURE in an appropriate alternative format (e.g. PDF, excel doc) as suggested by data management policies.

The procedures that will be followed for the collection, storage, protection, retention and destruction of all information comply with national and EU legislation.

Anonymised and summary data will be used for preparation and submission of academic publications- such data may also be presented at meetings/conferences or shared within the University of Strathclyde. Data will be deposited into PURE and will be preserved, curated, and assigned with a dataset DOI to aid discoverability and citations. Data will not be openly shared until intellectual property arrangements are in place. Data will also be used to inform a future intervention, thus access to data may need to be restricted.

After 10 years, the data will undergo a review process by the University's Research Data Management and Sharing Team in which will be decided whether the data remain in long term storage or not and thus will be deleted.

Appendix E: Study 2 data management plan

Project Name:	Evaluating the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes using the RE-AIM framework: A qualitative interview study	Funder:	University of Strathclyde Student Excellence Award
Project Description:	Mixed Methods Study		
Student:	William Hodgson	Principal Investigator/ Supervisor:	Dr Alison Kirk
Institution:	University of Strathclyde	Dept / School:	Physical Activity for Health
Date of First Version:	31 July 2022		
Date of Updates:			

This template is based on DCC (Digital Curation Centre). (2013). Checklist for a Data Management Plan. V.4.0. Edinburgh: Digital Curation Centre. Available online: http://www.dcc.ac.uk/resources/data-management-plans

What data (file types) will you collect or create?

List all the research data (file types) that you will collect /generate as part of your project. Examples are included on the first three rows to help you get started, and there are links to relevant info, where indicated (i.e. ℹ).

Data type	Original format	Preservation format*	Estimated volume	Intellectual Property Rights (IPR) owner ℹ	Active storage location	Completed storage location
Demographic details of participants taking part in the qualitative element of the study.	.docx	.docx	20 participants	University of Strathclyde	Qualtrics	Pure
Audio recordings of semi-structured interviews conducted with participants for qualitative analysis.	.m4a	.m4a	20 participant interviews	University of Strathclyde	OneDrive	Deleted after transcription
Transcriptions from audio recordings of semi-structured interviews conducted with participants for qualitative analysis.	.docx	.docx	20 participant interviews	University of Strathclyde	NVIVO thematic analysis software	OneDrive and Pure

Qualitative thematic analysis of participants semi-structured interviews	.docx	.docx	20 partcipant interviews	University of Strathclyde	NVIVO thematic analysis software	OneDrive and Pure

*Preservation formats should be easy to access without the need for specific proprietary software.

How will the data be collected or created?

- How will you collect or generate data?
    1. Participants who have consented to take part in the qualitative thematic analysis interviews will be emailed a link to a secure Qualtrics questionnaire designed to capture basic demographic details such as age and gender. Each participant will be provided with a unique four-digit ID number for use throughout this study. Their identidy will be anonymised.
    2. A semi-structured interview schedule will be produced. One-to-one interviews will be conducted with participants via the University Zoom system. Interviews will be audio recorded via an encrypted University Dictaphone. Once complte the audo recordings will be transcribed verbatium and the audio recording delted. The transcribed interviews will be uploaded onto the secure NVIVO thematic analysis system and analysis undertaken to develop themes relating to the study topic. Themes will be downloaded from NVIVO in a Microsoft Word format.
- How will you structure and name your folders and files?
    1. Demographic details of participants will be stored on the secure OneDrive system in a folder named participants demographic data. The excel document will only contain the participants unique four-digit ID number against their information. Once downloaded onto the secure University Pure system the data will be provided with a DOI number.
    2. Audio recordings from the semi-structured interviews will initially be stored on a secure University Dictaphone. These will be downloaded into a secure University OneDrive folder named partcipants interviews and deleted once transcribed.
    3. Transcribed partcipants interviews will be stored on in a secure University OneDrive folder named partcipants interviews. Each interview will be named by the four digit participant ID number. Once downloaded into the secure University Pure system the transcribed ineterviews will be provided with a unique DOI number.
    4. A study folder will be created on the secure University NVIVO system. This will be named after the study title. Transcribed interviews will be stored under the participants ID number. Identified themes will be downloaded into a secure University OneDrive folder and named Study Themes. Once downloaded into the secure University Pure system the themes will be provided with a DOI number.
- How will you handle versioning? (Each version will be labelled as V and number after the file name and the date the version was created)
- What quality assurance processes will you adopt? (Each document once created will be reviewed by my study supervisors)

What documentation and metadata will accompany the data?

What is data documentation?

Documentation may include details on the methodology used, analytical and procedural information, definitions of variables, vocabularies, units of measurement, description of instruments, software and hardware used, use conditions, and any assumptions made. For example, a survey questionnaire, or interview schedule is 'data documentation' because it **provides context to the data** collected from the survey and interviews.

Electronic Lab notebooks and readme files offer a mechanism for documenting data; as would a codebook, which lists and explains the variables and scales used when analysing data.

What is metadata?

Metadata is effectively 'data about data,' often 'intended for reading by machines, metadata helps to explain the purpose, origin, time references, geographic location, creator, access conditions and terms of use of a data collection' (UK Data Service, Metadata).

Why are documentation and metadata important/ required?
Many research funders expect researchers to publish metadata to accompany research data as part of the terms and conditions of the grant award/funding. In addition, the University encourages the creation, capture, and publication of comprehensive documentation and metadata so that the data - associated with Strathclyde's research projects and publications - is made findable, accessible, and assessable to the wider research community and to enable its reuse by others, for societal benefit. Consider, **how will you capture and create documentation and metadata**; rich, and meaningful documentation and metadata enable dataset/s to meet the **FAIR (Findable, Accessible, Interoperable, and Re-usable) data principles**. Data that are discoverable, and identifiable via a dataset DOI (Digital Object Identifier) are more easily re-usable and citable.

1. All data when complete will be uploaded onto the University Pure system for open access.

How will you manage any ethical issues?

Where a project/study involves working with people, or animals, there will be ethical considerations to address. If you are carrying out research involving human participants, you must consider whether consent is required to allow the data you collect to be archived, shared, and reused. Consider the following:

- Have you gained consent for data preservation and sharing from participants?
- How will you protect the identity of participants if required? For example, via anonymisation.
- How will sensitive data be handled to ensure it is stored and transferred securely and appropriately?

If collecting **personal data,** you must ensure it is managed in line with **data protection laws**. Ethical issues affect how you store data, who can see/use it, and how long it is retained.
Managing ethical concerns may include: anonymisation of data; referral to departmental or institutional ethics committees; and formal consent agreements. It is prudent to identify any issues and plan accordingly.
The University has templates for **Consent forms**, **Participant info sheets**, and **Privacy notices**, as well as a Code of Practice on Investigations Involving Human Beings accessible from https://www.strath.ac.uk/ethics/

1. A department ethics application will be submitted through the online CIS system.
2. All participants involved in the qualitative element of the study will be emailed a participant information sheet and consent form.

How will you manage copyright and IPR issues?

The default **licence applied to datasets** currently deposited in the University's institutional data repository is CC BY 4.0. Anyone who uses a dataset with this licence must 'must give appropriate credit, provide a link to the license, and indicate if changes were made'. **Researchers can request a different licence be applied to their dataset**, by arrangement, as best fits any contractual or ethical agreements pertaining to the research/study.
Where data have been generated using existing and/or secondary data sources, researchers must factor-in, and adhere to, relevant third-party licence and/or re-use agreements.
Please consider the following points:

- How will the data be licensed for reuse?
- Are there any restrictions on the reuse of third-party data?
- Will data sharing be postponed/restricted e.g., to publish or seek patents?
- Do the IPR owners have any reason to restrict data sharing?

Open data is typically made available under a **CC-BY licence**, meaning that anyone can reuse the data for any purpose, as long as they cite the source of the data.
Commercially sensitive data should be restricted accordingly

Once complete all data will be uploaded onto the University Pure system for open access and covered under the CC-BY Licence as above.

How will the data be stored during research, and how will you manage access and security?

The **University offers a number of secure file storage and sharing platforms** which are **automatically backed-up throughout the day**. A comparison of these platforms is available from the

Compare file storage options web page at https://www.strath.ac.uk/professionalservices/is/help/indepth/comparefilestorage/

Research data which are confidential, sensitive, and/or contain protectable IP (intellectual property) must not be stored on unencrypted storage. Researchers are encouraged to use the University's own systems over less secure storage platforms/methods.

When **working off campus**, or **if working with external project partners**, **arrangements can be made to facilitate joint/collaborative working via shared project folders** on the University's network/storage platforms, as outlined on the Compare file storage options web page.

Please refer to the **Compare file storage options** web page and consider the following:

- Will the data you create/collect/generate be stored on the University's network/storage platforms?
- How will data be transferred to the University's network/storage platforms if it originates from another location?
- How will you ensure that collaborators, supervisors, or participants can access your data securely?
- Will data be stored on H: drive; i: drive; OneDrive for Business; Teams; SharePoint, or elsewhere?

1. The data will be stored on the secure University OneDrive system.
2. As I am working remotely all data will be saved direct onto the University OneDrive system.
3. Files will be shared with my supervisors via the OneDrive share facility.

How will data preservation and open access to data be managed?

At, or near to project completion, or following publication, upload the data associated with your project/s, publications, theses, etc. **to the University's institutional data repository in Pure**, so that it can be catalogued, preserved, and made **openly accessible from the KnowledgeBase Research Information Portal**

If you are **planning to upload the data to an external data repository** (e.g., UK Data Service; GitHub) you must **create a registry record (with metadata and a persistent link, e.g., DOI) in Pure**, so that the University can record compliance with any funder mandate and keep track of the data. Instructions and guidance, on uploading data to Pure is available on the Data deposit web page, and from RDMS (Research Data Management & Sharing) staff.

Researchers should consider the following when selecting data for curation and preservation:

- What data must be retained &/or destroyed for contractual, legal, or regulatory purposes?
- How will you decide what other data to keep (e.g., that which does not underpin a publication)?
- What data will be shared openly?
- When will you make the data available?
- How will data be preserved and shared?
- How will completed datasets be organised?

Outputs (publications, theses, etc.) arising from public funding should contain **data (access /availability) statements,** to direct readers to the data which underpins and supports the research findings. **Data statements should include persistent links (e.g., a DOI/Digital Object Identifier)** to the data source. Placeholder DOIs (Digital Object Identifier) are available in advance of final manuscript submission from RDMS staff. Further info, including example statements, is available from the Data access statements web page.

In addition to uploading data, many research funders expect structured metadata - describing the research data - to be published. Metadata must be sufficient to allow others to understand what research data exists; why, when, and how it was generated; and how to access it. This expectation can be met by creating a dataset record in Pure and including the relevant details.

Once all data is finalised and ready for publication it will be uploaded onto the Pure system.

Are any restrictions on data sharing required?

- What restrictions are required on data sharing?
- How can these restrictions be minimised? (e.g., temporary embargo, partial sharing, one to one sharing, non-disclosure agreements)

Explain any necessary restrictions on sharing (e.g., commercial, privacy, or security reasons). If data cannot be shared, a dataset record should still be created in Pure so that the data can be catalogued and preserved long-term. In such cases, data can be uploaded to Pure but the data (files) restricted**,** whilst a record, containing metadata only, can be made publicly visible. The record should explain why the data is not accessible; the circumstances under which access may be granted; and who to contact for information about the dataset. **NB. If data relates to a patent application it should not be uploaded to Pure, or any other data repository, nor shared**, until such times as clearance has been given by the project PI and/or IP & Commercialisation staff.

There will be no requirement to restrict the data collected for this study.

Who is responsible for data management?

