Behavioural epidemiology of physical activity in disabled people

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Abstract

Evidence indicates that physical activity is beneficially associated with many physical and mental health outcomes in disabled people. However, disabled people are more likely to be physically inactive than non-disabled people and face additional barriers to participation. Evidence on physical activity and health in disabled people is small relative to the non-disabled population, and typically focuses on the most prevalent health conditions. In addition, few studies have considered the associations of a person's function with physical activity levels. This thesis presents four interlinked studies that aim to explore the relationship between health conditions, impairments, and physical activity levels, and identify actions to support disabled people to be active. Study 1 explores the measurement of disability within prospective and cross-sectional studies that included a device-based measurement of physical activity. Study 2 utilises data from the Health Survey for England to examine the cross-sectional associations of chronic conditions and disability with physical activity. In Study 3, data from the Sport England Active Lives survey is used to compare the type and duration of physical activity undertaken by disabled people, relative to non-disabled people. Lastly, Study 4 explores the actions disabled people feel are needed to help them be physically active. This thesis identifies diversity in disability measurement across physical activity studies and highlights the need for research to account for a person's impairment type(s) as well as health condition(s). Activity types were largely similar in disabled and non-disabled people, however duration was lower among disabled people. Recommended actions including improved accessibility of activity provision, training activity providers on how to support disabled people, and better transport to activities, were reported by disabled people. Evidence within this thesis can be used to improve research, provision, and future policy actions aimed at increasing physical activity levels of the disabled population.

List of contents

Tables

Figures

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Statement of jointly authored publications

This thesis is my own original work. For each chapter of this thesis, I identify below the collaboration I had with others and their levels of involvement.

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Chapter 2. Written by Shelby Carr. Reviewed by Dr Karen Milton and Dr Andrew Atkin.

Chapter 3. Shelby Carr was the lead author of the scoping review published as:

> Carr, S., Atkin, A. J., Jones, A. P., Pulsford, R., & Milton, K. (2023). A scoping review of disability assessment in prospective and cross-sectional studies that included device-based measurement of physical activity. *Journal of Physical Activity and Health*, *20(*8), 683-689. https://doi.org/10.1123/jpah.2023-0017.

Shelby Carr, Dr Andrew Atkin, Prof Andy Jones and Dr Karen Milton designed the study. Dr Richard Pulsford (on behalf of the ProPASS Consortium) devised the search strategy, undertook the literature searches and provided the results of the literature screening. Shelby Carr collected and extracted the data, conducted the analysis and drafted the original manuscript. This was reviewed by Dr Andrew Atkin, Prof Andy Jones and Dr Karen Milton.

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Shelby Carr, Dr Andrew Atkin and Dr Karen Milton designed the study. Shelby Carr conducted the focus groups, analysis and drafted the original manuscript, which was reviewed by Dr Andrew Atkin and Dr Karen Milton.

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Chapter 1. General introduction

1.1. Overview

This thesis is comprised of seven chapters, of which this introduction is Chapter 1. Chapter 2 is a literature review exploring: the history, models, and measurement of disability; the health benefits of physical activity; national and international physical activity guidelines; and the barriers and facilitators to physical activity participation for disabled people. In Chapters 3-6 I present the four studies that I have undertaken, which form the substantive contribution of this thesis. Each study poses distinct research questions, but all share a common theme in addressing key research gaps identified in the literature review. Each chapter is either published or under review at the time of submission, as outlined in the publication section of this thesis. The thesis closes with an overarching discussion and conclusion (Chapter 7) which considers key findings of the thesis, implications for future research and policy on this topic, and some personal reflections of my experience undertaking the PhD.

1.2. Introduction

Disability is an imprecisely defined concept,(1) with many definitions and measures that vary across countries.(2) Some definitions focus solely on a person's diagnosed health condition (medical perspective), whilst others consider a person's functional limitations and how environmental and societal influences impact a person's ability to undertake daily activities (social perspective). Iezzoni and Freedman(3) suggest that no single definition of disability will likely ever meet multiple societal needs, however for setting policies that affect population health, they advocate for a definition that incorporates both social and medical perspectives. In the United Kingdom (UK), the social perspective is more commonly favoured among policy-makers and disabled people.(4,5) Therefore, in this thesis I will be adopting the social model of disability and will use the term 'disabled people', as this is considered preferable among the UK disability community.(5) However, I acknowledge that other terminologies (such as 'people with disabilities') are favoured by some individuals, groups, and organisations.

In 2021, an estimated 1.3 billion people worldwide (16% of the world's population) were thought to be living with a disability.(6) In the UK, an estimated 14.6 million people (24% of the UK population) had a disability in the 2021/22 financial period; increasing by 5% points

over the last decade.(7) Data from the World Health Organization (WHO) indicate that life expectancy is increasing, from 67 years in 2000 to 73 years in 2019; however, some of these additional years are likely to be spent in poor health.(8) Modifiable behaviours such as physical inactivity, smoking, and an unhealthy diet, increase the likelihood of developing non-communicable diseases (NCDs), such as cardiovascular disease (CVD), cancer, chronic respiratory diseases and diabetes, which can subsequently lead to disability.(9) In addition to the prevention and management of NCDs, physical activity has a wide range of benefits, including improved mental health, cognitive function, and sleep.(10) To achieve these benefits, the WHO recommends that both disabled and non-disabled adults undertake at least 150-300 minutes of moderate or 75-150 minutes of vigorous intensity physical activity per week.(11) However, a large proportion of the population are insufficiently active, with an estimated 28% of adults worldwide not meeting these guidelines.(12) Of particular concern is that disabled people are less likely to be active than non-disabled people.(13) An estimated 500 million people are predicted to develop NCDs attributable to physical inactivity between 2020 and 2030, at an estimated annual cost of US$27 billion.(14) Increasing population levels of physical activity, particularly among disabled people, is therefore a public health priority. However, physical activity research on disabled people is limited. In particular, there are gaps in understanding of disabled people's physical activity patterns, how health conditions and impairment types interact to influence physical activity, and what support disabled people feel is needed to help them be more active.

1.3. Thesis aims

This thesis aimed to explore relationships between health conditions, impairments, and physical activity levels, and identify actions to support disabled people to be active. Study one (presented in Chapter 3) sought to explore whether and how disability has been assessed in prospective and cross-sectional studies that included device-based measurement of physical activity. Study two (Chapter 4) examined the association of type and number of impairments with physical activity levels in people with a chronic health condition. Study three (Chapter 5) examined the duration and types of physical activity that disabled people participate in compared to non-disabled people. Study four (Chapter 6) identified actions that disabled people feel are needed to support them to overcome the key barriers to being physically active.

Chapter 2. Literature Review

2.1. Chapter summary

The aim of this chapter is to provide a broad overview of the literature on disability and physical activity, locating the thesis in a wider social and research context. I begin by identifying historical developments in the disability field (Section 2.2), before outlining some of the common conceptual models of disability (Section 2.3) and assessment tools (Section 2.4). I then set the scene for disability within a physical activity context (Section 2.5), including the health benefits of physical activity for disabled people (Section 2.6), national and international guidelines (Section 2.7), physical activity prevalence (Section 2.8), correlates to participation (Section 2.9), and the WHO global action plan on physical activity (Section 2.10). I close this chapter by summarising the behavioural epidemiology framework (Section 2.11) and highlighting the specific gaps in the evidence that this thesis sought to address (Section 2.12).

2.2. History of disability

To keep this overview concise and applicable to the research presented in this thesis, I focus on the history and development of disability organisations and policy in the UK post the first World-War (WWI).

During WWI nearly two million soldiers were injured, and many required medical attention, ongoing care, and financial support to survive.(15) For medical professionals, simply treating soldiers wounded limbs was insufficient; they also needed to train soldiers on how to use their remaining limbs to their best ability.(16) To provide support for injured soldiers, the Central Council for the Care of Cripples was established by Sir Robert Jones; now known as Disability Rights UK.(17) This pan-disability charity is led by disabled people, who work with relevant organisations, public bodies and UK Government to evoke equal power, rights, and equality for disabled people.

During the Second World War (WWII), more than 300,000 people returned home with disabilities. In response, Dr Ludwig Guttmann opened a spinal injuries centre at Stoke Mandeville Hospital.(18) This largely held injured soldiers, who, as part of their rehabilitation, would take part in exercise and compete against each other in sports events. On 29th July 1948, the day of the opening ceremony of the London Olympic Games, Dr

Guttmann held a wheelchair archery competition on the hospital lawn, which is thought to have marked the beginning of the Paralympic Games.(19)

The 1940s and 50s saw many charities formed, campaigning for improvements to the support provided for disabled people. For example, 1946 saw the development of the National Association for Mental Health (now known as MIND)(20), and the National Association of Parents of Backward Children (now known as Mencap).(21) In 1948, following the election of a socialist government, the National Health Service was introduced.(22) This provided, for the first time, free healthcare (at the point of service) to every member of the British population, including support for injured soldiers from both WWI and WWII, and workers disabled by industrial accidents. Many other campaigning organisations were subsequently formed, further increasing pressure on the government to make improvements to the support available for disabled people. As a result, the Chronically Sick and Disabled Persons Act 1970,(23) was introduced which saw responsibility placed on local authorities to provide support and assistance for disabled adults and children. In the proceeding 25 years, further acts were developed including the Mental Health Act in 1983,(24) the Disabled Persons Act in 1986,(25) and the Disability Discrimination Act (DDA) in 1995.(26) The DDA provided disabled people protection against discrimination within employment, education, transport, provision of goods, and the exercise of public functions. This included protection against direct discrimination (i.e. where a disabled person is treated less favourably than another person, due to their disability), and harassment (i.e. violating a disabled person's dignity or creating a hostile or offensive environment for a disabled person).

The DDA was replaced with the UK Equality Act in 2010,(27) in which disability was listed as one of the nine characteristics that are protected from discrimination (age; gender reassignment; being married or in a civil partnership; being pregnant or on maternity leave; disability; race including colour, nationality, ethnic or national origin; religion or belief; sex; and sexual orientation). This is the current law in the UK, protecting people from direct and indirect discrimination, as well as harassment and victimisation. Much of the text from the DDA is incorporated into the Equality Act. Under the UK Equality Act 2010, a person is considered to have a disability if [1] they have a physical or mental impairment, and [2] the impairment has a substantial and long-term adverse effect on their ability to carry out normal day-to-day activities.(27, Section 6) In this definition, long-term is used to describe

an impairment which has lasted at least 12 months, or which is likely to be present for the rest of the person's life. Substantial effect takes into consideration any differences in the time taken to carry out an activity and the way in which an activity is undertaken, compared to a person without an impairment.

As a member of the United Nations (UN), the UK is bound by its policies and statutes; this includes the UN Convention on the Rights of Persons with Disabilities (UNCRPD).(28) The UNCRPD became effective in 2008 and was the first international convention to set minimal standards to ensure the protection and promotion of full and equal enjoyment of human rights and fundamental freedoms of disabled people. The convention includes 50 articles, setting out what countries need to do to ensure disabled people have the same rights as anybody else; for example freedom of expression and opinion, and access to employment and education. As part of the UNCRPD, the UK is committing to protecting and promoting the human rights of disabled people through eliminating disability discrimination. Enabling disabled people to live independently in the community, ensuring an inclusive education system, and ensuring disabled people are protected from all forms of exploitation, violence, and abuse.(29) The UNCRPD is broader than the UK Equality Act, as it includes short-term health conditions, such as severe mental health conditions lasting less than 12 months. A review was undertaken by the UN in 2017 that reported on how the UK was performing on disability rights.(30) The UN viewed several UK developments positively, including the 2016 Accessible Travel framework; however, many concerns and recommendations were reported. Among the recommendations were to make the UNCRPD part of UK law, to undertake a full review of UK laws and policies to ensure they align with the Convention, and to develop and implement a plan to improve disabled peoples' living conditions. The report also stressed the importance of including disabled people and disabled people's organisations when developing and implementing policies and laws.

2.3. Models of disability

Differing perspectives exist of what constitutes disability. In simple terms, approaches to characterising disability may be defined as those which focus primarily on a persons diagnosed condition (a 'medical' model), versus those which consider the influence of the environment and social surroundings on a person's ability to undertake daily activities (a 'social' model). In this section, I describe the medical and social models, as well as the

biopsychosocial model developed by the WHO to overcome the limitations of the medical and social perspectives.

2.3.1. Medical model of disability

The medical model of disability emerged in the mid-1800s as a result of advances in the medical science field.(31) The medical model views a person's prognosis/medical condition over the person's other characteristics,(32) whereby a person's disability is seen to be a key feature of their social identity.(33) The medical approach to disability assumes a person's disability to result from a physical and/or mental impairment that is independent of sociocultural, physical and political environments.(33) This characterisation typically places people into disability categories, rather than considering the universal challenges and problems experienced by people with different disabilities.(34) The medical model also views disability as an objective medical condition that requires treatment and/or rehabilitation to bring a person back to the norm.(35) Terms such as 'invalid', 'handicapped', and 'cripple', that are no longer considered acceptable, derived from this model.(36) The medical model is inherently normative, with people considered to be disabled if they are unable to function like a 'normal' person.(35) Given the involvement that medical professionals have in the care and treatment of disabled people, much research on disabled people has taken a medical perspective, categorising individuals by their health condition rather than considering the impact of wider environmental and societal influences.