- Who is responsible for implementing the plan, and ensuring it is reviewed and revised?
- Who will be responsible for each data management activity?
- How will responsibilities be split across partner sites in collaborative research projects?
- Will data ownership and responsibilities for research data management be part of any consortium agreement or contract agreed between partners?

As the lead author I will have full responsibility for the data management. This will be undertaken with support and guidance from my PhD supervisors.

What resources will you require to deliver your plan?

- Is additional specialist expertise (or training for existing staff) required?
- Do you require hardware or software which is additional to existing institutional provision?

No additional resources are required.

NB. Draft DMPs (Data Management Plans) can be uploaded to the DMP Inbox for review and feedback. Ideally, they should be treated as 'living' documents and reviewed over the course of a project/study.

Appendix F: Study 2 adults diagnosed with type 2 diabetes participant information sheet, consent form and baseline questionnaire

Adults Diagnosed with Type 2 Diabetes Participant Information Sheet and Consent Form

Please provide your name and email address here.

PARTICIPANT INFORMATION SHEET

Name of department: Computer and Information Sciences

Title of the study: Evaluating through the RE-AIM framework the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website: A mixed methods study.

Introduction
Type 2 Diabetes prevalence continues to increase globally (in 2019 around 463 million people were living with diabetes, and Type 2 Diabetes accounted for around 90% of all cases). Guidelines recommend an active lifestyle for managing Type 2 Diabetes and improving overall health, but adults with Type 2 Diabetes are reported to do less physical activity than adults without.

My Diabetes My Way (MDMW) is NHS Scotland's National Diabetes online education platform, available to all patients registered with diabetes in Scotland. The platform has educational text on physical activity and they are also now including Fitbit consumer activity tracker data to be uploaded.

The aim of this study is to understand (through the use of a framework called RE-AIM) the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website.

What is the purpose of this research?
Evaluate the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website.

Do you have to take part?
This study is voluntary- you should not feel compelled to take part- only if it is something that you are interested to do and feel that you have the time to get involved with. You are free to withdraw from the study at any time for any reason. You don't need to tell us why, although it would be useful to let the research team know of your decision. Withdrawal from the study at any stage will not change anything about how you are treated as an individual and we would respect your decision if you could no longer commit to the ongoing work.

What will you do in the project?
If you consent to take part in this study, we will ask you to undertake the following:

1. After the consent section of this form we ask you to please complete the questions designed to capture your basic demographic information such as age, gender etc.
2. We will ask you to take part in a one-to-one interview. This will be conducted via the secure Zoom conferencing system. The interview will be arranged at a time that suits you and an invite sent via email. The interview will last up to one hour and be conducted by one of the research team. Your identity will remain anonymous in all transcripts and published journal articles. The interviews will be recorded on the Zoom system and later transcribed into a Microsoft Word document. The recording will be deleted once transcription has been completed. The interview will focus on the use of Fitbit

activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website.

Why have you been invited to take part?
You have been asked to take part because you are an adult (18+ years of age) and diagnosed with type 2 diabetes and interested in contributing to ongoing research on the use of consumer activity trackers within type 2 diabetes health to support an active lifestyle and reduce sedentary behaviour.

What information is being collected in the project?
You will be provided with a unique four-digit participant ID number during interviews and your identification will remain anonymous throughout.

We are looking for opinions and views of the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website. The following information will be collected:

1. Basic demographic details such as age, gender etc.
2. You opinions and views in relation to the study topic.

Online questionnaires will used to capture demographic information by using the secure online Qualtrics data management system, which is fully compliant with the GDPR guidelines (https://www.qualtrics.com/uk/platform/gdpr/).

Where will the information be stored and how long will it be kept for?
Data will be processed by the research team based at the University of Strathclyde where the data collected will be downloaded and stored on secure servers. We will retain this anonymised data for a period of up to 10 years, after which point it will be comprehensively and securely destroyed. Only authorised members of the research team will have access to the network drive and locked filing cabinets. The University's network drives are backed up nightly.

Participant Confidentiality:
If you wish to withdraw from this study we would ask that you contact us via email asking to be withdrawn. You do not need to give us a reason for this decision. If you withdraw from the study, the information about you that has already been obtained will be kept. To safeguard participant's rights, the personally identifiable information used will be kept to a minimum. Personal data recorded on all documentation will be regarded as confidential and participants will be allocated a unique study number by the research team for reporting purposes. Participant's personal details will not be recorded on any surveys; only their designated unique study number will be included on these documents.

After the study:
Transcripts/meeting notes/questionnaire data will be stored securely for 10 years according to University of Strathclyde policy. Qualtrics online data will be removed 6 months after the study concludes- but will be retained in the Strathcloud servers/PURE in an appropriate alternative format (e.g. PDF, excel doc) as suggested by data management policies.

The procedures that will be followed for the collection, storage, protection, retention and destruction of all information comply with national GDPR and EU legislation.

What are the potential risks to you in taking part?
There are no anticipated risks to taking part.

What happens next?
Once you have read this participant information sheet and are happy to continue with the study, please sign the consent form on the next page and a member of the research team will be in touch by email.

If you have decided that you do not wish to take part, then do not sign the consent form. If you have chosen not to take part, then we'd like to sincerely thank you for your time and for considering this study.

If you require any more information or you are interested in being kept up to date with the latest papers and reports from this study, please contact the lead investigator William Hodgson via the following email address William.hodgson@strath.ac.uk

Chief Investigator details:
William Hodgson, Department of Physical Activity for Health at the University of Strathclyde
William.hodgson@strath.ac.uk

Ethical approval: This research was granted ethical approval by the Department of Computer and Information Sciences Ethics Committee.

cis-support@strath.ac.uk

CONSENT FORM

Confirmation and understanding of involvement in study:

	Yes (1)	No (2)
I confirm that I have read and understood the Participant Information Sheet for the above project and the research team have answered any queries to my satisfaction. (1)	○	○
I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long). (2)	○	○
I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. (3)	○	○
I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the personal data. (4)	○	○
I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study. (5)	○	○
I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available. (6)	○	○
I consent to being a participant in the project. (7)	○	○
I consent to being part of an online video recording as part of the project (8)	○	○

Consent

◯ I consent to take part in this study (1)

◯ I DO NOT consent to take part in this study (2)

Baseline Questionnaire

Please enter your 4-digit study participant number (contained within recruitment email)?

Q1 **Thank you for consenting to take part in this study.**

Q2 **What age are you in years?**

Q3 **How long have you been diagnosed with type 2 diabetes in years?**

Q4 **What is your current blood glucose level (HbA1c %)?**

Q5 **How would you describe your gender?**

◯ Man/ Male (including trans man) (1)

◯ Woman/ female (including trans woman) (2)

◯ I prefer not to answer (3)

◯ In another way (4)

Q6 **What is your highest level of education?**

◯ Degree or equivalent (1)

◯ Higher education (2)

◯ SVQ (3)

◯ School qualifications (4)

◯ Other qualifications (5)

◯ No qualifications (6)

◯ Don't know (7)

Q7 **What is your ethnicity?**

- ○ White (1)
- ○ Mixed/multiple ethnic groups (2)
- ○ Asian/ Asian British (3)
- ○ Black/African/Caribbean/Black Britsh (4)
- ○ Other ethnic group (5)
- ○ Prefer not to say (6)

Q8 **What country in the UK do you reside?**

- ○ England (1)
- ○ Northern Ireland (2)
- ○ Scotland (3)
- ○ Wales (4)

Q9 **What is your weight in kg?**

Q10 **What height are you in meters (two digits i.e. 1.82m)?**

Q11 **Would you describe your settings as urban or rural?**

- ○ Urban (1)
- ○ Rural (2)
- ○ Not sure (3)

Q12 **Which of the following condition(s) do you have?**

- ▢ I do not currently have any physical or mental health conditions (1)
- ▢ An autism spectrum disorder (2)
- ▢ Asthma (3)
- ▢ Arthritis (4)
- ▢ Alcohol or substance misuse (5)
- ▢ Coronary heart disease/heart failure (6)
- ▢ Chronic Obstructive Pulmonary Disease (COPD) (7)
- ▢ Cancer (8)
- ▢ Dementia (9)
- ▢ Diabetes (19)
- ▢ A learning disability (10)
- ▢ A mental health condition (11)
- ▢ Needs that arise from being older (e.g. support with mobility) (12)
- ▢ Another neurological condition (e.g. Parkinson's, Motor Neurone Disease or MS) (13)
- ▢ A physical disability (14)
- ▢ A sensory impairment (15)

☐ Stroke (16)

☐ Other (17)

☐ Prefer not to say (18)

Q13 **Have you used or presently own a consumer activity tracker e.g. Fitbit or Garmin?**

◯ Yes (1)

◯ Don't know (2)

◯ No (3)

Q14 **If yes, what make and model?**

◯ Make (1) ____

◯ Model (2) ____

Q15 **Have you used or presently use a fitness app on your smartphone?**

◯ Yes (1)

◯ Don't know (2)

◯ No (3)

Q16 **If yes, which app?**

Q17 **As part of your diabetes care have you received advice on physical activity?**

◯ Yes (1)

◯ No (2)

Q18 **If you answered yes to the previous question who provided the physical activity advice? (please choose all that are applicable)**

- ☐ Practice nurse (1)
- ☐ Specialist diabetes nurse (2)
- ☐ G.P. (3)
- ☐ Diabetes consultant (4)
- ☐ Physical activity/Fitness Instructor (5)
- ☐ Other (6)

Q19 **If other please explain who?**

Appendix G: Study 2 health care professionals participant information sheet, consent form and baseline questionnaire

Health Care Professionals Participant Information Sheet and Consent Form

Please provide your name and email address here.

PARTICIPANT INFORMATION SHEET

Name of department: Computer and Information Sciences

Title of the study: Evaluating through the RE-AIM framework the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website: A mixed methods study.

Introduction

Type 2 Diabetes prevalence continues to increase globally (in 2019 around 463 million people were living with diabetes, and Type 2 Diabetes accounted for around 90% of all cases). Guidelines recommend an active lifestyle for managing Type 2 Diabetes and improving overall health, but adults with Type 2 Diabetes are reported to do less physical activity than adults without.

My Diabetes My Way (MDMW) is NHS Scotland's National Diabetes online education platform, available to all patients registered with diabetes in Scotland. The platform has educational text on physical activity and they are also now including Fitbit consumer activity tracker data to be uploaded.

The aim of this study is to understand (through the use of a framework called RE-AIM) the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website.

What is the purpose of this research?

Evaluate the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website.

Do you have to take part?

This study is voluntary- you should not feel compelled to take part- only if it is something that you are interested to do and feel that you have the time to get involved with. You are free to withdraw from the study at any time for any reason. You don't need to tell us why, although it would be useful to let the research team know of your decision. Withdrawal from the study at any stage will not change anything about how you are treated as an individual and we would respect your decision if you could no longer commit to the ongoing work.

What will you do in the project?

If you consent to take part in this study, we will ask you to undertake the following:

1. After the consent section of this form we ask you to please complete the questions designed to capture your basic demographic information such as age, gender etc.
2. We will ask you to take part in a one-to-one interview. This will be conducted via the secure Zoom conferencing system. The interview will be arranged at a time that suits you and an invite sent via email. The interview will last up to one hour and be conducted by one of the research team. Your identity will remain anonymous in all transcripts and published journal articles. The interviews will be recorded on the Zoom system and later transcribed into a Microsoft Word document. The recording will be deleted once transcription has been completed. The interview will focus on the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website.

Why have you been invited to take part?

You have been asked to take part because you are a health care professional involved in the care of patients diagnosed with type 2 diabetes and interested in contributing to ongoing research on the use of consumer activity trackers within type 2 diabetes health to support an active lifestyle and reduce sedentary behaviour.

What information is being collected in the project?

You will be provided with a unique four-digit participant ID number during interviews and your identification will remain anonymous throughout.

We are looking for opinions and views of the use of Fitbit activity trackers to support physical activity and reduce sedentary behaviour in adults diagnosed with type 2 diabetes and registered with the interactive My Diabetes My Way website. The following information will be collected:

1. Basic demographic details such as age, gender etc.
2. You opinions and views in relation to the study topic.

Online questionnaires will used to capture demographic information by using the secure online Qualtrics data management system, which is fully compliant with the GDPR guidelines (https://www.qualtrics.com/uk/platform/gdpr/).

Where will the information be stored and how long will it be kept for?
Data will be processed by the research team based at the University of Strathclyde where the data collected will be downloaded and stored on secure servers. We will retain this anonymised data for a period of up to 10 years, after which point it will be comprehensively and securely destroyed. Only authorised members of the research team will have access to the network drive and locked filing cabinets. The University's network drives are backed up nightly.

Participant Confidentiality:
If you wish to withdraw from this study, we would ask that you contact us via email asking to be withdrawn. You do not need to give us a reason for this decision. If you withdraw from the study, the information about you that has already been obtained will be kept. To safeguard participant's rights, the personally identifiable information used will be kept to a minimum. Personal data recorded on all documentation will be regarded as confidential and participants will be allocated a unique study number by the research team for reporting purposes. Participant's personal details will not be recorded on any surveys; only their designated unique study number will be included on these documents.

After the study:
Transcripts/meeting notes/questionnaire data will be stored securely for 10 years according to University of Strathclyde policy. Qualtrics online data will be removed 6 months after the study concludes- but will be retained in the Strathcloud servers/PURE in an appropriate alternative format (e.g. PDF, excel doc) as suggested by data management policies.

The procedures that will be followed for the collection, storage, protection, retention and destruction of all information comply with national GDPR and EU legislation.

What are the potential risks to you in taking part?
There are no anticipated risks to taking part.

What happens next?
Once you have read this participant information sheet and are happy to continue with the study, please sign the consent form on the next page and a member of the research team will be in touch by email.

If you have decided that you do not wish to take part, then do not sign the consent form. If you have chosen not to take part, then we'd like to sincerely thank you for your time and for considering this study.

If you require any more information or you are interested in being kept up to date with the latest papers and reports from this study, please contact the lead investigator William Hodgson via the following email address William.hodgson@strath.ac.uk

Chief Investigator details:

William Hodgson, Department of Physical Activity for Health at the University of Strathclyde
William.hodgson@strath.ac.uk

Ethical approval: This research was granted ethical approval by the Department of Computer and Information Sciences Ethics Committee.

cis-support@strath.ac.uk

CONSENT FORM

Confirmation and understanding of involvement in study:

	Yes (1)	No (2)
I confirm that I have read and understood the Participant Information Sheet for the above project and the research team have answered any queries to my satisfaction. (1)	○	○
I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long). (2)	○	○
I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. (3)	○	○
I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the personal data. (4)	○	○
I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study. (5)	○	○
I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available. (6)	○	○
I consent to being a participant in the project. (7)	○	○
I consent to being part of an online video recording as part of the project (8)	○	○

Q5 Consent

- ◯ I consent to take part in this study (1)
- ◯ I DO NOT consent to take part in this study (2)

Health Professional Baseline Questionnaire

Q1 **What age are you in years?**

Q2 **How would you describe your gender?**

- ◯ Man/ Male (including trans man) (1)
- ◯ Woman/ female (including trans woman) (2)
- ◯ I prefer not to answer (3)
- ◯ In another way (4)

Q3 **What is your highest level of education?**

- ◯ Degree or equivalent (1)
- ◯ Higher education (2)
- ◯ SVQ (3)
- ◯ School qualifications (4)
- ◯ Other qualifications (5)
- ◯ No qualifications (6)
- ◯ Don't know (7)

Q4 **What is your ethnicity?**

- ◯ White (1)
- ◯ Mixed/multiple ethnic groups (2)
- ◯ Asian/ Asian British (3)
- ◯ Black/African/Caribbean/Black Britsh (4)
- ◯ Other ethnic group (5)
- ◯ Prefer not to say (6)

Q5 **What country in the UK do you reside?**

- ◯ England (1)
- ◯ Northern Ireland (2)
- ◯ Scotland (3)
- ◯ Wales (4)

Q6 **Would you describe your settings as urban or rural?**

- ◯ Urban (1)
- ◯ Rural (2)
- ◯ Not sure (3)

Q7 Which of the following best describes your occupation?

a) Medical Doctor (general practice) (1)
b) Medical Doctor (consultant) (2)
c) Nurse (general practice) (3)
d) Nurse (diabetes specialist) (4)
e) Diabetes Professional (5)
f) Fitness Professional (6)
g) Other (7)

Q8 If other please describe your occupation

Appendix H: Study 2 semi-structured interview schedule.

RE-AIM QuEST qualitative components: general and applied

Reach
Qualitative Inquiry
One to one meetings will be organised for April 2023 with health care professionals in involved in type 2 diabetes clinical care and adult (18+ years of age) patients diagnosed with type 2 diabetes. A semi-structured interview schedule will be prepared to explore the main RE-AIM components. Meetings will be audio recorded and later transcribed. Qualitative thematic analysis will be conducted. Under REACH the following components will be explored: 1. What are the barriers for patients using a Fitbit activity tracker? 2. What are the enablers for patients using a Fitbit activity tracker? 3. What are the barriers for patients registering their Fitbit activity tracker on the My Diabetes My Way system? 4. What are the enablers for patients registering their Fitbit activity tracker on the My Diabetes My Way system? 5. As a health care professional what support could be provided for patients to use a Fitbit activity tracker? 6. As a health care professional what support would patients need to register a Fitbit on the My Diabetes My Way platform? 7. Why do some patients after registering their Fitbit on the My Diabetes My Way system not upload their data? 8. Who would benefit most from the use of Fitbit activity trackers within type 2 diabetes clinical care? 9. How best would the use of Fitbit activity trackers within type 2 diabetes care be promoted? 10. As a health care professional are you able to access patients Fitbit data on the My Diabetes My Way system?
Effectiveness
Qualitative Inquiry
Under EFFECTIVENESS the following components will be explored: 1. Within type 2 diabetes care who would be the best person to interpret the physical activity/sedentary behaviour data from a Fitbit activity tracker? 2. In addition to the Fitbit activity data what additional support would patients require to make the most effective use of this information? 3. What additional training or support would health care professionals need to make the most effective use of the Fitbit activity tracker data?

4. How best can changes in physical activity or sedentary behaviour recorded on a Fitbit activity tracker be utilised within type 2 diabetes care?
5. What are the best methods of communicating the interpretation of the Fitbit data to patients?
   What are the most important elements of the Fitbit activity data for patients?

Adoption

Qualitative Inquiry

Under ADOPTION the following components will be explored:

1. What is the best way of promoting the use of Fitbit activity trackers within type 2 diabetes health care?
2. How aware are type 2 diabetes health care professionals that patients Fitbit data is available on the My Diabetes My Way system?
3. Why are some type 2 diabetes health care professionals not aware of the availability of patients Fitbit data?
4. How is the use of patients Fitbit data recorded in clinical care?
5. What training and support do type 2 diabetes health care professionals require so they can effectively use the Fitbit data?
6. What are the benefits of using the Fitbit data within clinical care?

Implementation

Qualitative Inquiry

Under IMPLEMENTATION the following components will be explored:

1. What are the key enablers for encouraging patients to register a Fitbit activity tracker on the system?
2. What are the key barriers stopping patients registering a Fitbit activity tracker on the system?
3. Who are the key health care professionals who could increase the number of patients using and registering Fitbit activity trackers on the platform?
4. What are the main challenges for increasing the number of patients registering a Fitbit activity tracker on the system?
5. What improvements within the My Diabetes My Way system would improve the interpretation of patients Fitbit data?
6. What would the main costs be for patients?
7. What are the main costs for health care providers?
8. How best can the effectiveness of Fitbit data be measured?

Maintenance

Qualitative Inquiry

Under MAINTENANCE the following components will be explored:

1. What long term infrastructure would be required to support the use of the Fitbit data in clinical care?
2. What additional training would health care staff require in order to maintain the use of the Fitbit data in clinical care?

3. What would be the main cost savings for the health service if the Fitbit data was used to promote physical activity and reduce sedentary behaviour?
4. What easy to understand methods would be used to communicate the outcomes of Fitbit use by patients?
5. Who would be best placed to manage and oversee the use of Fitbit data on the My Diabetes My Way platform?

Appendix I: Coding and Theme Development for "Awareness"

Coding Process

The coding process followed Braun and Clarke's (2006) six-phase framework for thematic analysis. Codes were generated from interview transcripts and grouped into sub-themes, which were then abstracted into the overarching theme of *Awareness*.

Main Theme: Awareness

Awareness captures participants' recognition of the existence, functions, and potential benefits of digital health tools and physical activity in type 2 diabetes care.

Sub-theme 1: My Diabetes My Way

Examples of Codes:

- Awareness of system availability: *"I am very familiar with this system and encourage all of my type 2 patients to register with it…"*
- Lack of awareness of integration: *"I was not aware that patients could upload their Fitbit data onto the system."*
- Initial unfamiliarity: *"Very little… Oh this looks brilliant. I was not aware of this."*

Flow Diagram:

A[Raw Interview Data] --> B[Initial Codes]

B --> C1[Code: Awareness of system availability]

B --> C2[Code: Lack of awareness of integration]

B --> C3[Code: Initial unfamiliarity]

C1 --> D[Sub-theme: My Diabetes My Way]

C2 --> D

C3 --> D

D --> E[Main Theme: Awareness]

Sub-theme 2: Benefits of Activity Tracking

Examples of Codes:

- Motivational role: *"I have a Fitbit so could give advice on how to use one. I do a lot of walking and I find this a great motivational tool."*
- Overcoming fear of technology: *"Providing support and advice on the use of these devices could assist in overcoming the fear of using technology for some."*
- Awareness of exercise levels: *"Hopefully the patient will be more aware of what exercise they are doing with a view to improving on present levels."*

Flow Diagram:

A[Raw Interview Data] --> B[Initial Codes]

B --> C1[Code: Motivational role]

B --> C2[Code: Overcoming fear of technology]

B --> C3[Code: Awareness of exercise levels]

C1 --> D[Sub-theme: Benefits of Activity Tracking]

C2 --> D

C3 --> D

D --> E[Main Theme: Awareness]

Sub-theme 3: Benefits to Health

Examples of Codes:

- Improved activity: *"The patient would benefit hopefully by being more active and see improvements in their health."*
- Increased activity levels: *"The patient would benefit most as this would hopefully improve their levels of activity."*
- Reduced reliance on medication: *"Long term this would benefit the patient's health with less reliance on medication and treatment for related health conditions."*

Flow Diagram:

A[Raw Interview Data] --> B[Initial Codes]

B --> C1[Code: Improved activity]

B --> C2[Code: Increased activity levels]

B --> C3[Code: Reduced reliance on medication]

C1 --> D[Sub-theme: Benefits to Health]

C2 --> D

C3 --> D

D --> E[Main Theme: Awareness]

Analytical Commentary

The theme of ***Awareness*** illustrates that while participants recognise the value of activity tracking and its health benefits, there is limited awareness of system integration (e.g., Fitbit data on MDMW). This gap suggests a need for structured training and communication strategies to enhance awareness among staff and patients.

Appendix J: Study 3 ethics application.

Title of research:
Exploring through the RE-AIM framework the use of Fitbit activity trackers to support an active lifestyle for adults diagnosed with type 2 diabetes. A mixed methods study.