2.3.2. Social model of disability

In the 1970s and 1980s, disabled people and organisations in Europe and North America began to dispute the medical model of disability.(37) In 1976, the Union of the Physically Impaired Against Segregation (UPIAS) in the UK stated "in our view it is society which disables physically impaired people. Disability is something imposed on top of our impairments by the way we are unnecessarily isolated and excluded from full participation in society".(38, p.14) Based on the principles of the UPIAS, Michael Oliver, a disabled activist and lecturer, subsequently formulated the social model of disability.(37,39) The social model of disability takes into consideration a person's environment and social surroundings, and how these may impede their ability to undertake day-to-day activities. It identifies 'impairment' as a person's difference (physical, cognitive, or social), with 'disability' being the social consequence of having an impairment.(39,40) It does not deny

the value of medical and rehabilitative care, but draws attention to the broader range of factors that limit disabled people's sense of empowerment and full engagement in society.

2.3.3. Biopsychosocial model of disability

Recognising the value of both the medical and social perspectives, in 1980 the WHO proposed a new approach to conceptualising disability. First known as the International Classification of Impairments, Disabilities and Handicaps (ICIDH),(41) the WHO developed a tool for the classification of the consequences of diseases (and injuries and other disorders) and their implications for the lives of individuals.(41) However, many disabled people and professionals criticised the ICIDH for its lack of recognition of the role of environmental influences in the creation of disability. After many revisions, in 2001 the WHO endorsed the International Classification of Functioning, Disability and Health (ICF).(42) The ICF aims to (42 p.5):

- provide a scientific basis for understanding and studying health and health-related states, outcomes, determinants, and changes in health status and functioning;
- establish a common language for describing health and health-related states in order to improve communication between different users, such as health care workers, researchers, policymakers and the public, including people with disabilities;
- permit comparison of data across countries, health care disciplines, services and time;
- provide a systematic coding scheme for health information systems.

The ICF (shown in Figure 2.1:) adopts a biopsychosocial perspective, considering disability to result from the dynamic interaction between an individual with a health condition and contextual (personal and environmental) factors. The model considers how these factors combine to negatively affect a person in terms of [1] functions of body systems and anatomical parts of the body ('Body functions and structures'); [2] ability to execute tasks ('Activities'); and [3] involvement in life situations ('Participation'). While depicted separately on the model, 'Activities' and 'Participation' are grouped together in the ICF classification system.

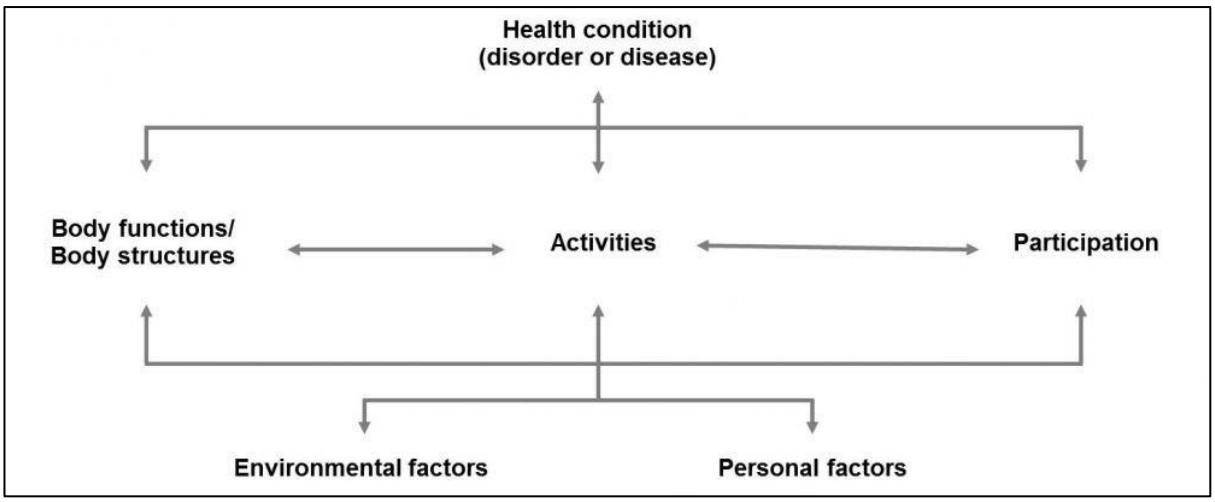

Figure 2.1: ICF model of disability(42, p.9)

The ICF was a significant breakthrough, utilising both the medical and social models and considering the interaction between the person with a health condition and environment influences.(43) It has made a difference to disability measurement and provides a common language among the complexity of functioning and disability.(44) The ICF model also has applicability to various areas of disability assessment, and has been used to inform the development of new measurement tools, administrative systems and policy.(42,44,45) However, it has also been under scrutiny, with researchers suggesting the framework is not entirely reflective of the lived experiences of disabled people. They highlight the need for greater collaboration with disabled people, and consideration of a person's quality of life and wellbeing in any future developments of the framework.(43,44) The use of the ICF model in full has also been lacking, with there being a tendency to leave out sections of the ICF (such as Environmental Factors, or Activities and Participation), and therefore a need for better full-application of the model.(44)

2.4. Disability assessment tools

Numerous tools exist for the assessment of disability, including the Global Activity Limitation Indicator,(46) Activities of Daily Living,(47) Instrumental Activities of Daily Living,(48) and the Late Life Function and Disability Instrument.(49,50) In this section, I focus on two internationally recognised measurement tools, the Washington Group measurement(51) and the WHO Disability Assessment Schedule 2.0 (WHODAS 2.0).(52)

2.4.1. Washington Group measurement

The Washington Group measurement(51) adopts the ICF framework of disability and function, by focusing on a person's difficulties in basic actions and activities. The tool addresses the need for a population-based measurement of disability that is suitable for censuses, national surveys, and can be used for international comparisons.(53) It includes questions relating to various domains of functioning, such as seeing, hearing, walking or climbing stairs, remembering or concentrating, self-care, and communication. A person is identified as 'with disability' if they report to have 'a lot of difficulty' or 'cannot do it at all' on at least one domain. The Washington Group measurement, particularly the short set (six-items), is a widely used tool internationally. However, although it allows for comparable information about disability globally, it does not identify all people with a disability (such as people with severe psychiatric and cognitive deficits).(53,54) The Washington Group measurement only identifies people with limitations in basic activities and is not appropriate to assess higher-order cognitive functions such as a person's ability to learn or make decisions. This presents a problem for health planners involved in allocating resources to disabled people with higher functional limitations who require support from health and social services.(55)

2.4.2. WHO Disability Assessment Schedule 2.0 (WHODAS 2.0)

The WHODAS 2.0 is an instrument used to measure disability and health at the population level, developed by the WHO.(52) The WHODAS 2.0 assesses level of functioning in the following six domains: cognition, mobility, self-care, getting along (interactions), life activities, and participation (social dimensions). It uses key features of the ICF, primarily focusing on a person's activity limitations and participation restrictions, rather than a person's health condition. A review of validation studies of the 12-item WHODAS 2.0 found it to be internally consistent, but one major concern raised was the multidimensionality of the scale. The tool aims to measure several constructs of function in one scale, making it difficult to interpret the contribution of each.(56) In addition, WHODAS 2.0 does not assess environmental factors (such as use of assistive technologies) that are included in the ICF framework.(57,58) That being said, a review by Federici et al(59) using evidence from across 94 countries, found WHODAS 2.0 to be a valid and reliable self-report measure of assessing disability, with applicability to various health conditions including arthritis, depression and schizophrenia.

2.5. Physical activity

Relative to the non-disabled population, disabled people are often overlooked in physical activity research. Much of the existing research in this population has taken a rehabilitative/medical approach, primarily focused on assessing the physical capabilities and limitations of individuals with spinal cord injuries (SCI), often in rehabilitation or clinical settings.(60) However, in more recent years, there has been growth in the volume of research examining the physiological and psychological benefits of physical activity for this population,(61,62) and an increased emphasis on promoting accessibility to physical activity opportunities for disabled people.(63) There has also been the development of specific physical activity guidelines for disabled people by the UK Chief Medical Officers (CMO) and the WHO.(64,65) In the following sections of the literature review, I summarise current knowledge and gaps in evidence as it relates to the health benefits of physical activity (Section 2.6), national and international physical activity guidelines (Section 2.7), current prevalence of physical activity (Section 2.8), correlates of physical activity for the disabled population (Section 2.9) and the WHO global action plan on physical activity (Section 2.10).

2.6. Health benefits of physical activity

In this section I begin with an overview of the health benefits of physical activity for non-disabled people before considering the benefits for disabled people and those with specific health conditions. I conclude with a summary of the key limitations in the current evidence.

Research on the health benefits of physical activity has largely focused on the non-disabled population. For this group, meeting physical activity guidelines is associated with lower lifetime risk of developing NCD's, such as CVD, type 2 diabetes, and some cancers including breast, colon and kidney.(66–69) As a result, physical activity is reported to increase a person's life expectancy by approximately 7 years, compared to inactive individuals.(70) Physical activity is also positively associated with improved physical function, and improvements to mental health and wellbeing.(71,72)

Compared to non-disabled people, the benefits of physical activity for disabled people are less researched, with the evidence typically taking a narrow focus, concentrating on a small number of the more common disabilities and health conditions.(73) Early studies on physical activity in disabled people primarily focused on assessing the physical capabilities

and limitations of individuals with SCI, often in rehabilitation or clinical settings.(60) SCI is still among the most commonly researched disability in the physical activity literature.(73) For people with SCI, physical activity is associated with increased cardiorespiratory fitness and muscle strength, improved body composition, and reduced risk of developing CVD.(74) Evidence is slowly growing on the physical and psychological health benefits of physical activity for people with other health conditions and disabilities. For example, physical activity has been shown to improve emotional functioning, mood, quality of life and psychological well-being, and reduce levels of stress, depression, anxiety, and pain among people with chronic health conditions and disabilities.(61,62,75) Among people with cancer, physical activity is associated with reduced fatigue, likelihood of reoccurrence, all-cause and cancer-specific mortality, and cancer-related cognitive impairment.(76–78) Physical activity has also been found to improve weight loss and the body's ability to effectively use glucose among people with type 2 diabetes,(79) and reduce mobility impairments in people with multiple sclerosis (MS).(80)

Existing evidence on this topic is largely consistent with the 'medical' conceptualisation of disability, defining participant groups based on their diagnosed health condition.(80–82) However, this is beginning to shift from a solely medical/diagnosed condition focus, toward a biopsychosocial perspective, as outlined in Section 2.3. In doing so, greater attention is being placed on the social and environmental factors, and the types of impairments a person experiences, that could impact their ability to undertake day-to-day activities. However, the current evidence base typically focuses on a single impairment type at one time, instead of assessing the variety and range of impairments a person could experience.

2.7. Physical activity guidelines

National and international physical activity guidelines for disabled people provide recommendations on the amount of physical activity required to achieve the health benefits outlined above, however these have been non-existent until recent years. In this section, I outline the UK (CMO) 2019 physical activity guidelines for disabled adults,(64) the WHO 2020 physical activity and sedentary behaviour guidelines people living with chronic conditions and people living with disabilities,(65) and highlight future research recommendations that emerged from the guideline development process.

2.7.1. UK CMO physical activity guidelines

The UK CMO 2019 physical activity guidelines(64) recommend that disabled adults should do at least 150 minutes of moderate intensity, or 75 minutes of vigorous intensity physical activity per week. Disabled adults should also do muscle strengthening exercises and aim to minimise the amount of time spent sedentary. These guidelines are consistent with those for non-disabled adults. The evidence used to inform these guidelines was restricted to a small number of disabilities (SCI, intellectual disabilities, cerebral palsy, amputees, visual impairment, and hearing impairment) due to the available evidence. Of the 255 articles reviewed, 145 (57%) were on SCI, compared to just three (1%) on hearing impairment.(83) Evidence was predominately cross-sectional, or used pre/post repeated measures designs, and there was a variety of different physical activity measures used including self-report and devices. This has implications for the comparability of the evidence, and the ability to draw firm conclusions on the levels of physical activity needed to produce health benefits in disabled people. The review identified priority areas for future research,(83) including [1] more information that emphasises the dose-response relationship between physical activity and health; [2] the development of quality instrumentation and data collection systems that enhance physical activity surveillance in disabled people; and [3] better consideration of the social, cultural, economic, and environmental factors that can influence a person's activity participation.

Alongside the UK CMO guidelines, infographics were produced to support their dissemination. Disabled people, organisations working with disabled people, and health professionals were invited to workshops to share their thoughts on the guidelines, and how they should be communicated to disabled people.(5) See Appendix 1. Those in attendance felt there was a need to place messages about the enjoyment and positive feelings that derive from being active at the forefront of the infographic. Promotion of the 150 minutes of physical activity per week was deemed motivational, but a message stating "even a little movement is better than nothing" was placed central in the infographic as some contributors felt 150 minutes could be seen as unrealistic and deter people from being active. For the same reason, 75 minutes of vigorous activity was not included in the infographic. Though the infographic includes somewhat similar messaging to the UK CMO guidance, it also highlights the benefits of physical activity for disabled adults, as seen by members of the target population group. In particular, disabled people emphasised the importance of ensuring the physical activity guidelines are seen as realistic, with less focus

on the volume of moderate or vigorous activity, and instead an emphasis on the benefits of doing something.