Study Aim
To evaluate, using the RE-AIM framework, the addition of Fitbit consumer activity trackers to the Weigh to Go programme to support adults with Type 2 diabetes to lead an active lifestyle.

How will participants be recruited?

The Weigh to Go programme is an established weight management and physical activity programme facilitated by NHS Lanarkshire and run through local council community centres and sport facilities. This study will not focus on the Weigh to Go programme as an intervention. The study will focus on the use of Fitbit activity trackers by consenting participants who have signed up for the Weigh to Go programme. Participants will also be invited to register the Fitbit activity tracker on the My Diabetes My Way website though the research team will not be accessing this system for data.

Adults (18+ years of age) diagnosed with Type 2 diabetes will be recruited when they register for the NHS Lanarkshire community-based Weigh to Go weight management and physical activity programme. At the community-based stage of the Weigh to Go programme (see attached letter of confirmation) participants will be provided with a recruitment flyer (included) which will set out the study inclusion and exclusion criteria. If interested in taking part, they will be asked to email the investigators (William Hodgson or David Kennedy) .

Health care and physical activity professionals who are directly involved in the delivery, provision, signposting and recruitment of participants onto the NHS Lanarkshire community-based Weigh to Go programme will be provided with a recruitment flyer (included) which will set out the inclusion and exclusion criteria. If interested in taking part they will be asked to email the investigators (William Hodgson or David Kennedy).

Participants can withdraw up to 48 hours after data collection after which all anonymity qualitative data will be included. Personal data can be withdrawn up to analysis in December 2024 but qualitative anonymous data will be retained.

We aim to recruit about 100 participants for the Fitbit element of the study. Ten of these will be asked to take part in the qualitative element. Ten health care professionals will be recruited for the qualitative interviews.

What will the participants be told about the proposed research study? Either upload or include a copy of the briefing notes issued to participants. In particular this should include details of yourself, the context of the study and an overview of the data that you plan to collect, your supervisor, and contact details for the Departmental Ethics Committee.

Once participants have shown interest to take part in this study they will be provided with a link via an email to a secure online Qualtrics participant information sheet and consent form. The participant information sheet will explain:

- The scope/aim of the study.
- Roles of participants involved.
- The time commitment asked of participants and broad timeline of the project.

The participant information sheets and consent form for both health care professionals and adults with type 2 diabetes are attached as a single document for the purpose of this.

This study is the year 3 element of the applicants PhD and supervised by Dr Alison Kirk, Dr Marilyn Lennon and Dr Xanne Janssen. They have all reviewed this ethics application and the study proposal (attached).

How will consent be demonstrated? Either upload or include here a copy of the consent form/instructions issued to participants. It is particularly important that you make the rights of the participants to freely withdraw from the study at any point (if they begin to feel stressed for example), nor feel under any pressure or obligation to complete the study, answer any particular question, or undertake any particular task. Their rights regarding associated data collected should also be made explicit.

Those interested in taking part in this study will be asked within the recruitment email to follow a link to the secure online Qualtrics participant information sheet and consent form. If participants agree to take part in this study, they will confirm this on the Qualtrics consent form. Consent forms will be downloaded from Qualtrics in Microsoft Word format and stored securely on the University OneDrive system.

The participant information sheets and consent forms for the health care professionals and adults with type 2 diabetes are attached to this application as a single document.

What will participants be expected to do? Either upload or include a copy of the instructions issued to participants along with a copy of or link to the survey, interview script or task description you intend to carry out. Please also confirm (where appropriate) that your supervisor has seen and approved both your planned study and this associated ethics application.

Adults with type 2 diabetes recruitment
Adults with Type 2 diabetes will be recruited through the NHS Lanarkshire community-based Weigh to Go programme via a study flyer (attached). This flyer will be promoted by the Weigh to Go programme team at the point of registration. The flyer will give information about the study and will ask potential participants to contact the researchers via their University email addresses. The project participant information sheet and consent form will be uploaded onto the secure Qualtrics platform and if potential participants email to express an interest in participating, they will be sent via email and link to the Qualtrics participant information sheet and consent form. Each potential participant will be provided with a unique four-digit identification number.

Adults with type 2 diabetes baseline survey
Once participants consent a baseline secure Qualtrics survey will be sent via an email link to obtain participant details including demographics and diabetes related medical data (date diagnosed, treatment type, most recent HbA1c and other co-morbidities; height, weight, physical activity levels using the International Physical Activity Questionnaire (short form) and physical literacy. The baseline and end of study questionnaire is attached as a single document for the purpose of this application.

Adults with type 2 diabetes Fitbit onboarding
Fitbit consumer activity trackers (supplied by Fitbit to support this study) will be provided for each participant at no cost. Each Fitbit will be set-up and registered with the Fitbit platform by the investigators. Each participant will be provided with the registration details (email address and password) so they can access the Fitbit website and app. This will allow them to access their personal Fitbit activity data. The research team will have access to the Fitbit account for access to the participants activity data. Participants will be asked to use the Fitbit for the duration of the Weigh to Go programme (approximately 30 weeks). The Fitbit will be delivered to the participant prior to their first Weigh to Go session by the researcher David Kennedy. They will also be given information on linking their Fitbit data with the My Diabetes My Way online platform an established diabetes education and information platform used within the NHS. The study staff will not have access to the participants My Diabetes My Way data. The research team will analyse Fitbit data over the 30 weeks in relation to: daily steps; physical activity intensity and sedentary behaviour. The data will be statistically analysed using SPSS software to identify any change in physical activity and sedentary behaviour over the duration of the Weigh to Go programme.

Adults with type 2 diabetes end of study survey
In addition, a second Qualtrics survey will be developed and sent to participants on completion of the Weigh to Go programme (30-weeks) to obtain follow up data on: current diabetes management (current treatment and most recent HbA1c); height, weight, physical activity using the International Physical Activity Questionnaire (short form) and physical literacy. This is attached as a single document also containing the baseline questionnaire.

Adults with type 2 diabetes quantitative interviews
Participants will also be invited to take part in one-to-one interviews designed to explore their use of the Fitbit in more detail. The one-to-one interviews will be held over the secure University Zoom conferencing system and recorded. A semi-structured interview schedule will be developed and followed during the interview.

Participants will be able to keep the Fitbit at the end of the study.

Health care professionals recruitment and qualitative analysis
Diabetes Health care professionals and individuals involved in the delivery, management or referral process of the NHS Lanarkshire Weigh to Go program will also be invited to take part in a one-to-one interview designed to explore their views on the integration of Fitbit data into diabetes care. A study flyer will be circulated with information about the study. If someone is interested in taking part in the study, they will be asked to contact the

investigators via their University email addresses. The project participant information sheet and consent form will be uploaded onto the secure Qualtrics platform, and a link emailed to the participant along with a unique four-digit identification number. The one-to-one interviews will be held over the secure University Zoom conferencing system and recorded. A semi-structured interview schedule will be developed to guide the interview.

All interviews will be recorded and transcribed verbatim using the inbuilt Zoom system. Once transcribed all recordings will be deleted. During meetings and transcriptions, the participants identity will remain anonymous.

Qualitative thematic analysis will be conducted on the transcribed interviews using the NVIVO system. This analysis will follow the 6-stage process recommended by Braun and Clark (familiarisation (repeated reading of the transcripts), initial coding (identification of words or sentences connected to the analysis), initial development of themes (combining of codes into themes), review of identified themes, naming and finalisation of themes and preparation of the final journal article).

A copy of the study proposal is attached. This has been reviewed by the study supervisors Dr Alison Kirk, Dr Marilyn Lennon and Dr Xanne Janssen.

What data will be collected and how will it be captured and stored? In particular indicate how adherence to the Data Protection Act and the General Data Protection Regulation (GDPR) will be guaranteed and how participant confidentiality will be handled.

The data will be:
Quantitative
The research team will collect activity data (daily steps, physical activity intensity and sedentary time) via the Fitbit activity tracker provided to each adult diagnosed with type 2 diabetes during their involvement in the 30-week NHS Lanarkshire Weigh to Go programme. Both the participant and research team will have access to the Fitbit data through the Fitbit website. At the conclusion of the 30-week Weigh to Go programme the research team will download this data from the Fitbit website in Microsoft Excel format and store it on the secure University OneDrive platform. Quantitative analysis will be conducted on this data looking for changes in activity over the 30-week period.

Qualitative
The research team will collect qualitative interview data via recorded Zoom sessions with participants. The Zoom recordings will be transcribed verbatim onto a Microsoft Word document and uploaded onto the secure NVIVO thematic analysis system. Qualitative thematic analysis will be conducted to identify themes relating to the study. All Zoom recordings will be deleted once transcription has been completed.

Following University protocols, we will ensure data collected are treated securely at all times and ensure that consent forms are stored separately to any data collected. Once the study is complete (December 2024) all data will be removed from the Qualtrics system and stored within a University of Strathclyde one drive folder for longer term secure storage.

Once the Fitbit data has been downloaded the device will be removed from the Fitbit website.

Participants will be informed that information they provide may appear in published reports but will remain anonymised at all times.

How will the data be processed? (e.g. analysed, reported, visualised, integrated with other data, etc.) Please pay particular attention to describing how personal or sensitive data will be handled and how GDPR regulations will be met.
Analyses will be conducted by the research team based at the University of Strathclyde within the secure one drive folder. Reports and visuals will be produced for scientific publication (e.g. using NVIVO, SPSS and Standard Microsoft Programmes). Top level summaries will be shared with study participants but no identifiable information will be shared or published.

How and when will data be disposed of? Either upload a copy of your data management plan or describe how data will be disposed.
PDF File: (max 10MB)
After the study: Meeting notes and questionnaire data will be stored securely for 10 years according to University of Strathclyde policy. Our Qualtrics online data will be removed 6 months after the study concludes- but anonymised data will be retained in the one drive servers/PURE in an appropriate alternative format (e.g. PDF, excel doc) as suggested by data management policies.

The procedures that will be followed for the collection, storage, protection, retention and destruction of all information comply with national and EU legislation.

Anonymised and summary data will be used for preparation and submission of academic publications- such data may also be presented at meetings/conferences or shared within the University of Strathclyde. Data will be deposited into PURE and will be preserved, curated, and assigned with a dataset DOI to aid discoverability and citations. Data will not be openly shared until intellectual property arrangements are in place. Data will also be used to inform a future intervention, thus access to data may need to be restricted.

After 10 years, the data will undergo a review process by the University's Research Data Management and Sharing Team in which will be decided whether the data remain in long term storage or not and thus will be deleted.

Appendix K: Study 3 data management plan

Project Name:	Evaluation, using the RE-AIM framework, the addition of Fitbit consumer activity trackers to the Weigh to Go programme to support adults with Type 2 diabetes to lead an active lifestyle.	Funder:	University of Strathclyde Student Excellence Award
Project Description:	Mixed Methods Study		
Student:	William Hodgson	Principal Investigator/ Supervisor:	Dr Alison Kirk
Institution:	University of Strathclyde	Dept / School:	Physical Activity for Health
Date of First Version:	7 March 2024		
Date of Updates:			

This template is based on DCC (Digital Curation Centre). (2013). Checklist for a Data Management Plan. V.4.0. Edinburgh: Digital Curation Centre. Available online: http://www.dcc.ac.uk/resources/data-management-plans

What data (file types) will you collect or create?

List all the research data (file types) that you will collect /generate as part of your project. Examples are included on the first three rows to help you get started, and there are links to relevant info, where indicated (i.e. ⓘ).