2.7.2. WHO physical activity and sedentary behaviour guidelines

In 2020, the WHO released separate physical activity and sedentary behaviour guidelines for people living with chronic conditions and people living with disabilities.(65) The guidelines recommend that adults should do at least 150–300 minutes of moderate physical activity, or at least 75-150 minutes of vigorous activity per week, and also muscle strengthening activities on 2 days a week, consistent with what is recommended for adults without a chronic condition or disability. These guidelines were primarily developed through undertaking an updated search of the evidence used to inform the 2018 Physical Activity Guidelines for Americans.(84) The research used to inform the guidelines specifically for adults living with chronic conditions showed consistencies in the dose-response association to that of the general population.(65) For the disabled population guidelines, due to the limited available evidence, the guideline development group considered whether there was sufficient evidence to suggest the guidelines for the general population would not be applicable to disabled people. Given a lack of evidence in this regard, the general population guidelines were extrapolated to disabled people.

The WHO and UK CMO guidelines are an important step towards improving physical activity promotion and disability inclusion. However, the review process for the WHO guidelines highlighted the limited high-quality evidence on physical activity in disabled people. The guidelines for people living with chronic conditions was limited to evidence for four chronic conditions (cancer, hypertension, type 2 diabetes and HIV), with the guidelines for people living with disabilities limited to evidence for eight disabilities (MS, SCI, intellectual disability, Parkinson's disease, stroke, schizophrenia, major clinical depression, and attention deficit hyperactivity disorder (ADHD)). Among the umbrella reviews conducted to inform the guidelines, HIV, diabetes and stroke were the only chronic conditions and disabilities to have more than ten systematic reviews, demonstrating the limited evidence on a wide variety of health conditions and disabilities. Recommendations published alongside these guidelines highlighted the need for research, particularly prospective cohort studies, to explore the health benefits of physical activity across all ages and for a more diverse range of conditions and disabilities, including cancer sites other than breast and colon.(85) Additionally, the recommendations emphasised the need for future

physical activity research to explore disabled people's levels of function and the types of impairment experienced,(85,86) echoing the broader societal shift in the conceptualisation of disability, away from the medical model towards a biopsychosocial perspective, as highlighted in Section 2.3.

2.8. Physical activity prevalence

In the UK, physical activity prevalence estimates for disabled people are somewhat limited. In the Sport England Active Lives 2021/22 cross-sectional survey, 47% of adults with a disability or long-term health condition met the physical activity guidelines, compared to 68% of adults without a condition or disability.(13) In both population groups this marked a 2%-point increase compared to the previous year,(13) suggesting that physical activity levels in all adults could be improving, though disabled people were still less likely to be active compared to non-disabled people. The Active Lives survey is the most nationally representative physical activity survey in England, though based on self-reported data. That being said, others have also identified differences in physical activity levels between disabled and non-disabled people. For example, using device-based data from 96706 participants in Biobank, Barker et al(87) identified that participants without a chronic disease undertook an average of 705 minutes of moderate physical activity per week, compared to 644 minutes for people with a chronic disease. Meanwhile, vigorous activity varied from 27 minutes per week for people without a chronic disease, to 24 minutes per week for people with. Among all the 147 diseases accounted for in their research, the lowest moderate and vigorous activity was identified in people with CVD and chronic neurological disorders. This study highlights the variation in activity levels between people with and without a chronic disease, as well as variation among people with different diseases, however the sample is not nationally representative.(88)

Global estimates of physical activity levels in disabled people are non-existent, with current national and international surveillance systems reported to be either good at measuring physical activity, or good at measuring disability, but seldom both.(89) National and international physical activity surveillance rarely include this population group, though it is unclear why.(90) At a country level, there are some countries who also report physical activity levels of their disabled and non-disabled population. For example, in America, using data from the National Health and Nutrition Examination Survey 2017-18, 45% of people without a disability met the physical activity guidelines, compared to 33% of people

with.(91) Meanwhile in Australia, data from the National Health Survey 2020-21 identified 25% of all adults met the physical activity guidelines, though this included both people with and without a disability. For disabled people, the proportion meeting the guidelines varied from 16% for people with a psychosocial disability to 30% in people with a speech or sensory disability.(92) Whilst these results are useful within countries, due to differences in methodologies, it would not be appropriate to make between country comparisons. Recommendations for future research have highlighted a need to improve local, regional and national physical activity surveillance systems for disabled people, in order to facilitate improved estimates of activity levels and inform better targeting of physical activity campaigns.(90,93)

2.9. Correlates of physical activity

Despite the plethora of benefits associated with physical activity, many disabled people are insufficiently active and experience barriers to physical activity over and above those faced by non-disabled people.(94) In this section, I introduce the ecological framework and highlight some of the most common barriers and facilitators to physical activity for disabled people.

2.9.1. Ecological framework

The ecological framework was first developed by Bronfenbrenner(95) as a systems theory to identify influences of the environment on a child's development at four levels: microsystem, mesosystem, exosystem, and macrosystem. The ecological framework has seen many iterations over the years to encompass changes in the environments and contexts in which we live. One iteration was created by McLeroy et al(96) as a framework to promote health related behaviour change. Encompassing the role of both social and environmental factors, the framework consists of five levels of influence: intrapersonal (e.g. characteristics of the individual); interpersonal (e.g. social network and social support systems); institutional (e.g. social institutions and organisational characteristics); community (e.g. relationships among organisations); and policy (e.g. local and national laws and policies). The ecological framework is recognised worldwide and has been used in physical activity research for a variety of population groups, such as children and pregnant women.(97,98) See Figure 2.2. This framework will be used to structure my discussion of disabled people's barriers and facilitators of physical activity in the proceeding sub-section.

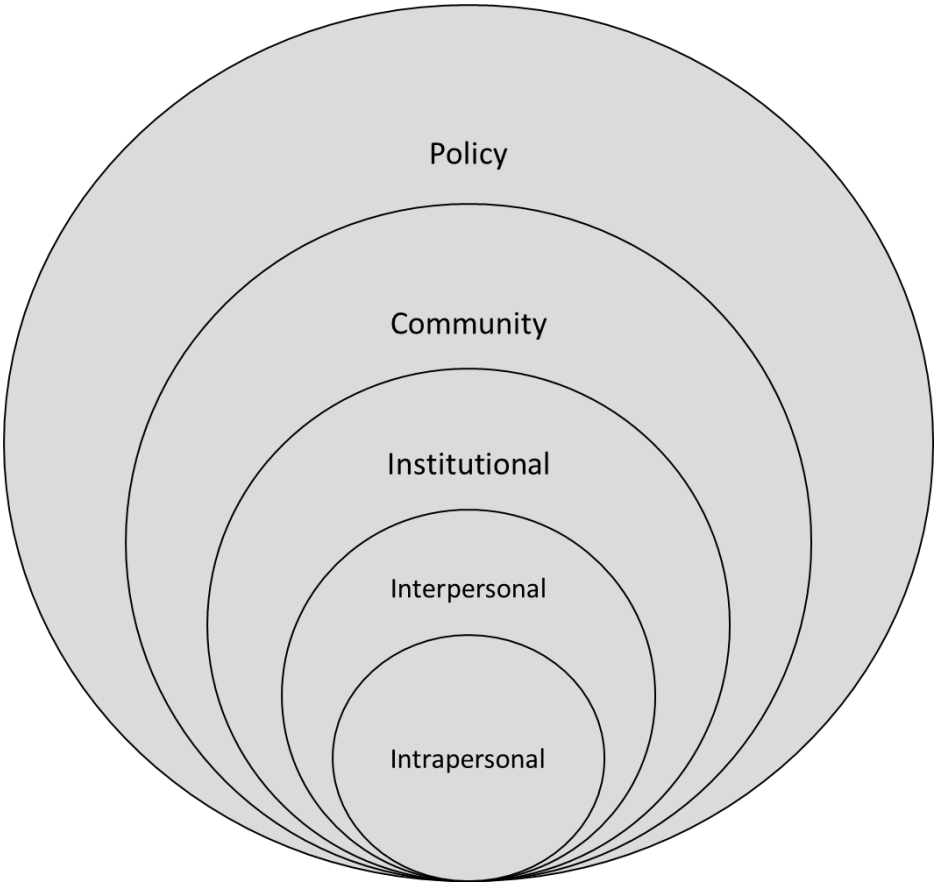

Figure 2.2: Ecological Framework

2.9.2. Barriers and facilitators to physical activity

Identifying the correlates associated with physical activity participation is important for improving researchers and activity providers understanding of the influences on a person's activity levels. A recently published systematic review of review articles identified 229 factors associated with physical activity in people with physical, sensory and intellectual disabilities, which were categorised into common themes and classified within the five levels of the ecological framework.(89) The common themes in each level are displayed in Figure 2.3. This work built on an earlier review which highlighted the diversity of barriers and facilitators to physical activity for disabled people and was the first to demonstrate how the ecological model can be used to conceptualise factors related to physical activity in disabled people.(99)

The most common barriers identified in the review were accessibility, transportation, and financial costs, with 15 or more reviews identified for each factor. To elaborate, insufficient adaptations to activities and a lack of adapted equipment prevent disabled people from

accessing activities.(100,101) Inaccessible environments, such as uneven surfaces and a lack of drop curbs, as well as lack of support from activity providers, can also limit disabled people's opportunities and motivation to be active.(102) Additionally, high transportation and programme costs can also hinder participation,(99,103) with disabled people more likely to be unemployed and of lower socioeconomic position,(104) resulting in less discretionary spending. Though these factors are among the most commonly reported barriers to participation, there are several other barriers that must also be highlighted, such as functional limitations, insufficient training for physical activity instructors on how to support disabled people, and other people's negative attitudes toward the disabled population.(89) Often these barriers are overlooked, with researchers aiming to provide easy classification groupings to improve the readability of their findings, for example, either focusing on just one level of the ecological framework or grouping several correlates into one category. However, this lack of detail means findings become unrepresentative of the experiences faced by disabled people.(94)

Factors that can facilitate physical activity uptake in disabled people have been far less explored. The most common facilitators to physical activity, reported in 10 or more of the included review articles, were the opportunity to meet and spend time with others, social support from family and friends, and health care professionals.(89) In particular, support from family and peers to engage in physical activity fosters a sense of motivation and inclusion,(99,105) whilst healthcare professionals play a pivotal role in physical activity promotion as respected sources of advice about health behaviours.(5,105) As with barriers, there are other facilitators to participation for disabled people including being provided with physical activity information during rehabilitation, and an individual's self-efficacy levels.(89) Associations can also have a reverse influence, for example whilst healthcare providers can encourage uptake, their own lack of knowledge and motivation to be active can often be a barrier towards promoting physical activity.(94)

There are several more barriers to physical activity reported by disabled people in comparison to facilitators, as highlighted above, and this is likely reflective of many disabled people's attitudes towards physical activity. Disabled people are more likely to focus on the barriers to participation, whereas non-disabled people are more likely to focus on the benefits of exercise.(106) Therefore it is important that activity providers, local

councils, as well as government policies aim to minimise the barriers to participation for disabled people in order to encourage this target population to be active.

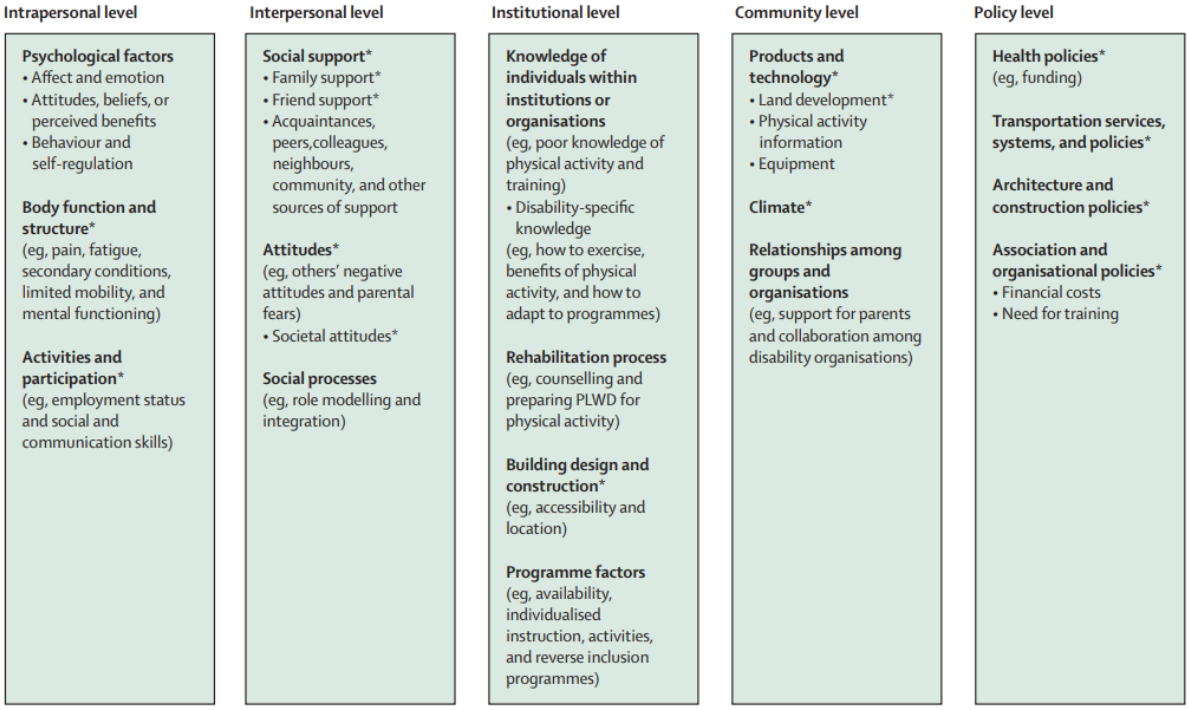

Figure 2.3: Factors relating to physical activity participation in disabled people(89)

2.10. WHO global action plan on physical activity

The WHO Global Action Plan on Physical Activity 2018-2030 (GAPPA) was developed to help countries scale up policy actions to promote physical activity. The GAPPA recommends 20 policy actions that are categorised into four objectives; active societies, active environments, active people, and active systems.(93) See Appendix 2. The GAPPA's mission is to ensure people have access to safe and enabling environments, and diverse opportunities to be active. It also acknowledges the need for widespread engagement from diverse stakeholders to maximise local and global impact of physical activity promotion.(107) The need for improvements to national physical activity surveillance systems to monitor sociocultural and environmental determinants of physical inactivity were also highlighted.

The GAPPA is applicable to all target population groups, including disabled people. However, it has experienced limited government support from countries at all income levels,(108) preventing improvements to access and provision for all populations to be more active. Insufficient skills among the physical activity workforce to advocate for the

implementation of the GAPPA, and a lack of awareness of the GAPPA in wider agencies and communities have also presented challenges for the implementation of this action plan.(108)

2.11. Behavioural Epidemiology Framework

The Behavioural Epidemiology Framework illustrates the breadth of research relevant to understanding health related behaviours.(109) As displayed in Figure 2.4, the five phases of the Behavioural Epidemiology Framework are [1] establish links between behaviours and health, [2] develop methods for measuring the behaviour, [3] identify factors that influence the behaviour, [4] evaluate interventions to change the behaviour, and [5] translate research into practice. Each phase builds upon the previous phase(s), in a somewhat linear process, however there are feed-back and feed-forward elements, with each phase able to influence and inform another. The framework can be used to assess the development of a topic of study. For example, research disciplines in their early stages of development are likely to have a predominant focus on research in the earlier phases of the framework, with emphasis shifting towards policy development and implementation as the field matures.

Each study undertaken in this thesis can be considered in the context of this framework. The first three studies draw on the earlier phases of the behavioural epidemiology framework (specifically phases 2-3), with the final study delving into the translation of research into policy (phase 5). The relevance of each study to the Behavioural Epidemiology Framework is described in the next section (Section 2.12).

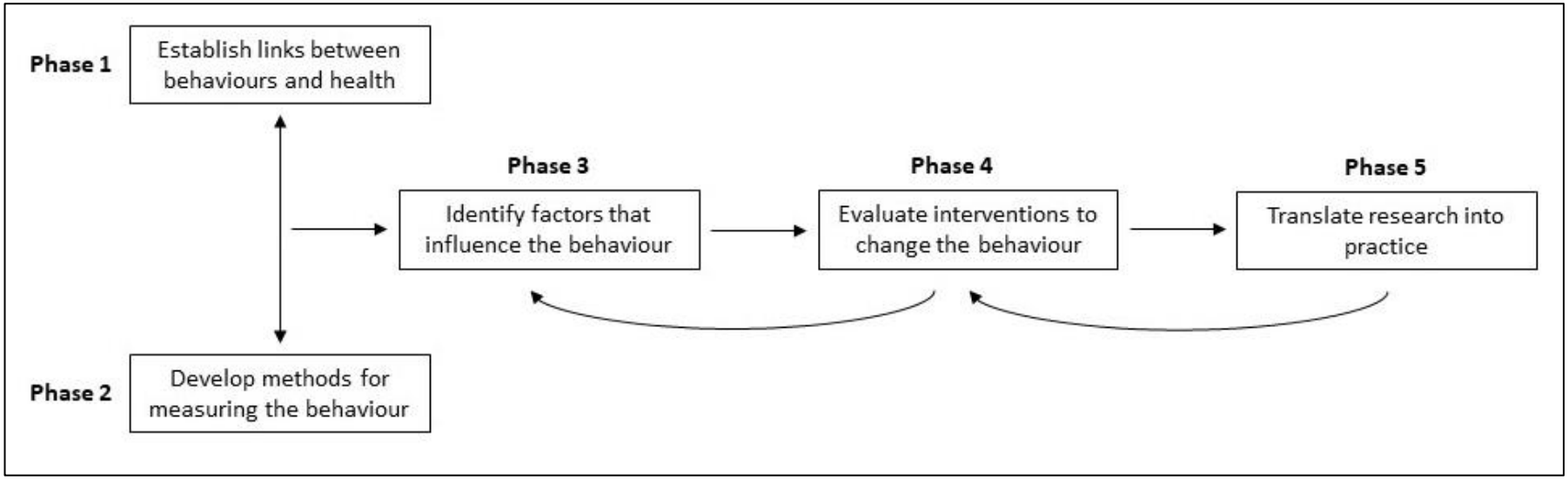

Figure 2.4: Behavioural Epidemiology Framework

2.12. Thesis rationale, aims, and structure

The primary aim of this thesis is to explore relationships between health conditions, impairments and physical activity levels, and identify actions to support disabled people to be active. Below, I describe the aims and methods of each study, and how they address gaps in current evidence and previous research recommendations. The methods for each study are described in more detail in the corresponding study chapters (Chapters 3-6).

Given the limited evidence that was available to inform the development of the physical activity guidelines for people with chronic conditions and disabilities, Study 1, presented in Chapter 3, sought to explore whether and how disability has been assessed in epidemiological studies that included a device-based measurement of physical activity. Aligned with phase 2 of the Behavioural Epidemiology Framework, this scoping review examines questionnaire items of included studies and aligns them to the ICF components of health condition, body functions and structures, and activities and participation.

To address the suggested need for increased focus on a person's function or impairment type as well as health condition, Study 2, presented in Chapter 4, explores whether there are differences in physical activity levels among people with the same health condition, based on differences in the type and number of impairments experienced. This study aligns with phase 3 of the Behavioural Epidemiology Framework and uses data from the Health Survey for England 2018 to explore the cross-sectional associations of chronic conditions and disability with self-reported physical activity among adults.

While previous evidence has highlighted lower prevalence of physical activity among disabled people, research has rarely explored the types of activity that disabled people engage in. By exploring this matter, we can better understand the activity types of disabled and non-disabled people to identify where there may be discrepancies and highlight areas where physical activity provision may need to be improved. Therefore, Study 3, presented in Chapter 5, uses data from the 2018/19 Sport England Active Lives survey to explore the duration and types of physical activity that disabled people participate in compared to non-disabled people. This study aligns to phase 3 of the Behavioural Epidemiology Framework.

Previous research has identified many barriers to physical activity participation for disabled people, however, less is known about the actions needed to help support disabled people

to be active. As a result, Study 4, presented in Chapter 6, aims to identify the actions that need to be taken to support disabled people to overcome barriers to being active. This qualitative study involves focus groups with disabled people and aligns with phase 5 of the Behavioural Epidemiology Framework.

The final chapter of this thesis, Chapter 7, is the discussion and conclusion. This chapter brings together the key findings and implications of the thesis for future physical activity research, policy and practice.

A steering group of representatives from Sport England, Activity Alliance and the Office for Health Improvement and Disparities (formerly Public Health England) was established to help guide the direction of the research to ensure the findings would have policy relevance. Meetings with the steering group were held periodically throughout the PhD to update on progress, discuss ideas for each study and gather feedback on the proposed scope and methods. These discussions occasionally continued between meetings, via email, when further feedback and input from the steering group was required. The input from the steering group helped to shape the datasets selected for studies 2 and 3, and Activity Alliance supported the recruitment of participants for Study 4.

Chapter 3. A scoping review of disability assessment in prospective and cross-sectional studies that included device-based measurement of physical activity

3.1. Chapter summary

The first study of four sought to explore the assessment of disability in physical activity related studies.

The manuscript is presented here, the full reference for which is:

Carr, S., Atkin, A. J., Jones, A. P., Pulsford, R., & Milton, K. (2023). A scoping review of disability assessment in prospective and cross-sectional studies that included device-based measurement of physical activity. *Journal of Physical Activity and Health*, *20(*8), 683-689. https://doi.org/10.1123/jpah.2023-0017.

3.2. Background

Emerging evidence indicates that physical activity is beneficially associated with many physical and mental health outcomes in disabled people. This includes improved mood, psychological well-being and overall quality of life, and reduced self-reported depression, stress and pain.(62,75) Physical activity also has a role in the prevention and management of chronic disease in this population, including coronary heart disease, type 2 diabetes, stroke and some types of cancer.(66,110)

Whilst evidence exists on the benefits of physical activity for disabled people, the volume of research is small relative to that for the non-disabled population. Less than 5% (n=1235) of articles published in the five highest ranked medical journals between 1999 and 2019 focused on disabled people, and less than 7% (n=77) of these addressed physical activity and/or health.(89) Thus, while the available evidence has started to provide insights, relatively little is known about how active disabled people are, and the types of actions needed to address barriers and support disabled people to be physically active.(86) There is, therefore, a need for further high-quality research on physical activity in disabled people, especially given some preliminary data suggest disabled people are twice as likely to be physically inactive compared to the non-disabled population.(111)

The WHO 2020 physical activity and sedentary behaviour guidelines(65) were the first global guidelines to address people living with chronic conditions and impairments. The guideline development group reviewed the evidence on the association between physical activity and health outcomes in four chronic conditions (cancer, hypertension, type 2 diabetes and HIV) and eight types of impairment or disability (MS, SCI, intellectual disability, Parkinson disease, stroke, major clinical depression, schizophrenia, and ADHD; however, due to the small volume of evidence identified, they also considered the applicability of the general population guidelines to disabled people.(112) They found no evidence to suggest the general population guidelines would not be applicable, and thus extrapolated the general population guidelines to all disabled people. The guidelines note, however, that disabled people might need to consult a health professional to determine the appropriate type and amount of physical activity.(65)

It is possible that the limited availability of high-quality scientific evidence in the field of disability and physical activity is due to limited funding for research in this population and/or the complexity of measuring disability in this context. For example, physical activity research has typically adopted a medical model, classifying people by their diagnosed health condition, rather than considering the nature of their impairment(s). This approach could be problematic, especially where there is wide variation in the severity of symptoms and/or the nature of impairment experienced by people with the same diagnosed condition. There is a need to better understand how disability is currently assessed in physical activity research and whether improvements in this area might facilitate the development of a more robust evidence base.

According to the WHO ICF,(42) disability results from the dynamic interaction between an individual with a health condition and contextual (personal and environmental) factors. The ICF considers how these factors combine to negatively affect people in terms of [1] body functions and structures; [2] ability to execute tasks/activities; and [3] involvement/participation in life situations (further detail is provided in the 'methods' section). This scoping review used ICF to explore whether disability has been assessed in epidemiological studies that included accelerometer-based measurement of physical activity in adults, and if so, what information on disability was captured.

To note, we have chosen to consistently use the term 'disabled people' throughout the paper, as this term is typically more accepted among the UK disability community(5) (where the authors are based), however we acknowledge that other terminologies (such as 'people with disabilities') are preferred among some individuals, groups and organisations.

3.3. Methods

This review was conducted in accordance with the Joanna Briggs Institute guidelines for scoping reviews,(113) and is reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) framework.(114) A protocol was developed *a priori*, as described below, and was later made available on the Open Science Framework (DOI: https://doi.org/10.17605/OSF.IO/C2JHV).

3.3.1. Eligibility Criteria

Our search strategy focused on publications, but the unit of analysis for the review was "study", findings from which may have been reported across multiple publications. Studies were considered for inclusion if they met the following criteria: [1] observational studies that were either prospective or cross-sectional and representative of a national or regional population; [2] report data on adults (over the age of 18 years) alone, or separately from any data on children or adolescents; and [3] include accelerometer measurement of physical activity. We restricted the review to studies that included accelerometer measurement of physical activity to keep the number of potentially eligible studies to a manageable size. There was no sample size requirement. Studies only reporting data on children and adolescents, or studies only reporting data on cohorts of participants recruited due to the presence of a clinical condition were excluded. We were interested in understanding the assessment of disability within population-based observational studies, and hence the exclusion of studies focused on specific clinical subgroups. Searches were limited to articles published in English-language peer-reviewed scientific journals. Searches were not limited by publication date.