Data type	Original format	Preservation format*	Estimated volume	Intellectual Property Rights (IPR) owner ⓘ	Active storage location	Completed storage location
Fitbit data	.xlsx	.xlsx	60 participants	UoS	OneDrive	Pure
Qualitative thematic analysis data	.docx	.docx	20 participants	UoS	NVIVO and OneDrive	Pure

*Preservation formats should be easy to access without the need for specific proprietary software.

How will the data be collected or created?

- How will you collect or generate data? The quantitative data will be collected from Fitbit devices provided for participants. These devices were synced with a Fitbit account set up by the study team. Fitbit data collected will include daily steps, physical activity intensity, daily sedentary time and distance moved. The Fitbit data will be downloaded from the Fitbit account in excel format and quantitative analysis conducted. Qualitative interviews will be conducted with participants and transcribed onto a word document. These will be uploaded onto the NVIVO thematic analysis platform. Identified codes will be produced in word format.
- How will you structure and name your folders and files? All files (excel and word) will be stored on the secure University OneDrive system.
- How will you handle versioning? Each version will be labelled as V and number after the file name and the date the version was created.
- What quality assurance processes will you adopt? Each document once created will be reviewed by my study supervisors.

The University's Information Governance Unit have guidance on **file naming** and **version control** at https://strath.sharepoint.com/sites/igu/SitePages/ManagingRecords.aspx

What documentation and metadata will accompany the data?

What is data documentation?

Documentation may include details on the methodology used, analytical and procedural information, definitions of variables, vocabularies, units of measurement, description of instruments, software and hardware used, use conditions, and any assumptions made. For example, a survey questionnaire, or interview schedule is 'data documentation' because it **provides context to the data** collected from the survey and interviews.

Electronic Lab notebooks and readme files offer a mechanism for documenting data; as would a codebook, which lists and explains the variables and scales used when analysing data.

What is metadata?

Metadata is effectively 'data about data,' often 'intended for reading by machines, metadata helps to explain the purpose, origin, time references, geographic location, creator, access conditions and terms of use of a data collection' (UK Data Service, Metadata).

Why are documentation and metadata important/ required?

Many research funders expect researchers to publish metadata to accompany research data as part of the terms and conditions of the grant award/funding. In addition, the University encourages the creation, capture, and publication of comprehensive documentation and metadata so that the data - associated with Strathclyde's research projects and publications - is made findable, accessible, and assessable to the wider research community and to enable its reuse by others, for societal benefit.

Consider, **how will you capture and create documentation and metadata**; rich, and meaningful documentation and metadata enable dataset/s to meet the **FAIR (Findable, Accessible, Interoperable, and Re-usable) data principles**. Data that are discoverable, and identifiable via a dataset DOI (Digital Object Identifier) are more easily re-usable and citable.

1. A study protocol has been developed and available for review.
2. All data when complete will be uploaded onto the University Pure system for open access. No participant personal details will be recorded. Each will be given a unique four-digit ID number.

How will you manage any ethical issues?

Where a project/study involves working with people, or animals, there will be ethical considerations to address. If you are carrying out research involving human participants, you must consider whether consent is required to allow the data you collect to be archived, shared, and reused. Consider the following:

- Have you gained consent for data preservation and sharing from participants?
- How will you protect the identity of participants if required? For example, via anonymisation.
- How will sensitive data be handled to ensure it is stored and transferred securely and appropriately?

If collecting **personal data,** you must ensure it is managed in line with **data protection laws**. Ethical issues affect how you store data, who can see/use it, and how long it is retained.

Managing ethical concerns may include: anonymisation of data; referral to departmental or institutional ethics committees; and formal consent agreements. It is prudent to identify any issues and plan accordingly.

The University has templates for **Consent forms**, **Participant info sheets**, and **Privacy notices**, as well as a Code of Practice on Investigations Involving Human Beings accessible from https://www.strath.ac.uk/ethics/

Ethical approval has been granted by the CIS ethics committee.

How will you manage copyright and IPR issues?

The default **licence applied to datasets** currently deposited in the University's institutional data repository is CC BY 4.0. Anyone who uses a dataset with this licence must 'must give appropriate credit, provide a link to the license, and indicate if changes were made'. **Researchers can request a different licence be applied to their dataset**, by arrangement, as best fits any contractual or ethical agreements pertaining to the research/study.

Where data have been generated using existing and/or secondary data sources, researchers must factor-in, and adhere to, relevant third-party licence and/or re-use agreements.

Please consider the following points:

- How will the data be licensed for reuse?
- Are there any restrictions on the reuse of third-party data?
- Will data sharing be postponed/restricted e.g., to publish or seek patents?
- Do the IPR owners have any reason to restrict data sharing?

Open data is typically made available under a **CC-BY licence**, meaning that anyone can reuse the data for any purpose, as long as they cite the source of the data.
Commercially sensitive data should be restricted accordingly

Once complete all data will be uploaded onto the University Pure system for open access and covered under the CC-BY Licence as above.

How will the data be stored during research, and how will you manage access and security?

The **University offers a number of secure file storage and sharing platforms** which are **automatically backed-up throughout the day**. A comparison of these platforms is available from the **Compare file storage options** web page at https://www.strath.ac.uk/professionalservices/is/help/indepth/comparefilestorage/
Research data which are confidential, sensitive, and/or contain protectable IP (intellectual property) must not be stored on unencrypted storage. Researchers are encouraged to use the University's own systems over less secure storage platforms/methods.
When **working off campus**, or **if working with external project partners**, **arrangements can be made to facilitate joint/collaborative working via shared project folders** on the University's network/storage platforms, as outlined on the Compare file storage options web page.
Please refer to the **Compare file storage options** web page and consider the following:

- Will the data you create/collect/generate be stored on the University's network/storage platforms?
- How will data be transferred to the University's network/storage platforms if it originates from another location?
- How will you ensure that collaborators, supervisors, or participants can access your data securely?
- Will data be stored on H: drive; i: drive; OneDrive for Business; Teams; SharePoint, or elsewhere?

4. The data will be stored on the secure University OneDrive system.
5. As I am working remotely all data will be saved direct onto the University OneDrive system.
6. Files will be shared with my supervisors via the OneDrive share facility.

How will data preservation and open access to data be managed?

At, or near to project completion, or following publication, upload the data associated with your project/s, publications, theses, etc. **to the University's institutional data repository in Pure**, so that it can be catalogued, preserved, and made **openly accessible from the KnowledgeBase Research Information Portal**
If you are **planning to upload the data to an external data repository** (e.g., UK Data Service; GitHub) you must **create a registry record (with metadata and a persistent link, e.g., DOI) in Pure**, so that the University can record compliance with any funder mandate and keep track of the data. Instructions and guidance, on uploading data to Pure is available on the Data deposit web page, and from RDMS (Research Data Management & Sharing) staff.
Researchers should consider the following when selecting data for curation and preservation:

- What data must be retained &/or destroyed for contractual, legal, or regulatory purposes?
- How will you decide what other data to keep (e.g., that which does not underpin a publication)?
- What data will be shared openly?
- When will you make the data available?
- How will data be preserved and shared?
- How will completed datasets be organised?

Outputs (publications, theses, etc.) arising from public funding should contain **data (access /availability) statements,** to direct readers to the data which underpins and supports the research findings. **Data statements should include persistent links (e.g., a DOI/Digital Object Identifier)** to the data source. Placeholder DOIs (Digital Object Identifier) are available in advance of final manuscript submission from RDMS staff. Further info, including example statements, is available from the Data access statements web page.
In addition to uploading data, many research funders expect structured metadata - describing the research data - to be published. Metadata must be sufficient to allow others to understand what

research data exists; why, when, and how it was generated; and how to access it. This expectation can be met by creating a dataset record in Pure and including the relevant details.

Once all data is finalised and ready for publication it will be uploaded onto the Pure system.

Are any restrictions on data sharing required?

- What restrictions are required on data sharing?
- How can these restrictions be minimised? (e.g., temporary embargo, partial sharing, one to one sharing, non-disclosure agreements)

Explain any necessary restrictions on sharing (e.g., commercial, privacy, or security reasons). If data cannot be shared, a dataset record should still be created in Pure so that the data can be catalogued and preserved long-term. In such cases, data can be uploaded to Pure but the data (files) restricted**,** whilst a record, containing metadata only, can be made publicly visible. The record should explain why the data is not accessible; the circumstances under which access may be granted; and who to contact for information about the dataset. **NB. If data relates to a patent application it should not be uploaded to Pure, or any other data repository, nor shared**, until such times as clearance has been given by the project PI and/or IP & Commercialisation staff.

There will be no requirement to restrict the data collected for this study as all identifiable information will be removed.

Who is responsible for data management?

- Who is responsible for implementing the plan, and ensuring it is reviewed and revised?
- Who will be responsible for each data management activity?
- How will responsibilities be split across partner sites in collaborative research projects?
- Will data ownership and responsibilities for research data management be part of any consortium agreement or contract agreed between partners?

As the lead author I will have full responsibility for the data management. This will be undertaken with support and guidance from my supervisors.

What resources will you require to deliver your plan?

- Is additional specialist expertise (or training for existing staff) required?
- Do you require hardware or software which is additional to existing institutional provision?

No additional resources are required.

NB. Draft DMPs (Data Management Plans) can be uploaded to the DMP Inbox for review and feedback. Ideally, they should be treated as ‘living’ documents and reviewed over the course of a project/study.

Appendix L: Weigh to Go participant's participant information sheet consent form and baseline questionnaire

Fitbit Participant Information Sheet
Name of department: Department of Computer and Information Sciences

Title of the study: Exploring through the RE-AIM framework the use of Fitbit activity trackers to support an active lifestyle for adults diagnosed with type 2 diabetes. A mixed methods study.

Introduction

We would like to invite you to take part in this research project. The following study is conducted by researchers at the University of Strathclyde. The project is supervised by Dr Alison Kirk, Reader in Physical Activity for Health in the School of Psychological Sciences and Health, Dr Marilyn Lennon, Reader in Digital Health and Wellness in the Department of Computer and Information Sciences and Dr Xanne Janssen, Senior Teaching Fellow in Physical Activity for Health in the School of Psychological Sciences and Health, University of Strathclyde and supported by William Hodgson and David Kennedy both postgraduate students studying Physical Activity for Health. For any queries about the study, you can contact the study team by emailing either william.hodgson@strath.ac.uk or david.kennedy@strath.ac.uk

What is the purpose of this research?

Type 2 Diabetes prevalence continues to increase globally. In 2021 around 537 million people were living with diabetes, and Type 2 Diabetes accounted for around 90% of all cases. Clinical guidelines recommend an active lifestyle for managing Type 2 Diabetes and improving overall health, but adults with Type 2 Diabetes do less physical activity than adults without. Diabetes health professionals find physical activity promotion challenging and as a result of time and resource constraints, it's underused in diabetes care. NHS Scotland has well-established diabetes patient management systems. All relevant professionals use SCI-Diabetes, which contains electronic primary and secondary care medical records. In addition, My Diabetes My Way (MDMW) is NHS Scotland's National Diabetes online education platform, available to all patients registered with diabetes in Scotland and allows patients to see their health records. As a result of recent developments people with diabetes can now link a Fitbit activity tracker to this online platform. Weigh to Go is an established community-based weight management programme which consists of a 15-week Active phase and 15-week Maintenance phase. In the Active phase participants receive a 45-minute educational workshop and 45-minute circuit-based physical activity session each week. The programme is free and delivered in local leisure centres and community facilities. At the moment very few adults with Type 2 diabetes are referred to and participate in this programme. For this study we will provide participants free of charge a Fitbit activity tracker to use during the 30-weeks of the Weigh to Go programme both during the physical activity sessions but also at home and work. We would like to explore if receiving a Fitbit device could help people to refer to and participate in this programme and explore people's views on whether activity trackers could be a useful tool to support people with diabetes to lead an active lifestyle.