3.3.2. Information Sources

Literature searches were completed in March 2020 (updated in November 2021) using the following databases: MEDLINE (Ovid); Embase; PsychINFO; Health Management Information Consortium; Web of Science - Core collection; SPORTDiscus through

EBSCOhost; and CINAHL (Cumulative Index to Nursing & Allied Health Literature) through EBSCOhost. A base search strategy was developed in MEDLINE (Ovid) and syntaxes altered accordingly for subsequent database searches. Se**e** Appendix 3 for the full search strategy for MEDLINE. Supplementary searches were completed through bibliographic screening, forward and backward citation searches of articles, and correspondence with experts in the field to identify other studies that potentially met the inclusion criteria. The search strategy included title, abstract and subject word searches for Medical Subheading (MeSH) terms relating to physical behaviour, physical activity, sedentary behaviour, device-based measurement of movement (accelerometer, accelerometry, motion sensor, device), and terms denoting cross-sectional and prospective observational studies.

3.3.3. Selection of Sources of Evidence

Following the removal of duplicates, titles and abstracts of all articles returned by the searches were independently screened by two reviewers to assess whether the study described by the article was eligible for inclusion. Disagreement between reviewers was resolved in consultation with a third arbiter. Full-text versions of articles included at initial screening were then assessed by one reviewer, who consulted with the third arbiter from the initial screen stage on any uncertainties. For the studies identified, we attempted to obtain all questionnaires, used to collect any form of data, across the lifetime of the study up to November 2021 using the protocol detailed below.

Protocol

To obtain questionnaires, or a data dictionary of study questions and response options, the following steps were taken:

1. Online search; for example, through the Google search engine, to identify a study website.
2. Exploration of study documents/papers; for example, study protocol or published research papers.
3. Contact via:
    i. ‘Contact us’ form on the study website
    ii. Any contact details/email address on study website, for study lead, principal investigator or data collection team.
    iii. Emailing the PI or corresponding author on a research paper.

In Step 3, contact attempts were made over a four-week period. If no response was received within two weeks of the first contact, a follow up contact attempt was made. If no response was received within a further two weeks, the study was excluded.

3.3.4. Data charting process

A data charting template was developed to extract information on how each study captured the following three dimensions of ICF: [1] health conditions; [2] body functions and structures; and [3] activities and participation. During initial development, a trial data extraction was undertaken on ten studies by two authors independently and then compared to ensure all relevant data would be extracted and consistently recorded. Following agreement, data extraction for all studies was undertaken, led by the lead author, who engaged the last author on any aspects of uncertainty. Final decisions were reached through discussion between these two authors. See Appendix 4 for a complete list of the information extracted on each study. In summary:

[1] Health Condition

Health condition is the umbrella term used by the ICF for disease, disorder, injury, or trauma. We categorised each health condition that was assessed in each study according to the International Statistical Classification of Disease and Related Health Problems (ICD-10) (115) to provide a standard classification system across studies. We present results based on 14 chapters from the ICD-10; [1] Endocrine nutritional and metabolic diseases; [2] Diseases of the circulatory system; [3] Diseases of the respiratory system; [4] Neoplasms; [5] Diseases of the musculoskeletal system and connective tissue; [6] Diseases of the nervous system; 7) Mental and behavioural disorders; [8] Diseases of the eye and adnexa; [9] Diseases of the digestive system; [10] Diseases of the genitourinary system; [11] Certain infectious and parasitic diseases; [12] Diseases of the ear and mastoid process; [13] Diseases of the skin and subcutaneous tissue; [14] Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism.

[2] Body Functions and Structures

In the ICF, body functions refer to the “physiological functions of the body systems (including psychological functions)”, and body structures are the “anatomical parts of the body such as organs, limbs and their components”.(42 p.10) Within the ICF, body functions and structures are one component but classified under two sections. For this review, the

two sections have been combined under the following chapters [1] Mental and nervous system; [2] Sensory and pain; [3] Cardiovascular, haematological, immunological, and respiratory; [4] Voice and speech; [5] Neuromusculoskeletal and movement-related; [6] Digestive, metabolic and endocrine; [7] Genitourinary and reproductive; and [8] Skin and related structures.

[3] Activities and Participation

The ICF utilises a combined system for categorising a person's ability to execute tasks/activities and involvement/participation in life situations (referred to as 'activities and participation' from here). Within the ICF categorisation system for activities and participation, there are nine chapters: [1] Learning and applying knowledge; [2] General tasks and demands; [3] Communication; [4] Mobility; [5] Self-care, [6] Domestic life; [7] Interpersonal interactions and relationships; [8] Major life areas; and [9] Community, social and civic life.

3.3.5. Synthesis of Results

The unit of analysis was study. We included all question-sets that each study used across its lifetime. Data were synthesised narratively, focussing on the frequency and characteristics of measurement in the three domains of [1] health condition, [2] body functions and structures, and [3] activities and participation. A study only had to capture the data once, at any point in its history, for a frequency count to be recorded. Where percentages are reported, these are based on the total number of included studies. As we were only gathering questionnaire items, ethical approval was not required.

3.4. Results

As depicted in Figure 3.1, 84 studies where eligible for inclusion in the review. Following the protocol to obtain study questionnaires, 16 studies were excluded, either due to no reply or because we were unable to obtain sufficient information on the questionnaire items used. Therefore, 68 studies were included in the synthesis. Thirty-seven (54%) took place within Europe. The remaining studies were predominately located within North America (n=16, 24%), although studies were also included from South America (n=5, 7%), Australia and Oceania (n=5, 7%), Asia (n=4, 6%), and Africa (n=1, 1%). Appendix 5 provides study name and corresponding study number, as well as location and source.

Of the 68 included studies, 8 (12%) did not collect any information related to health conditions, body functions and structures, or activities and participation. Fifty-one (75%) had questions related to health conditions, 43 (63%) had questions related to body functions and structures, and 51 (75%) included questions related to activities and participation.

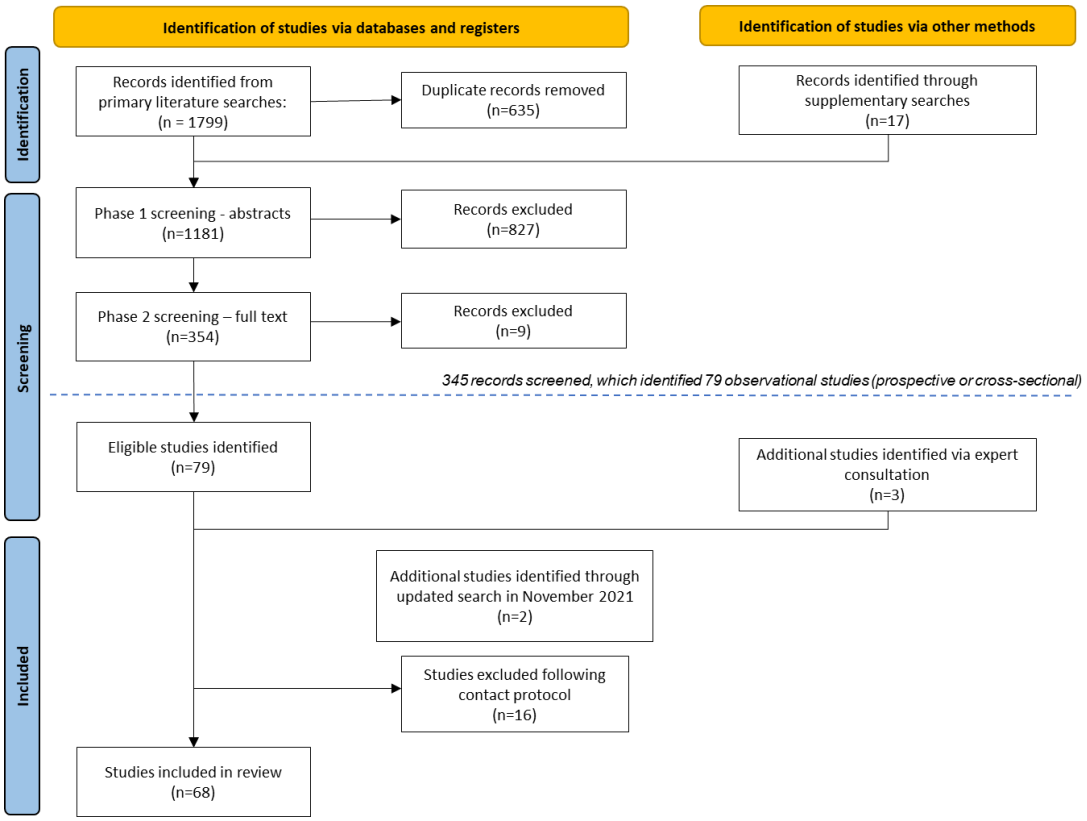

Figure 3.1: Overview of study selection process

3.4.1. Health Conditions

Table 3.1 presents the number and percentage of studies that asked whether participants currently or previously had one or more specific condition, disease or other health related disorder, grouped according to 14 chapters from the ICD-10.(115) Fifty-one (75%) studies included at least one question where participants reported whether they had previously or currently had a specific condition, disease or other health disorder which fell into one or more ICD-10 chapter. One study had an open-ended question where participants were asked to report what conditions they currently had, with no specific conditions or diseases named. Most frequently, studies ascertained information about conditions from the 'Endocrine, nutritional, and metabolic diseases' chapter of ICD-10 (n=48, 71%), most commonly diabetes. This was closely followed by diseases of the circulatory system (n=47,

69%) such as high blood pressure or a heart attack, and diseases of the respiratory system (n=43, 63%) such as asthma and chronic obstructive pulmonary disease (COPD). In most instances, an open-text question followed, where participants could report any other health conditions or diseases that were not explicitly mentioned within the study's questionnaire(s).

Table 3.1: Frequency of studies that assessed health conditions, based on ICD-10 classification.

ICD-10 chapter	N	%	Study Reference No.
Endocrine, nutritional, and metabolic diseases	48	70.6	1-3,5,7-18,20,22,24-28,30-34,36-38,40,41,43,45,46,48-58,60
Diseases of the circulatory system	47	69.1	1-3,7-18,20,22,24-28,30-34,37,38,40,41,43-46,48-58,60
Diseases of the respiratory system	43	63.2	1,2,5,7-14,16,17,20,22,24-28,30,32-34,37,38,40,41,43-46, 48-55,57,58,60
Neoplasms	37	54.4	2,5,7-13,16,22,24,26-28, 30,32,34,36-38,40,41,44-46,48,49,51-58,60
Diseases of the musculoskeletal system and connective tissue	35	51.5	1,2,4,5,7,8,10-12,14,16,22,24,26,27,30,32-34, 37,38,40,41,43,45,49,51-58,60
Diseases of the nervous system	31	45.6	1,2,5,7,9-12,16,24,26,28,30,32-34,36-38,41,43,45,46,48,52,54-58,60
Mental and behavioural disorders	29	42.6	1,2,7,9,11,13,14,16,24,26-28,30,32-34,37-39,40,41,43,45,46,52-58,60
Diseases of the eye and adnexa	24	35.3	2,3,5,7,8,12,16,24,26,30,32,33,37,40,41,43,45,46,49,52,56-58,60
Diseases of the digestive system	22	32.4	1,5,7,9,10,12,16,22,28,33,34,38,40,41,43,48,52-54,57,58,60
Diseases of the genitourinary system	21	30.9	1,3,5,7,9,10,12,16,22,25,26,28,34,37,41,44,46,53,55,57,60
Certain infectious and parasitic diseases	15	22.1	2,5,9,10, 27,28,38,40,44,48,49,53,54,57,60
Diseases of the ear and mastoid process	11	16.2	5,8,26,30,32,40,41,45,46,57,60
Diseases of the skin and subcutaneous tissue	11	16.2	1,5,11,13,26,30,34,41,45,57,60
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	5	7.4	8,25,34,44,60

3.4.2. Body Functions and Structure

As displayed in Table 3.2, of the 68 included studies, 43 (63%) included questions related to participants' body functions and structures. Most questions related to a person's body functions, rather than structures. There was considerable variation in the style of questions. Some studies included a validated measure, such as the Mini-Mental State Examination (n=6, 9%) to assess cognitive impairment.(116) Others, such as the Northern Finland Birth Cohort (corresponding study number 41), asked participants to select a statement that best describes their health today with response options on a 5-point scale from "Can think clearly and logically; my memory works flawlessly" to "I am constantly delirious and have no sense of time and place". 'Mental and nervous system' was the most common category assessed; in particular, questions most frequently related to a person's memory and emotional functions. No studies asked questions on body functions and structures related to the chapter of skin and related structures.

Table 3.2: Frequency of studies that asked about each chapter within body functions and structures on the ICF.

Body functions and structures chapter	N	%	Study Reference No.
Mental and nervous system	38	55.9	1-5,7,9,11,12,16,22-26,28,30,33-42,45,46,49,52,54-60
Sensory and pain	38	55.9	1-9,11,13,16,20,22-26,28,30,33-35,37-41,45,46,49,52-54,56,58-60
Cardiovascular, haematological, immunological, and respiratory systems	13	19.1	1,2,7,16,22,24,26,28,41,45,52,58,60
Neuromusculoskeletal and movement-related	10	14.7	1,7,9,16,34,35,42,54,58,60
Voices and speech	8	11.8	22,24,34,41,42,46,53,8,60
Digestive, metabolic, and endocrine systems	1	1.5	60
Genitourinary and reproductive	1	1.5	60
Skin and related structures	0	0	

3.4.3. Activities and Participation

Table 3.3 shows the number and percentage of studies that asked questions about activities and participation, as categorised by the ICF. Fifty-one (75%) studies included questions related to a person's activities and participation, but there was considerable diversity in the number and type of questions asked. Forty-five (66%) asked about two or more of the nine activity and participation chapters, with 19 (28%) asking questions about five or more of the chapters. Questions related to mobility were asked most frequently (n=48,71%), although the level of detail differed considerably. For example, the ActiFE ULM study (corresponding study number 1), asked participants how difficult it was for them to carry out daily activities on their own, while Maastricht Study (corresponding study number 35) asked participants to report on their ability to undertake a variety of different activities including getting around the house, getting in and out of bed, washing face and hands, and doing light and heavy household activities. 'Mobility' and 'Self-care' were asked about by over half of studies, with some including measures such as the EuroQol-5D(117) (n=9, 13%), 36-item Short Form Health Survey (118) (n=9, 13%) or 12-item Short Form Health Survey (119) (n=9, 13%). Least frequently referred to was interpersonal interactions and relationships (n=3, 4%).

Table 3.3: Frequency of studies that asked about each chapter within activities and participation on the ICF.

Activities and participation chapter	N	%	Study Reference No.
Mobility	48	70.6	1-9,12,13,16,19-30,33-35,37-43,45-49,52-60
Self-care	38	55.9	1-7,11,12,16,20-22,24-26,28-30,33-35,37,38,40,42,43,46,47,49,52-58,60
Learning and applying knowledge	28	41.2	1,2,4,7-9,11,16,22,24,26,34,36-42,46,49,52,53,55-58,60
Communication	28	41.2	1,2,6,8,9,11,12,20,22,24,26,33,36-39,41,42,46,47,49,52,53,55-58,60
Domestic life	28	41.2	1,4,7,11,12,16,22,24,26,28,30,33,35,37-40,42,46,47,52-58,60
General tasks and demands	14	20.6	1,2,24,26,28,33,35,40,41,42,46,47,55,56
Community, social and civic life	14	20.6	1,4,19,23,24,26,34,37,39,40,42,45,46,59
Major life areas	10	14.7	19,24,26,32,47,53,55-57,60,
Interpersonal interactions and relationships	3	4.4	26,55,60

3.5. Discussion

Findings from this scoping review indicate that most studies asked something about health conditions, body functions and structures, and/or life activities and participation; however, there was substantial diversity in the number and type of questions asked. This has implications for the comparability of evidence across studies and subsequent understanding of the relationships between disability, physical activity, and health. Though some studies asked about more than one body function or structure, or addressed several ICD-10 chapters, this may have been across several different questionnaires, delivered at different phases of the study. In addition, some of the assessments were limited to subgroups of participants, rather than the whole sample.

Within this scoping review, questions about disability were included in most studies, with only 8 of the 68 (12%) not asking any questions at all. In terms of the three domains of interest, assessment of health conditions was most common, likely because it was an outcome of interest in many of the included studies. Where studies only assessed health conditions (and not body functions and structures, and/or activities and participation), they are limited to looking at the physical activity and health relationship across health condition sub-groups. However, people with the same health condition can experience different symptoms and impairments in body functions and face different barriers to being physically active. Carr et al(120) found the number and types of impairment experienced was highly variable within and between people with different chronic health conditions. They also found physical activity levels to vary among people with the same chronic condition, depending on their type of impairment. Within this scoping review, 63% of studies included questions related to participants' body functions and structures, and 75% included questions related to a person's activities and participation. Though relatively high, the level of detail captured was often limited, with some studies only asking questions relating to one chapter within each of these two components of the ICF. Including an assessment of disability in physical activity research which accounts for functional and activity limitations, in addition to health conditions, would allow for an improved understanding of the implications of a person's health condition upon their ability to undertake physical activity (121).

The WHO advocates the use of the WHODAS 2.0, which is a 36-item questionnaire that assesses disability in adults.(52) It is applicable across cultures and addresses the ICF's

'activities and participation' component of disability. We did not identify any studies within this review that included the WHODAS 2.0, although many of the included studies were conducted prior to the WHODAS 2.0 being published. Use of a consistent measure of disability across studies would improve comparability of research findings and facilitate more possibilities for pooled data analysis, which is essential to advancing health information systems.(122)

There are several strengths and limitations of this scoping review. In terms of strengths, this is the first review to explore the extent and nature of disability assessment in observational studies that included device-based measurement of physical activity. The review was reported in accordance with PRISMA-ScR guidelines. We conducted duplicate screening of titles and abstracts, and no date limits were imposed on database searches. We also didn't include any reference to disability within our search strategy to enable the inclusion of studies that were drawn from the general population, rather than solely focusing on studies that targeted people with specific health conditions or impairments. In terms of limitations, the measurement and categorisation of health conditions, body functions and structures, and activities and participation varied across studies, making it challenging to classify studies in terms of their overall assessment of the different domains of interest. There may therefore be some subjectivity in the typology presented. We also solely focused on research published in English-language, and research which used an accelerometer-based measurement of physical activity. Exploring research which has used other measures of physical activity, such as self-report, may provide different findings and this is a potential avenue for future research. For this scoping review we focused on questionnaire items and did not include tests of physical function that studies may have undertaken, such as grip strength, sight, or hearing tests. These types of tests may provide a more valid assessment of impairment than the self-report tools considered in this review.

3.6. Conclusion

This scoping review is the first to assess the extent and nature of disability assessment in research studies of the adult population that included an accelerometer measurement of physical activity. It highlights the need to consider how health conditions, body functions and structures, and activities and participation are measured and categorised in future research. To strengthen the evidence base on physical activity in disabled people and to

improve comparability of evidence across studies, we stress the need for a consistent approach to measuring disability in future physical activity related research.

Chapter 4. The cross-sectional associations of chronic conditions and disability with self-reported physical activity among adults in England

4.1. Chapter summary

Study 1 identified that while much physical activity research asks about a person's health condition, body functions and structures, and/or activities and participation, the volume and question types asked differed considerably across studies. Previous research has emphasised a need to shift away from assessing only chronic conditions, to also exploring function/impairment type,(85,86) as these may have differing impacts on physical activity levels. Therefore, this study sought to address whether there is an association between chronic conditions and impairment type with levels of physical activity.

The manuscript is presented here, the full reference for which is:

> Carr, S., Atkin, A. J., Jones, A. P., & Milton, K. (2023). The cross-sectional associations of chronic conditions and disability with self-reported physical activity among adults in England. *Preventive Medicine*, 177, 107754. https://doi.org/10.1016/j.ypmed.2023.107754.

4.2. Background

According to the WHO ICF, disability is an outcome of the interaction between health conditions and contextual (personal and environmental) factors.(2,42) There are around 15 million people in England with a chronic health condition.(123) With an ageing population, this figure is rising and so too is the prevalence of disability.(2) A growing body of evidence suggests numerous benefits of physical activity for both the prevention and management of chronic health conditions.(124,125) Data indicate, however, that physical inactivity is responsible for one in six deaths in the UK, resulting in an estimated annual cost of £7.4 billion to the UK economy.(126) People living with a chronic condition or disability are more likely to be physically inactive than non-disabled people,(127) making them an important target group for physical activity promotion.

In 2020 the WHO published the first global guidelines on physical activity and sedentary behaviour for people living with chronic conditions and disabilities.(65) Separate guidelines were produced for these two population groups, although chronic conditions and disability are inextricably linked. For example, whilst Parkinson's is a chronic disease, it was

considered within the evidence reviews underpinning the WHO 'disability' guidelines due to its long-term impact on neurological function. Recommendations from the WHO review process included the need to expand disability research beyond a limited number of specific health conditions, and for future research to better account for diversity in the physical and mental function of people living with a disability.(86)

Much research in the physical activity field has focused on population groups with chronic conditions, without consideration of differing degrees of disability or impairment.(86) There is likely to be variation in the number and types of impairments that individuals with the same chronic health condition experience, which will impact their capacity to undertake physical activity. For example, among people with MS, there can be varying symptoms and levels of severity, which lead to differences in a person's ability to participate in physical activity.(128) In addition, a recent report by Ross et al.(129) identified that adults with a mobility limitation are less likely to meet physical activity guidelines compared to those with other functional limitations or without a disability. However, because physical activity research has typically focused on chronic conditions only, we have limited understanding of the variation in impairments experienced by people with chronic conditions, or how the combination of chronic health conditions and impairments impacts participation in physical activity. Examining the types of impairments that people experience because of a chronic health condition will enable a better understanding of the implications of health conditions on physical activity participation, allowing interventions to be better designed and targeted to support these groups.

The objectives of this study were to: [1] describe the number and types of impairments reported by people with selected chronic conditions; [2] describe the levels of physical activity participation in people with different chronic conditions; [3] examine the association of type and number of impairments with physical activity levels in people with a chronic condition; and [4] examine the relative importance of chronic conditions and impairments as correlates of physical activity.

4.3. Methods

4.3.1. Study sample

Data were from the Health Survey for England (HSE), an annual national survey conducted since 1991 to monitor trends in health and health related behaviours in children and

adults.(130) HSE uses multi-stage stratified probability sampling to recruit a nationally representative sample of the general population. Data collected in 2018 were selected because this was the most recent available wave to include information on the outcomes of interest for this analysis. HSE 2018 data were collected via an interview, which included verbal responses to questions and completion of a questionnaire.(131) For objectives one to three of this study, the analytical sample comprised participants aged 16 years and over that self-reported having a chronic condition, as defined below. For objective four, the analytical sample also included participants who did not report to have a chronic condition.

4.3.2. Measures

Chronic health conditions

Participants reported whether they had any "*physical or mental health conditions or illnesses lasting or expected to last 12 months or more*". If they responded 'yes' to this question, they were asked to identify up to six conditions or illnesses, which were recorded verbatim. Responses were categorised by the HSE team prior to the data being made available for analysis. Excluding categories labelled 'other' such as 'other endocrine/ metabolic', where we were unable to clearly identify a person's specific health condition, seven condition groups were identified for inclusion in this study: [1] diabetes; [2] stroke and/or ischemic heart disease (IHD); [3] hypertension; [4] chronic obstructive pulmonary disease (COPD); [5] asthma; [6] arthritis/rheumatism/fibrositis; and [7] back problems.

Impairments

As a follow on to the chronic health conditions question above, participants were asked whether "*any of your conditions or illnesses affect you in the following areas?*" [1] vision; [2] hearing; [3] mobility; [4] dexterity; [5] learning or understanding or concentrating; [6] memory; [7] mental health; [8] stamina or breathing or fatigue; [9] social or behavioural; [10] other; and [11] none of the above. Due to small sample sizes (n<65), 'social or behavioural' and 'other' were only included in our descriptive statistics and analyses of the number of impairments and the association with physical activity.

Physical activity

Participants completed the International Physical Activity Questionnaire - Short-Form(IPAQ-SF),(132) comprising 7-items assessing frequency and duration of walking, moderate, and vigorous intensity physical activity in the previous 7 days. Following

established guidelines for data processing and analysis of IPAQ,(133) weekly minutes of each activity were calculated by multiplying the reported duration (minutes) of a typical bout of activity by the number of days on which the activity was undertaken. The Metabolic Equivalents (METS) of each activity (walking = 3.3, moderate = 4.0 and vigorous = 8.0) was multiplied by minutes per week to provide an estimate of total MET-minutes of physical activity per week. Two physical activity outcomes were used for this analysis: MET-minutes of physical activity and walking-minutes per week.

Covariates

Participants reported their date of birth (16+ years, 5-year age bands), sex (male, female), ethnicity (White, Black, Asian, mixed/multiple ethnic background, any other ethnic group) and level of education (none, below degree, and degree or equivalent (NVQ level 4 or 5, or university degree)). These were the covariates for this study.

4.3.3. Data analysis

Sample characteristics and the number of impairments reported by participants with each chronic condition are presented as frequencies and percentages. As the data were not normally distributed, median and interquartile ranges (IQR) are reported for the two physical activity outcomes. To accommodate the substantial proportion of zero values observed for each physical activity outcome, multivariable Poisson regression models were used to estimate the association of a) impairment type, b) number of impairments, and c) impairment type and chronic condition (mutually adjusted) with physical activity (MET-minutes per week and walking-minutes per week). We used the robust estimator of variance to account for mild violations of the underlying model assumptions (mean not equal to the variance). Models were adjusted for age (fitted as a quadratic term), sex, ethnicity and education as described above, and analyses were conducted separately for each chronic health condition groups. For objectives 3 and 4, we mutually adjusted models for all impairment types (objective 3) and impairment type and chronic condition (objective 4) to ascertain relative associations with physical activity outcomes. We present results using incidence rate ratios (IRR) and 95% confidence intervals (CI), where an IRR less than one indicates a lower level of activity in the exposed group relative to the reference group. Variance inflation factors (VIF) were assessed to check for collinearity; all VIF's were below 3.5, with the majority <2. A *P* value less than .05 was considered statistically significant. All analyses were conducted using Stata 17.(134)

4.3.4. Ethics

Ethical approval for the HSE between 2016 and 2019 was granted from East Midlands Nottingham 2 Research Ethics Committee in 2015 (Reference no. 15/EM/0254). Additional elements to the 2018 survey were approved in October 2017.(135) Verbal consent was acquired from participants, and participants were informed that consent would be assumed if they took part in the survey. This study uses anonymised, publicly available data obtained from the UK Data Service (https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=8649).