The Weigh to Go programme is an established weight management and physical activity facilitated by NHS Lanarkshire and run through local council community centres and sport facilities. This study will not focus on the Weigh to Go programme as an intervention. The study will focus on the use of Fitbit activity trackers by consenting participants who have signed up for the Weigh to Go programme. Participants will also be invited to register the Fitbit activity tracker on the My Diabetes My Way website though the research team will not be accessing this system for data.

Do you have to take part?

Taking part is completely voluntary. You can withdraw at any time without giving a reason until the point where data analysis has been concluded which is expected to be the December 2024. This will not affect any other aspects of your diabetes treatment or role.

What will you do in the project?

We are asking you to read through this participant information sheet and if you agree to take part in this study select the yes button after the consent form.

Stage 1

1. If you consent to take part in this study you will be provided with a four-digit unique ID number to protect your identity at all stages of the study.
2. As a participant you will be asked to complete an initial online survey to obtain details such as age, gender and present physical activity levels. This will take approximately 20 mins to complete.

3. A Fitbit consumer activity tracker will be provided by the research team. Fitbit activity trackers are worn on the wrist and monitor your steps, distance walked, height climbed, sedentary behaviour and sleep. Each Fitbit will be set-up and registered with the Fitbit website by the research team. You will be provided with the Fitbit log in details so that you can access your own activity data. Both you and the research team will have access to the Fitbit account. You will be asked to use the Fitbit constantly throughout the Weigh to Go Programme (30-weeks) and during your daily life. If the Fitbit requires recharging we ask that you do this during your normal sleeping time. We encourage you to engage with the Fitbit website and app in relation to use, activity and progress monitoring. The research team will analyse use in relation to:
    a. Daily steps.
    b. Weekly exercise intensity (minutes).
    c. Weekly sedentary time (minutes).
4. We will also invite you to register on the NHS My Diabetes My Way website and upload your Fitbit data onto this platform. The research team will not have access to your My Diabetes My Way data.
5. After the 30-week Weigh to Go programme you will be sent an end of study survey to obtain details of your physical activity (Approximately 20 mins).
6. You will be able to keep the Fitbit activity tracker at the end of the study.

Stage 2
You will be invited to take part in a one-to-one interview designed to explore your use of the Fitbit and My Diabetes My Way during the study period (30-weeks). If you do not want to take part in an interview you are free to withdraw from the study at this stage. The interview will be held over the secure University Zoom conferencing system and recorded. Throughout your identity will remain anonymous. During the interview the researcher will ask a series of questions and you will have the opportunity to discuss your experiences of using the Fitbit activity tracker and My Diabetes My Way platform.

Why have you been invited to take part?
We are looking for participants that meet the following inclusion and exclusion criteria:

Inclusion Criteria
1. Adult (18 + years of age).
2. Diagnosed with type 2 diabetes.
3. Residing in the UK.
4. Able to read and write in English.
5. Has access to the internet for data transfer.

Exclusion Criteria
1. Been advised by a health care professional not to undertake physical activity.
2. Currently uses a Fitbit device.

What are the potential risks to you in taking part?
Throughout this study you are advised to refrain from physical activity if feeling unwell and if appropriate seek medical advice as and when to start being active again.

What information is being collected in the project?
Following University protocols, we will ensure data collected is treated securely at all times. Any information that you may give may appear in published reports but your identity will remain anonymous. More specifically:
- Consent forms

    - You will be given a personal four-digit ID number once you consent to take part in the study. Your consent form information will be stored in a separate location to outcome measures at all times. Once the study is complete (i.e. December 2024) all data will be stored securely for 10 years before being removed. Separate folders, password protected, will be set up on the secure University OneDrive system for the storage of all study data. No data will be stored on the investigators personal computers.

- Fitbit data collection:

- All Fitbit activity data will be downloaded from the Fitbit website in Microsoft Excel format and stored on the secure University Microsoft OneDrive platform. All identifiable information will be deleted prior to storage. At the conclusion of the 30-week Weigh to Go program the Fitbit will be unregistered from the account set up for the study which will allow you to set a personal Fitbit account in your own name.

- Questionnaire data:

    - Similar to consent forms, Online questionnaire data collection will employ a secure website (www.qualtrics.com) and data collected will be stored on encrypted, password protected OneDrive folders. Information collected will include age, gender, diabetes duration, blood glucose level, weight, height and physical activity information.

Your email and other personal identifiable information will be deleted at the conclusion of this study. All other data collected will be kept strictly confidential and will be stored and destroyed securely within 10 years after completion of the project. Any data that is published will not identify you. The University of Strathclyde is a data controller under data protection legislation. Under data protection legislation we are required to identify our legal basis for processing personal data, which in the case of this project is data necessary for the performance of a task carried out in the public interest.

We will ask for your consent to process data for the stated purpose.

You can request that your personal data is withdrawn by emailing either william.hodgson@strath.ac.uk or david.kennedy@strath.ac.uk. Withdrawal of personal data can be requested up to the end of the data collection period. After this time data will be processed for analysis which makes it difficult to identify and remove.

We are processing personal identifiable data (your email address, first name and age), which is classified as special category data under data protection legislation. Processing of special category data is necessary for archiving purposes in the public interests, scientific or historical research purposes or statistical purposes in accordance with Article 89(1) based on Union or Member State law which shall be proportionate to the aim pursued, respect the essence of the right to data protection and provide for suitable and specific measures to safeguard the fundamental rights and the interests of the data subject.

Post-trial interviews will be conducted via the secure University Zoom conferencing system and recorded. The recordings will be transcribed verbatim. Once transcribed the recorded interview will be deleted from the system. Throughout participants details and identity will remain anonymous. Transcribed interviews will be stored on the encrypted University OneDrive system and password protected. These folders will only be accessible by the research team. At the conclusion of this project all transcribed interviews will be deleted from the University cloud system. In future academic publications any quotes used from interviews will remain anonymous.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 2018. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 2018. Details of the University Privacy Notice can be found by following this link https://www.strath.ac.uk/media/ps/rkes/ethics/Privacy_Notice_Research_Participants_Oct18.pdf

You have the right to access your personal data held by the University; you have the right to have your data erased; you are entitled to have personal data rectified if it is inaccurate or incomplete; and you can restrict the processing of your personal information. To exercise these rights please contact dataprotection@strath.ac.uk.

If you have any concerns/issues with the way the University has processed your personal data, you can contact the Data Protection Officer at dataprotection@strath.ac.uk. You also have the right to lodge a complaint against the University regarding data protection issues with the Information Commissioner's Office (https://ico.org.uk/concerns/).

The University investigators involved in this project are Dr Alison Kirk, Dr Marilyn Lennon, Dr Xanne Janssen, William Hodgson and David Kennedy

Chief Investigator details:

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

Chief Investigator contact details:

Dr Alison Kirk,
Reader in Physical Activity for Health,
School of Psychological Sciences and Health,

Level 5, Graham Hills Building, Room 532,
University of Strathclyde,
Glasgow,
G1 1QE
Email: alison.kirk@strath.ac.uk

Ethical approval: This research was granted ethical approval by the Department of Computer and Information Sciences Ethics Committee (cis-support@strath.ac.uk)

Consent Form

Name of department: Department of Computer and Information Sciences

Title of the study: Exploring through the RE-AIM framework the use of Fitbit activity trackers to support an active lifestyle for adults diagnosed with type 2 diabetes. A mixed methods study.

I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.

- I confirm that I meet the inclusion criteria for this study.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - Zoom recordings of interviews that identify me.
    - my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I confirm that I have not been advised by a medical professional to refrain from physical activity.
- I consent to being a participant in the project.
- I consent to being audio and/or video recorded as part of the project

If you agree to take part in this study, could you please click the yes icon below.

PhD Year 3 DP Baseline

Q1 **Thank you for consenting to take part in this study**

Q2 **Please enter your 4-digit study participant number?**

Q3 **What age are you in years?**

Q4 **How long have you been diagnosed with type 2 diabetes in years?**

Q5 **What is your current blood glucose level (HbA1c %)?**

Q6 **How would you describe your gender?**

- Man/ Male (including trans man) (1)
- Woman/ female (including trans woman) (2)
- I prefer not to answer (3)
- In another way (4)

Q7 **What is your highest level of education?**

- Degree or equivalent (1)
- Higher education (2)
- SVQ (3)
- School qualifications (4)
- Other qualifications (5)
- No qualifications (6)
- Don't know (7)

Q8 **What is your ethnicity?**

- White (1)
- Mixed/multiple ethnic groups (2)
- Asian/ Asian British (3)
- Black/African/Caribbean/Black Britsh (4)
- Other ethnic group (5)
- Prefer not to say (6)

Q9 **What is your weight in kg?**

Q10 **What height are you in meters (two digits i.e. 1.82m)?**

Q11 **Would you describe your settings as urban or rural?**

- ◯ Urban (1)
- ◯ Rural (2)
- ◯ Not sure (3)

12 **Which of the following condition(s) do you have?**

- ☐ I do not currently have any physical or mental health conditions (1)
- ☐ An autism spectrum disorder (2)
- ☐ Asthma (3)
- ☐ Arthritis (4)
- ☐ Alcohol or substance misuse (5)
- ☐ Coronary heart disease/heart failure (6)
- ☐ Chronic Obstructive Pulmonary Disease (COPD) (7)
- ☐ Cancer (8)
- ☐ Dementia (9)
- ☐ Diabetes (19)
- ☐ A learning disability (10)
- ☐ A mental health condition (11)
- ☐ Needs that arise from being older (e.g. support with mobility) (12)
- ☐ Another neurological condition (e.g. Parkinson's, Motor Neurone Disease or MS) (13)
- ☐ A physical disability (14)

- A sensory impairment (15)
- Stroke (16)
- Other (17)
- Prefer not to say (18)

Q13 **Have you used or presently own a consumer activity tracker e.g. Fitbit or Garmin?**

- Yes (1)
- Don't know (2)
- No (3)

Q14 **If yes, what make and model?**

- Make (1) ____
- Model (2) ____

Q15 **Have you used or presently use a fitness app on your smartphone?**

- Yes (1)
- Don't know (2)
- No (3)

Q16 **If yes, which app?**

Q17 **Physical activity can include sport, exercise, play, walking, cycling or being active around the home. Please answer the following questions related to physical activity.**

Q18 **Please choose the options applicable to you.**

	Not at all like me 1	Neutral 2	Quite like me 3	Very much like me 4	Not really like me 5
I want to take part in physical activity ()					
I like to challenge myself in different physical activities ()					
Physical activity is part of my everyday life ()					

Q19 **Confidence is belief in yourself that you can do things. Please answer the following questions in relation to confidence.**

Q20 **Please choose the options applicable to you.**

	Not at all like me 1	Not really like me 2	Neutral 3	Quite like me 4	Very much like me 5
I feel confident when taking part in my chosen physical activities ()					
I feel confident to take part in lots of different physical activities ()					
I am confident when trying new physical activities by myself or with others ()					

Q21 **Physical competence is how good we are at different physical activities. Please answer the following questions in relation to physical competence.**

Q22 **Please choose the options applicable to you.**

	1	2	3	4	5
I am good at many different physical activities (E.g. walking, cycling, swimming, yoga, preferred sports, jogging, aerobics) ()					
I keep trying and challenging myself in different physical activities. ()					
I believe I have lots of skills that I can use in different physical activities. ()					

Q23 **What we know and understand helps us decide whether we will take part in physical activity for life. Please answer the following questions.**

Q24 **Please choose the options applicable to you.**

	Not at all like me 1	Not really like me 2	Neutral 3	Quite like me 4	Very much like me 5
I know why physical activity is good for me now and for the future ()					
I know what physical activities I am good at ()					
I enjoy taking part in physical activity the more I understand it ()					
I know which physical activities are available in my area ()					
I know which physical activities I am able to take part in (consider pain, falls risk, mobility) ()					

Q25 **Overall, what is your current level of physical activity? (where moderate activity would be slightly out of breath and vigorous being breathing heavily)**

- ○ At least 150 mins/week of moderate physical activity, 75 mins/week vigorous physical activity, or an equivalent combination of these. (1)
- ○ 60-149 mins/week of moderate physical activity, 30- 74 mins/week vigorous physical activity, or an equivalent combination of these. (2)
- ○ 30-59 mins/week of moderate physical activity, 15- 29 mins/week vigorous physical activity or an equivalent combination of these. (3)
- ○ Less than 30 mins/week of moderate physical activity, less than 15 mins/week vigorous physical activity, or an equivalent combination of these. (4)

Q26 **How familiar or unfamiliar are you with any U.K. based physical activity (PA) guidelines for adults?**

- ○ Not heard of these (1)
- ○ Heard of it, but very unfamiliar (2)
- ○ Heard of it, but mainly unfamiliar (3)
- ○ Broadly familiar (4)
- ○ Very familiar (5)

Q27 **What level of awareness do you have about the benefits of physical activity?**

- ○ I am not aware of these (1)
- ○ Aware of these, but very unfamiliar (2)
- ○ Aware of these, but mainly unfamiliar (3)
- ○ Broadly aware (4)
- ○ Very aware (5)

Q28 **Sedentary question**: On an average day, in the last seven days, what proportion of the day did you spend sitting?
Please mark your proportion on the line.

0= None of the day										10= All of the day
0	1	2	3	4	5	6	7	8	9	10

1 ()	

Q29 **As part of your diabetes care have you received advice on physical activity?**

- ◯ Yes (1)
- ◯ No (2)

Q30 **If you answered yes to the previous question who provided the physical activity advice? (please choose all that are applicable)**

- ☐ Practice nurse (1)
- ☐ Specialist diabetes nurse (2)
- ☐ G.P. (3)
- ☐ Diabetes consultant (4)
- ☐ Physical activity/Fitness Instructor (5)
- ☐ Other (6)

Q31 **If other please explain who?**

Q32 **In answering the following questions,**
Vigorous physical activities refer to activities that take hard physical effort and make you breath much harder than normal. Moderate physical activities refer to activities that take moderate physical effort and make you breath somewhat harder than normal.

Q33 **During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling,?**

- None (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4 (5)
- 5 (6)
- 6 (7)
- 7 (8)

Q34 **How much time in total did you usually spend on one of those days doing vigorous physical activities in hours and minutes?**

Q35 **Again, think only about those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.**

- None (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4 (5)
- 5 (6)
- 6 (7)
- 7 (8)

Q36 **How much time in total did you usually spend on one of those days doing moderate physical activities in hours and minutes?**

Q37 **During the last 7 days, on how many days did you walk for at least 10 minutes at a time? This includes walking at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure.**

- ○ None (1)
- ○ 1 (2)
- ○ 2 (3)
- ○ 3 (4)
- ○ 4 (5)
- ○ 5 (6)
- ○ 6 (7)
- ○ 7 (8)

Q38 **How much time in total did you usually spend walking on one of those days in hours and minutes?**

Appendix M: Health care professionals participant information sheet, consent form and baseline questionnaire

HCP Participant Information Sheet
Name of department: Department of Computer and Information Sciences

Title of the study: Exploring through the RE-AIM framework the use of Fitbit activity trackers to support an active lifestyle for adults diagnosed with type 2 diabetes. A mixed methods study.

Introduction

We would like to invite you to take part in this research project. The following study is conducted by researchers at the University of Strathclyde. The project is supervised by Dr Alison Kirk, Reader in Physical Activity for Health in the School of Psychological Sciences and Health, Dr Marilyn Lennon, Reader in Digital Health and Wellness in the Department of Computer and Information Sciences and Dr Xanne Janssen, Senior Teaching Fellow in Physical Activity for Health in the School of Psychological Sciences and Health, University of Strathclyde and supported by William Hodgson and David Kennedy both postgraduate students studying Physical Activity for Health. For any queries about the study, you can contact the study team by emailing either william.hodgson@strath.ac.uk or david.kennedy@strath.ac.uk

What is the purpose of this research?

Type 2 Diabetes prevalence continues to increase globally. In 2021 around 537 million people were living with diabetes, and Type 2 Diabetes accounted for around 90% of all cases. Clinical guidelines recommend an active lifestyle for managing Type 2 Diabetes and improving overall health, but adults with Type 2 Diabetes do less physical activity than adults without. Diabetes health professionals find physical activity promotion challenging and as a result of time and resource constraints, it's underused in diabetes care. NHS Scotland has well-established diabetes patient management systems. All relevant professionals use SCI-Diabetes, which contains electronic primary and secondary care medical records. In addition, My Diabetes My Way (MDMW) is NHS Scotland's National Diabetes online education platform, available to all patients registered with diabetes in Scotland and allows patients to see their health records. As a result of recent developments people with diabetes can now link a Fitbit activity tracker to this online platform. Weigh to Go is an established community-based weight management programme which consists of a 15-week Active phase and 15-week Maintenance phase. In the Active phase participants receive a 45-minute educational workshop and 45-minute circuit-based physical activity session each week. The programme is free and delivered in local leisure centres and community facilities. At the moment very few adults with Type 2 diabetes are referred to and participate in this programme. For this study we will provide participants free of charge a Fitbit activity tracker to use during the 30-weeks of the Weigh to Go programme both during the physical activity sessions but also at home and work. We would like to explore if receiving a Fitbit device could help people to refer to and participate in this programme and explore people's views on whether activity trackers could be a useful tool to support people with diabetes to lead an active lifestyle.

The Weigh to Go programme is an established weight management and physical activity facilitated by NHS Lanarkshire and run through local council community centres and sport facilities. This study will not focus on the Weigh to Go programme as an intervention. The study will focus on the use of Fitbit activity trackers by consenting participants who have signed up for the Weigh to Go programme. Participants will also be asked to register the Fitbit activity tracker on the My Diabetes My Way website though the research team will not be accessing this system for data.

Do you have to take part?

Taking part is completely voluntary. You can withdraw at any time without giving a reason until the point where data analysis has been concluded which is expected to be the December 2024.

What will you do in the project?

We are asking you to read through this participant information sheet and if you agree to take part in this study select the yes button after the consent form.

Stage 1

7. If you consent to take part in this study you will be provided with a four-digit unique ID number so as to protect your identity at all stages of the study.
8. As a participant you will be asked to complete an initial survey to obtain details such as age, gender and occupation (Approximately 20 mins)
9. You will be invited to take part in a one-to-one interview designed to explore your role in the Weigh to Go programme and the use of a Fitbit activity tracker and the NHS My Diabetes My Way system by participants during the intervention. The interview will be held over the secure University Zoom conferencing system and recorded. Throughout your identity will remain anonymous. During the interview the researcher will ask a series of questions and you will have the opportunity to discuss your experiences of participants using the Fitbit activity tracker and My Diabetes My Way platform.

Why have you been invited to take part?
We are looking for participants that meet the following inclusion and exclusion criteria:

Inclusion Criteria

6. Adult (18 + years of age).
7. A health care professional involved in the NHS Lanarkshire Weigh to Go programme.
8. Residing in the UK.
9. Able to read and write in English.
10. Has access to the internet for data transfer.

What are the potential risks to you in taking part?
There are no identifiable risks for taking part in this study.

What information is being collected in the project?
Following University protocols, we will ensure data collected is treated securely at all times. You will be encouraged to contact the researchers through the researchers email addresses provided below. Any information that you may give may appear in published reports but your identity will remain anonymous. More specifically:

- Consent forms
    - You will be given a personal four-digit ID number once you consent to take part in the study. You consent form information will be stored in a separate location to outcome measures at all times. Once the study is complete (i.e. December 2024) all data will be removed. Separate folders, password protected, will be set up on the secure University OneDrive system for the storage of all study data. No data will be stored on the investigators personal computers.
- Questionnaire data:
    - Similar to consent forms, Online questionnaire data collection will employ a secure website (www.qualtrics.com) and data collected will be stored on encrypted, password protected OneDrive folders.

Your email and other personal identifiable information will be deleted at the conclusion of this study. All other data collected will be kept strictly confidential and will be stored and destroyed securely within 10 years after completion of the project. Any data that is published will not identify you. The University of Strathclyde is a data controller under data protection legislation. Under data protection legislation we are required to identify our legal basis for processing personal data, which in the case of this project is data necessary for the performance of a task carried out in the public interest.
We will ask for your consent to process data for the stated purpose.
You can request that their personal data be withdrawn by emailing either william.hodgson@strath.ac.uk or david.kennedy@strath.ac.uk. Withdrawal of personal data can be requested up to the end of the data collection period. After this time data will be processed for analysis which makes it difficult to identify and remove.
We are processing personal identifiable data (your email address, first name and age), which is classified as special category data under data protection legislation. Processing of special category data is necessary for archiving purposes in the public interests, scientific or historical research purposes or statistical purposes in accordance with Article 89(1) based on Union or Member State law which shall be proportionate to the aim pursued, respect the essence of the right to data protection and provide for suitable and specific measures to safeguard the fundamental rights and the interests of the data subject.
Post-trial interviews will be conducted via the secure University Zoom conferencing system and recorded. The recordings will be transcribed verbatim. Once transcribed the recorded interview will be deleted from the system. Throughout participants details and identity will remain anonymous. Transcribed interviews will be stored on the encrypted University OneDrive system and password protected. These folders will only be accessible by the research team. At the conclusion of this project all transcribed interviews will be deleted from the University cloud system. In future academic publications any quotes used from interviews will remain anonymous.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 2018. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 2018. Details of the University Privacy Notice can be found by following this link https://www.strath.ac.uk/media/ps/rkes/ethics/Privacy_Notice_Research_Participants_Oct18.pdf
You have the right to access your personal data held by the University; you have the right to have your data erased; you are entitled to have personal data rectified if it is inaccurate or incomplete; and you can restrict the processing of your personal information. To exercise these rights please contact dataprotection@strath.ac.uk.
If you have any concerns/issues with the way the University has processed your personal data, you can contact the Data Protection Officer at dataprotection@strath.ac.uk. You also have the right to lodge a complaint against the University regarding data protection issues with the Information Commissioner's Office (https://ico.org.uk/concerns/).
The University investigators involved in this project are Dr Alison Kirk, Dr Marilyn Lennon, Dr Xanne Janssen, William Hodgson and David Kennedy
Chief Investigator details:
Thank you for reading this information – please ask any questions if you are unsure about what is written here.
Chief Investigator contact details:

Dr Alison Kirk,
Reader in Physical Activity for Health,
School of Psychological Sciences and Health,
Level 5, Graham Hills Building, Room 532,
University of Strathclyde,
Glasgow,
G1 1QE
Email: alison.kirk@strath.ac.uk

Ethical approval: This research was granted ethical approval by the Department of Computer and Information Sciences Ethics Committee (cis-support@strath.ac.uk).

Consent Form
Name of department: Department of Computer and Information Sciences
Title of the study: Exploring through the RE-AIM framework the use of Fitbit activity trackers to support an active lifestyle for adults diagnosed with type 2 diabetes. A mixed methods study.
I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.

- I confirm that I meet the inclusion criteria for this study.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - Zoom recordings of interviews that identify me.
    - my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.
- I consent to being audio and/or video recorded as part of the project

If you agree to take part in this study could you please click the yes icon below.