4.4. Results

From a total sample of 6684, 2243 adults reported having at least one of the seven chronic conditions of interest. Demographic characteristics and experience of impairment for the whole sample and stratified by chronic condition are presented in Table 4.1. Of those with a chronic condition, 55% (n=1243) were female, 69% (n=1538) were aged 55 years or above, and 21% (n=474) were 75 years or above. Across the seven conditions, stroke and/or IHD was reported least frequently (n=211, 9%), with arthritis/rheumatism/fibrositis reported most frequently (n=839, 37%). Compared to those without a chronic condition (n=4441), those with a chronic condition were older (21% versus 6% aged 75+, p = < 0.01) and reported lower levels of education (21% versus 32% with a degree or equivalent, p = < 0.01) but did not differ by sex.

Table 4.1: Demographic characteristics and impairment type, stratified by chronic condition. Data from the Health Survey for England 2018.

	No chronic condition	**Any chronic condition**	Diabetes	Stroke and/or IHD	Hyperten-sion	COPD	Asthma	Arthritis/ rheumatism/ fibrositis	Back problems
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
	4441	2243	424 (18.9)	211 (9.4)	531 (23.7)	170 (7.6)	438 (19.5)	839 (37.4)	422 (18.8)
Age									
16-34	1413 (31.8)	140 (6.2)	8 (1.9)	4 (1.9)	3 (0.6)	0 (0.0)	84 (19.2)	9 (1.1)	36 (8.5)
35-54	1628 (36.7)	565 (25.2)	90 (21.2)	17 (8.1)	112 (21.1)	23 (13.5)	148 (33.8)	161 (19.2)	152 (36.0)
55-74	1144 (25.8)	1064 (47.4)	225 (53.1)	116 (55.0)	281 (52.9)	107 (62.9)	160 (36.5)	449 (53.5)	178 (42.2)
75+	256 (5.8)	474 (21.1)	101 (23.8)	74 (35.1)	135 (25.4)	40 (23.5)	46 (10.5)	220 (26.2)	56 (13.3)
Sex									
Female	2393 (53.9)	1243 (55.4)	199 (53.1)	85 (40.3)	258 (48.6)	89 (52.4)	257 (58.7)	555 (66.2)	246 (58.3)
Male	2048 (46.1)	1000 (44.6)	225 (46.9)	126 (59.7)	273 (51.4)	81 (47.7)	181 (41.3)	284 (22.9)	176 (41.7)
Ethnicity									
White	3730 (84.0)	2029 (90.5)	345 (81.4)	193 (91.5)	464 (87.4)	165 (97.1)	394 (90.0)	789 (94.0)	381 (90.3)
Black	151 (3.4)	66 (2.9)	31 (7.3)	5 (2.4)	18 (3.4)	1 (0.6)	8 (1.8)	16 (1.9)	11 (2.6)
Asian	421 (9.5)	102 (4.6)	38 (7.3)	9 (4.3)	33 (6.2)	4 (2.4)	21 (4.8)	25 (3.0)	20 (4.7)
Mixed/multiple ethnic	82 (1.9)	20 (0.9)	2 (0.5)	2 (1.0)	4 (0.8)	-	8 (1.8)	4 (0.5)	4 (1.0)
Any other ethnic group	43 (1.0)	20 (0.9)	7 (1.7)	1 (0.5)	10 (1.9)	-	5 (1.1)	3 (0.4)	5 (1.2)
Education									

Degree or equivalent	1428 (32.4)	457 (20.5)	73 (17.3)	32 (15.3)	123 (23.2)	12 (7.1)	117 (26.8)	141 (16.9)	80 (19.0)
Below degree	2304 (52.2)	1072 (48.0)	198 (46.9)	89 (42.6)	250 (47.1)	69 (40.6)	224 (51.4)	377 (45.2)	218 (51.8)
None	682 (15.5)	705 (31.6)	151 (35.8)	88 (42.1)	158 (29.8)	89 (52.4)	95 (21.8)	316 (37.9)	123 (29.2)
Impairments									
Vision		257 (11.5)	77 (18.2)	43 (20.4)	67 (12.6)	23 (13.5)	38 (8.7)	108 (12.9)	41 (9.7)
Hearing		306 (13.6)	73 (17.2)	48 (22.8)	81 (15.2)	25 (14.7)	50 (11.4)	144 (17.2)	54 (12.8)
Mobility		1074 (47.9)	190 (44.8)	122 (57.8)	178 (33.5)	117 (68.8)	137 (31.3)	575 (68.5)	277 (65.6)
Dexterity		649 (28.9)	101 (23.8)	68 (32.2)	86 (16.2)	69 (40.6)	86 (19.6)	369 (44.0)	202 (47.9)
Learning		187 (8.3)	36 (8.5)	41 (19.4)	35 (6.6)	21 (12.4)	28 (6.4)	80 (9.5)	49 (11.6)
Memory		294 (13.1)	63 (14.9)	64 (30.3)	62 (11.7)	36 (21.2)	55 (12.6)	119 (14.2)	73 (17.3)
Mental health		301 (13.4)	45 (10.6)	30 (14.2)	52 (9.8)	35 (20.6)	61 (13.9)	122 (14.5)	92 (21.8)
Stamina		892 (39.8)	147 (34.7)	124 (58.8)	153 (28.8)	154 (90.6)	280 (63.9)	323 (38.5)	159 (37.7)
Social or behavioural		64 (2.9)	12 (2.8)	3 (1.4)	13 (2.5)	3 (1.7)	19 (4.3)	16 (1.9)	27 (6.4)
Other		38 (1.7)	8 (1.9)	3 (1.4)	9 (1.7)	2 (1.2)	9 (2.1)	16 (1.9)	4 (1.0)
None		620 (27.6)	149 (35.1)	35 (16.6)	233 (43.9)	10 (5.9)	103 (23.5)	141 (16.8)	74 (17.5)

Note: Ethnicity and education sample sizes are less than the total sample due to missing data (n=20 and 36 respectively). Sum of condition specific subsamples exceeds overall chronic condition subsample (N=2243) due to some participants reporting multiple conditions. Sum of impairment subsamples exceeds overall or condition specific subsample due to some participants reporting multiple impairments.

4.4.1. Objective 1: Describe the number and types of impairments reported by people with chronic conditions

As presented in Table 4.1, mobility impairment (n=1074, 48%) and stamina impairment (n=892, 40%) were reported most frequently across the seven chronic conditions. Social or behavioural impairment was the least commonly reported impairment type. Twenty-eight percent (n=620) of participants with a chronic health condition reported having none of the impairments listed. Figure 4.1 displays the number of impairments reported by participants with each chronic condition. Participants with hypertension were most likely to report having no impairment (n=238, 45%), while participants with COPD (n=33, 19%) or stroke and/or IHD (n=42, 20%) were most likely to report having five or more impairments.

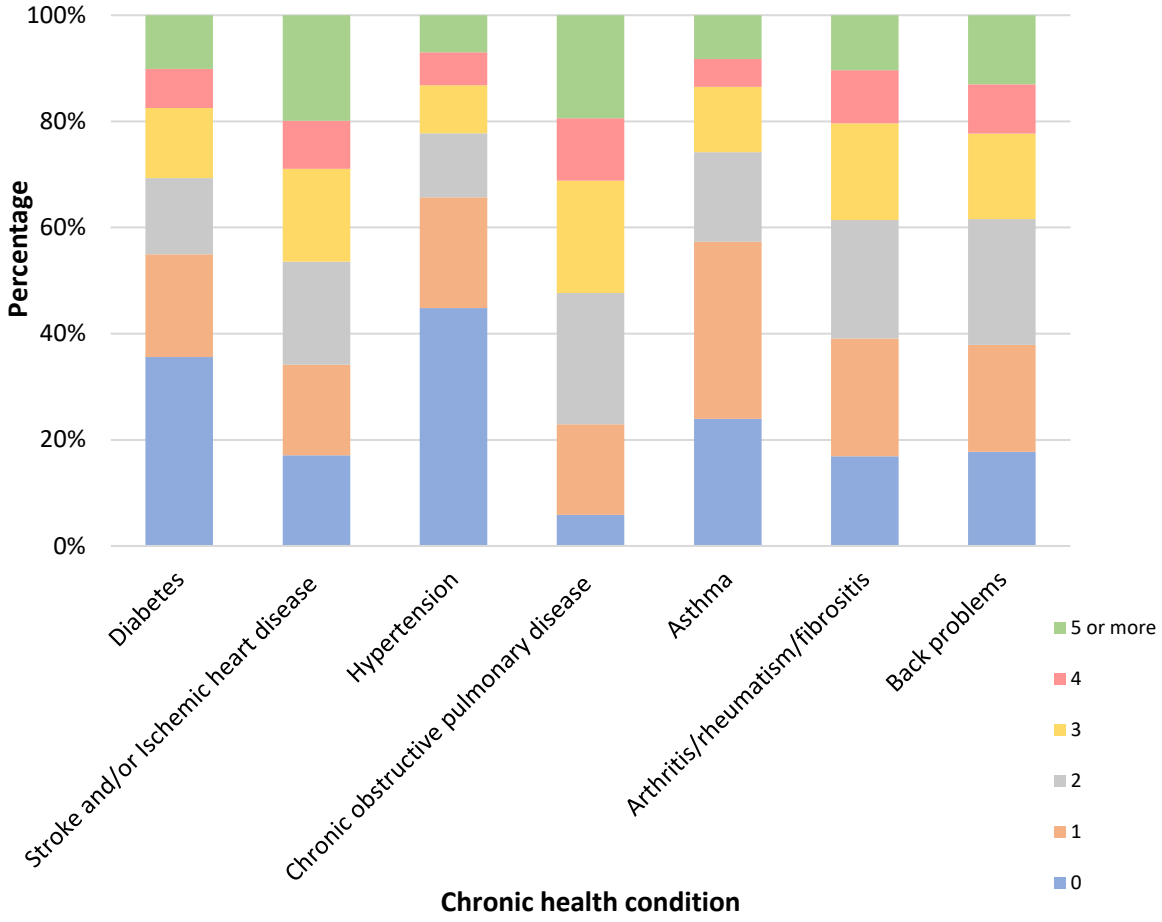

Figure 4.1: Cumulative percentage of the number of impairments, stratified by chronic health condition. Data from the Health Survey for England 2018.

4.4.2. Objective 2: Describe the levels of physical activity participation in people with different chronic conditions

Total MET minutes of physical activity per week and walking minutes per week are presented in Table 4.2, stratified by chronic condition. Median MET-minutes of physical activity per week ranged from 454 to 2093, whilst median walking-minutes ranged from 105 to 280. Participants with asthma reported the highest MET-minutes of physical activity and walking-minutes per week, whilst those with COPD reported the fewest.

Table 4.2: Median and interquartile range (IQR) for MET-minutes of physical activity and walking minutes per week, stratified by chronic condition, and those with no chronic condition. Data from the Health Survey for England 2018.

	MET-minutes of physical activity per week			**Walking-minutes per week**		
	N	Median	IQR	N	Median	IQR
No chronic condition	3654	2892	1386 - 4986	3657	240	60 – 540
Diabetes	323	1386	347 - 2970	325	210	60 - 420
Stroke and/or IHD	155	990	99 - 3226	156	140	0 - 508
Hypertension	420	1766	594 - 3683	424	210	80 - 600
COPD	140	454	0 - 2079	141	105	0 - 315
Asthma	364	2093	693 - 4479	365	280	105 - 630
Arthritis/rheumatism/fibrositis	679	1043	139 - 3360	679	160	20 - 490
Back problems	354	1425	297 - 3793	355	210	40 - 540

Some participants provided incomplete physical activity responses (ranging from 29-787 participants, 16-27% across the eight samples); consequently, sample sizes vary across physical activity outcomes.

4.4.3. Objective 3: Association of type and number of impairments with physical activity levels

The association of impairment type with MET-minutes of physical activity and walking-minutes, stratified by chronic condition, is presented in Figure 4.2 and Figure 4.3. In participants with diabetes, hypertension, or arthritis/rheumatism/fibrositis, having a mobility impairment was associated with lower levels of physical activity across both outcomes compared to individuals with the same chronic health condition but no mobility impairment. In participants who reported having stroke and/or IHD or arthritis, having a dexterity impairment was associated with lower levels of physical activity (both outcomes). The largest relative difference in physical activity across both outcomes was found among individuals with COPD and a memory impairment (MET-minutes: IRR = 0.29, 95% CI = 0.13 – 0.69, p = < 0.01; Walking-minutes: IRR = 0.32, 95% CI = 0.16 – 0.63, p = < 0.01).