PhD Year 3 Professionals Baseline

Q1 **Thank you for consenting to take part in this study.**

Q2 **Please enter your 4-digit study participant number?**

Q3 **What age are you in years?**

Q4 **How would you describe your gender?**

- Man/ Male (including trans man) (1)
- Woman/ female (including trans woman) (2)
- I prefer not to answer (3)
- In another way (4)

Q5 **What is your highest level of education?**

- Degree or equivalent (1)
- Higher education (2)
- SVQ (3)
- School qualifications (4)
- Other qualifications (5)
- No qualifications (6)
- Don't know (7)

Q6 **What is your ethnicity?**

- White (1)
- Mixed/multiple ethnic groups (2)
- Asian/ Asian British (3)
- Black/African/Caribbean/Black Britsh (4)
- Other ethnic group (5)
- Prefer not to say (6)

Q7 **Which of the following best describes your occupation?**

- ◯ Medical Doctor (general practice) (1)
- ◯ Medical Doctor (consultant) (2)
- ◯ Nurse (general practice) (3)
- ◯ Nurse (diabetes specialist) (4)
- ◯ NHS (Scot) Management (5)
- ◯ Diabetes Professional (6)
- ◯ Fitness Professional (7)
- ◯ Other (8)

Q8 **If other please describe your occupation**

Appendix N: Study 3 End of Study Questionnaire

PhD Year 3 DP End of Study

Q1 **Please enter your 4-digit study participant number?**

Q2 **What is your current blood glucose level (HbA1c %)?**

Q3 **What date was your last blood glucose level (HbA1c %) measured (month and year)?**

Q4 **What is your weight in kg?**

Q5 **What height are you in meters (two digits i.e. 1.82m)?**

Q6 **Physical activity can include sport, exercise, play, walking, cycling or being active around the home. Please answer the following questions related to physical activity.**

Q7 **Please choose the options applicable to you.**

	Not at all like me	Neutral	Quite like me	Very much like me	Not really like me
	1	2	3	4	5
I want to take part in physical activity ()					
I like to challenge myself in different physical activities ()					
Physical activity is part of my everyday life ()					

Q8 **Confidence is belief in yourself that you can do things. Please answer the following questions in relation to confidence.**

Q9 **Please choose the options applicable to you.**

	Not at all like me	Not really like me	Neutral	Quite like me	Very much like me
	1	2	3	4	5
I feel confident when taking part in my chosen physical activities ()					
I feel confident to take part in lots of different physical activities ()					
I am confident when trying new physical activities by myself or with others ()					

Q10 **Physical competence is how good we are at different physical activities. Please answer the following questions in relation to physical competence.**

Q11 **Please choose the options applicable to you.**

1	2	3	4	5

I am good at many different physical activities (E.g. walking, cycling, swimming, yoga, preferred sports, jogging, aerobics) ()	
I keep trying and challenging myself in different physical activities. ()	
I believe I have lots of skills that I can use in different physical activities. ()	

Q12 **What we know and understand helps us decide whether we will take part in physical activity for life. Please answer the following questions.**

Q13 **Please choose the options applicable to you.**

	Not at all like me 1	Not really like me 2	Neutral 3	Quite like me 4	Very much like me 5
I know why physical activity is good for me now and for the future ()					
I know what physical activities I am good at ()					
I enjoy taking part in physical activity the more I understand it ()					
I know which physical activities are available in my area ()					
I know which physical activities I am able to take part in (consider pain, falls risk, mobility) ()					

Q14 **Overall, what is your current level of physical activity? (where moderate activity would be slightly out of breath and vigorous being breathing heavily)**

- ○ At least 150 mins/week of moderate physical activity, 75 mins/week vigorous physical activity, or an equivalent combination of these. (1)
- ○ 60-149 mins/week of moderate physical activity, 30- 74 mins/week vigorous physical activity, or an equivalent combination of these. (2)
- ○ 30-59 mins/week of moderate physical activity, 15- 29 mins/week vigorous physical activity or an equivalent combination of these. (3)
- ○ Less than 30 mins/week of moderate physical activity, less than 15 mins/week vigorous physical activity, or an equivalent combination of these. (4)

Q15 **How familiar or unfamiliar are you with any U.K. based physical activity (PA) guidelines for adults?**

- ◯ Not heard of these (1)
- ◯ Heard of it, but very unfamiliar (2)
- ◯ Heard of it, but mainly unfamiliar (3)
- ◯ Broadly familiar (4)
- ◯ Very familiar (5)

Q16 **What level of awareness do you have about the benefits of physical activity?**

- ◯ I am not aware of these (1)
- ◯ Aware of these, but very unfamiliar (2)
- ◯ Aware of these, but mainly unfamiliar (3)
- ◯ Broadly aware (4)
- ◯ Very aware (5)

Q17 **Sedentary question**: On an average day, in the last seven days, what proportion of the day did you spend sitting?
Please mark your proportion on the line.

0= None of the day — 10= All of the day

0 1 2 3 4 5 6 7 8 9 10

1 ()

Q18 **In answering the following questions,**
Vigorous physical activities refer to activities that take hard physical effort and make you breath much harder than normal. Moderate physical activities refer to activities that take moderate physical effort and make you breath somewhat harder than normal.

Q19 **During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling,?**

- None (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4 (5)
- 5 (6)
- 6 (7)
- 7 (8)

Q20 **How much time in total did you usually spend on one of those days doing vigorous physical activities in hours and minutes?**

Q21 **Again, think only about those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.**

- None (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4 (5)
- 5 (6)
- 6 (7)
- 7 (8)

Q22 **How much time in total did you usually spend on one of those days doing moderate physical activities in hours and minutes?**

Q23 **During the last 7 days, on how many days did you walk for at least 10 minutes at a time? This includes walking at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure.**

○ None (1)

○ 1 (2)

○ 2 (3)

○ 3 (4)

○ 4 (5)

○ 5 (6)

○ 6 (7)

○ 7 (8)

Q24 **How much time in total did you usually spend walking on one of those days in hours and minutes?**

Appendix O: Weigh to Go participants Fitbit Data (Link to Excel Document)

https://strath-my.sharepoint.com/:x:/r/personal/ckb16145_uni_strath_ac_uk/Documents/Bill%20Hodgson%20PhD%20Folder/Thesis/Thesis%20Appendix/All%20Participant%20Fitbit%20Data.xlsx?d=wa77e7687b6724381907313bef0114789&csf=1&web=1&e=1k1yoF

Appendix P: Study 3 semi-structured interview schedule

REACH
1. What for you were the barriers using a Fitbit activity tracker? 2. What for you were the enablers for using a Fitbit activity tracker? 3. How did you find registering the Fitbit (barriers and enablers)? 4. What support would you need or want to use a Fitbit activity tracker in this context (registering / using / seeing and using your data)? 5. What would motivate you (or others) to actually upload and use your Fitbit data after registering? 6. Who do you think would benefit most from the use of Fitbit activity trackers within type 2 diabetes clinical care? 7. How do you think the use of Fitbit data within type 2 diabetes care can be best promoted? 8. Who provides support/care for you? 9. What do you think could make it easier/harder for patients to participate in the program (you? Others)? 10. What do you think could make it easier/harder for patients to use activity trackers in the program? 11. What strategies do you think we could develop to specifically recruit those who are most underserved or at risk and enable their participation (prompt: what would have encouraged you)? 12. How did you hear about the program? 13. What information in the recruitment strategy was attractive to you? 14. Who do you think are the best people to support patients access the program? 15. How do you think we could get more people to participant in an intervention like this? 16. Can you describe the likelihood that you will continue in the program (why/why not)? 17. How did you hear about this program? Probe: through [specific organization name], flyer, friends, relatives. 18. What made you interested in joining? (e.g., what information attracted you to the program) Prompts: group class, exercise type, offered through [specific organization name], diabetes management.

19. What did you think the program could help you accomplish? Probe: Improve overall personal health, manage chronic disease, improve functional fitness, a doctor recommended [the program], reach fitness goals, weight goals etc.
20. Did the programme meet your objectives (why/why not)?
21. What do you think are the best ways to tell people about the program? Probe: Community flyers, doctor referral, phone calls, email, etc. Where else can we advertise?

Effectiveness

1. Within type 2 diabetes care who would be the best person to interpret the physical activity/sedentary behaviour data from a Fitbit activity tracker?
2. In addition to the Fitbit activity data what additional support would you or others require to make the most effective use of this information?
3. What are the best methods of communicating the interpretation of the Fitbit data to patients?
4. What are the most important elements of the Fitbit activity data for patients?
5. What would make you feel like this program was impactful for you?
6. What program characteristics would you prefer to see in the intervention? Probes: tracking, in a group, one-on-one, social support, feedback on goals, diaries, social support
7. What should be included to teach you how to be more physically active while using a Fitbit activity tracker during the program?
8. What are some of the ways the program is having a positive impact in your life?
9. Please share any ways the program has had any unintended negative impacts on your life.
10. How can we improve the positive impacts of the program?
11. What are some of the ways the program has had a positive impact in your life?
12. Please share any ways the program had a negative impact on your life.

Adoption

1. How aware are type 2 diabetes patients that Fitbit data can be uploaded onto the My Diabetes My Way system?

2. Why are some type 2 diabetes patients not aware of the ability to upload Fitbit data onto the My Diabetes My Way system?
3. What training and support do type 2 diabetes patients need so they can effectively upload their Fitbit data onto the My Diabetes My Way system?
4. What are the benefits of using the Fitbit data within clinical care?
5. Where would it be convenient for the classes to meet?
6. Think about who should instruct/lead this program. What type of person would be most helpful?
    a. Probe: credentials, characteristics, what would s/he do that would be most helpful?
7. What is your perception on the skills of the program leader?
8. What is your perception on the characteristics of the program leader?
9. Who do you think should lead the program sessions in the future? Probe: health educator, community member, certified fitness instructor, graduate research assistant, etc.

Implementation

1. What are the key enablers for encouraging patients to register a Fitbit activity tracker on the system?
2. What are the key barriers stopping patients registering a Fitbit activity tracker on the system?
3. Who are the key health care professionals who could increase the number of patients using and registering Fitbit activity trackers on the platform?
4. What are the main challenges for increasing the number of patients registering a Fitbit activity tracker on the system?
5. What improvements within the My Diabetes My Way system would improve the interpretation of patients Fitbit data?
6. What would the main costs be for patients?
7. What are the main costs for health care providers?
8. How do you feel about the use of Fitbit activity trackers as an aid to support you being physically activity?
9. Probe: What do you want the program to focus on? Have you ever attended a similar program? If so, what was your experience?
10. How often should the program meet?

11. How long should the program be?
12. What would you like to do in this program?
13. How do you feel about the frequency of meeting for the program?
14. How did you feel about the cost of participating in the program?
15. How do you think the program should be delivered in the future?
16. How often should the class meet?
17. How long should sessions last?
18. Where should the class be held?
19. How did you feel about the cost of participating in the program?

Maintenance

1. What do you think the main cost savings for the health service would be if the Fitbit data was used to promote physical activity and reduce sedentary behaviour?
2. What are the best methods of communicating to you the analysis of Fitbit data between the start and finish of the program?
3. Who do you think would be best placed to manage and oversee the use of Fitbit data on the My Diabetes My Way platform?

4. What do you think might ensure participants continue being physically active at the end of the 30-week program?
5. Can you describe the likelihood that you will continue to be physically active once the program is over?
6. Now that the program is over, what, if anything, are you doing to remain physically active?
7. Now that the program is over, what challenges, if any, have you faced remaining physically active?
8. What parts of the program helped (or didn't help) you stay involved from the beginning to the end?
9. What changes of the program could have helped you stay more involved in over the full 30 weeks?