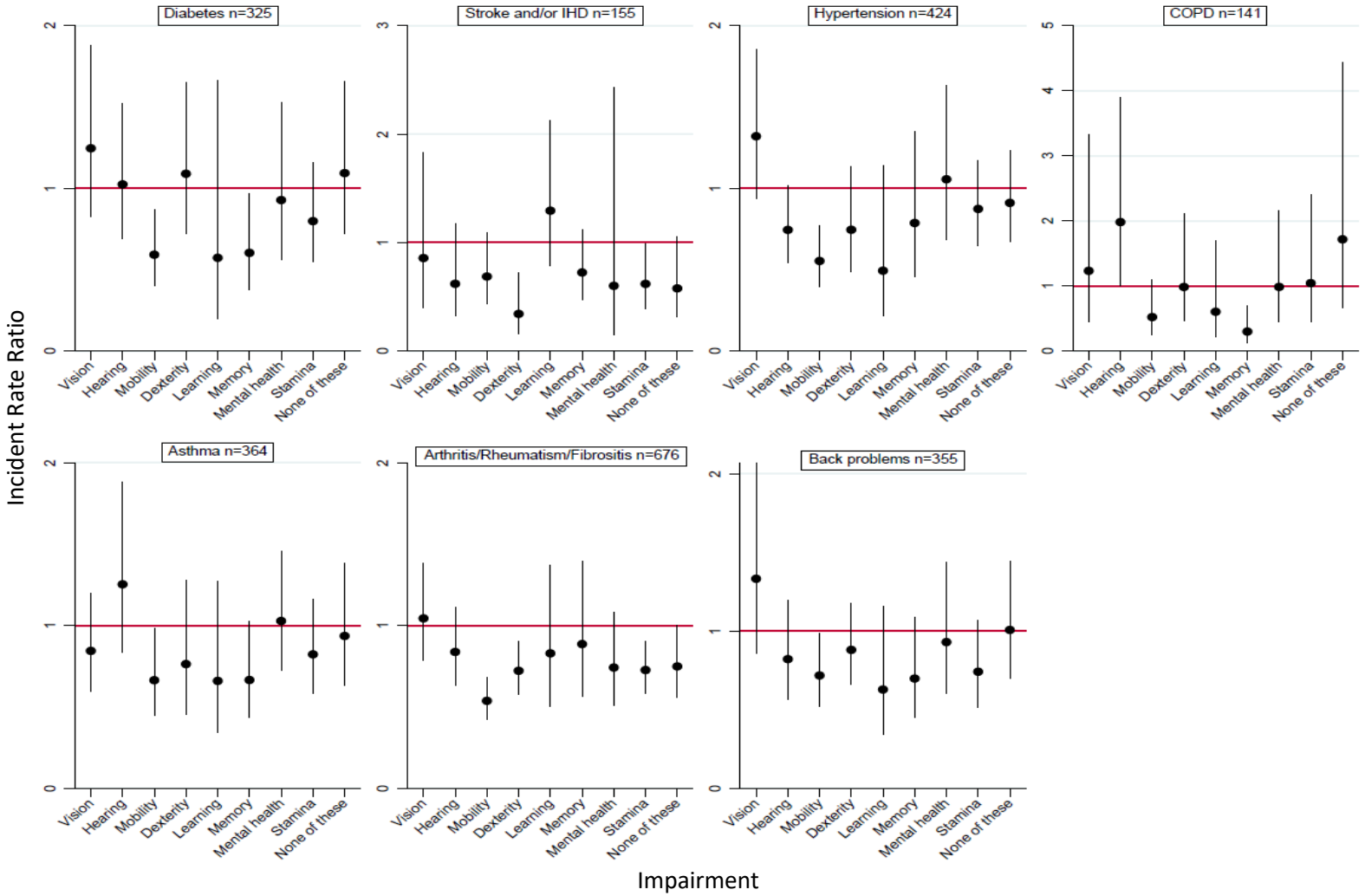

Figure 4.2: Incidence rate ratio and 95% confidence intervals for MET-minutes of physical activity per week, across impairment types and stratified by chronic condition. Data from the Health Survey for England 2018.

Interpretation: Incident rate ratio less than one indicates lower MET-minutes of physical activity compared to participants with the same chronic health condition but not the impairment titled.

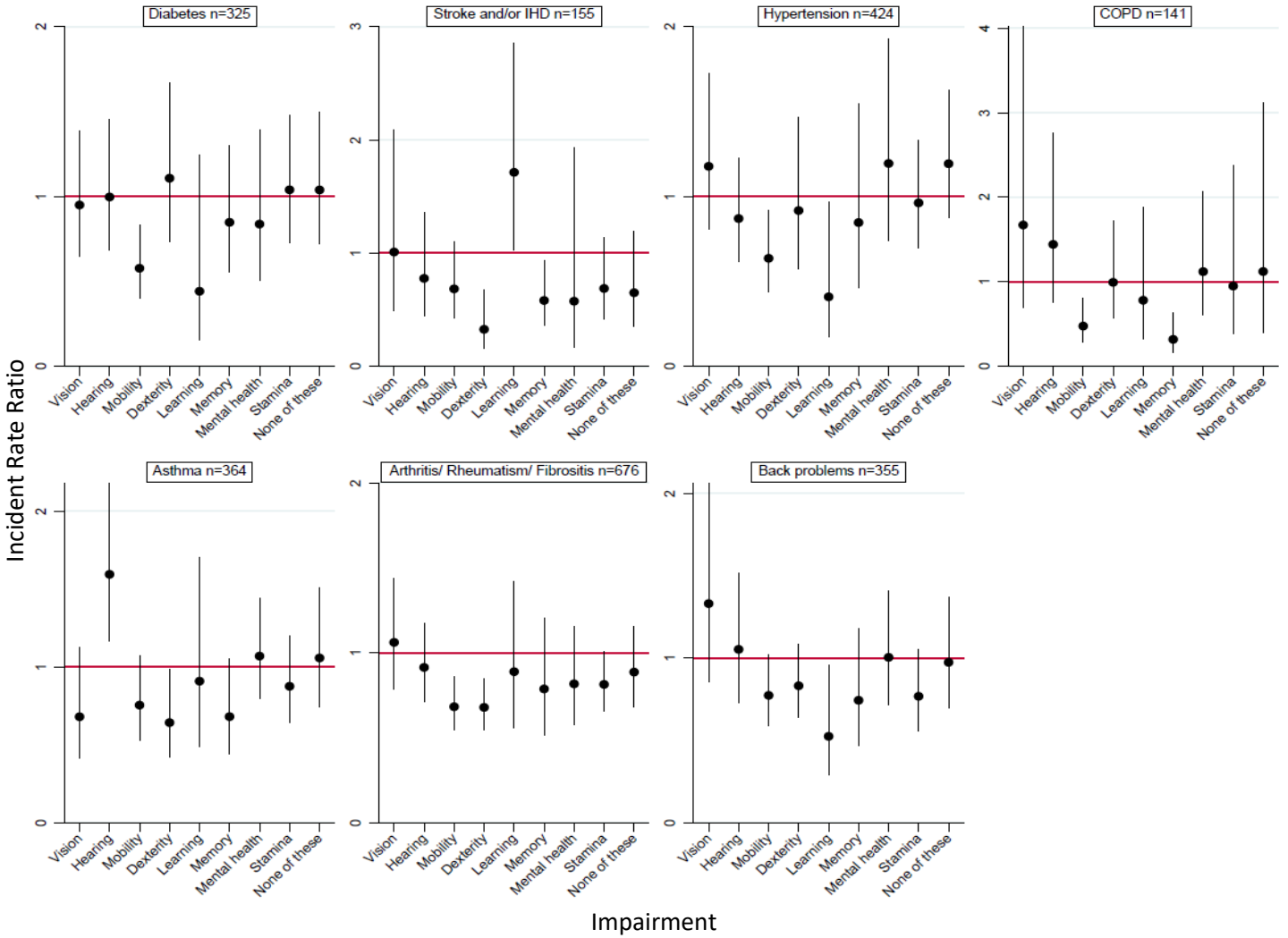

Figure 4.3: Incidence rate ratio and 95% confidence intervals for walking minutes per week, across impairment types and stratified by chronic condition. Data from the Health Survey for England 2018.

Interpretation: Incident rate ratio less than one indicates lower walking-minutes compared to participants with the same chronic health condition but not the impairment titled.

The association of number of impairments with MET-minutes and walking-minutes, stratified by chronic condition, is presented in Figure 4.4 and Figure 4.5. For both outcomes, there was a negative association between number of impairments and levels of physical activity (*p* for trend <0.01 in all cases); this pattern was observed for all condition subgroups. For example, participants with diabetes reported lower MET-minutes of physical activity per week as the number of impairments increased, from -27% for those with one impairment (IRR = 0.73, 95% CI = 0.51 - 1.05, $p = 0.09$) to -90% for individuals with five or more impairments (IRR = 0.10, 95% CI = 0.05 - 0.20, $p < 0.01$) compared to people with no impairment.

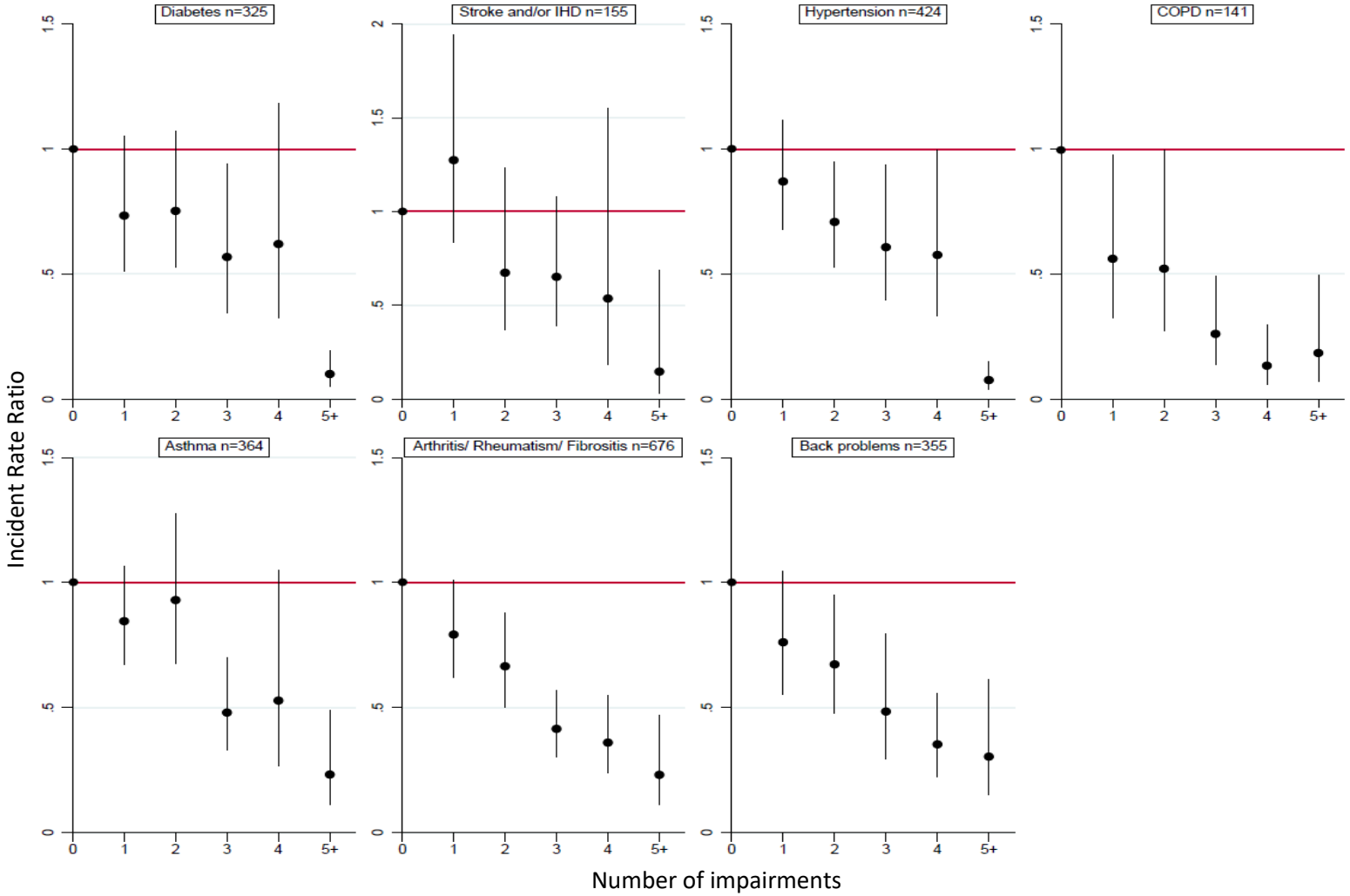

Figure 4.4: Incidence rate ratio and 95% confidence intervals for MET-minutes of physical activity per week, by number of impairments and stratified by chronic condition. Data from the Health Survey for England 2018.

Interpretation: Incident rate ratio less than one indicates lower MET-minutes of physical activity compared to participants with the same chronic health condition but no impairment.

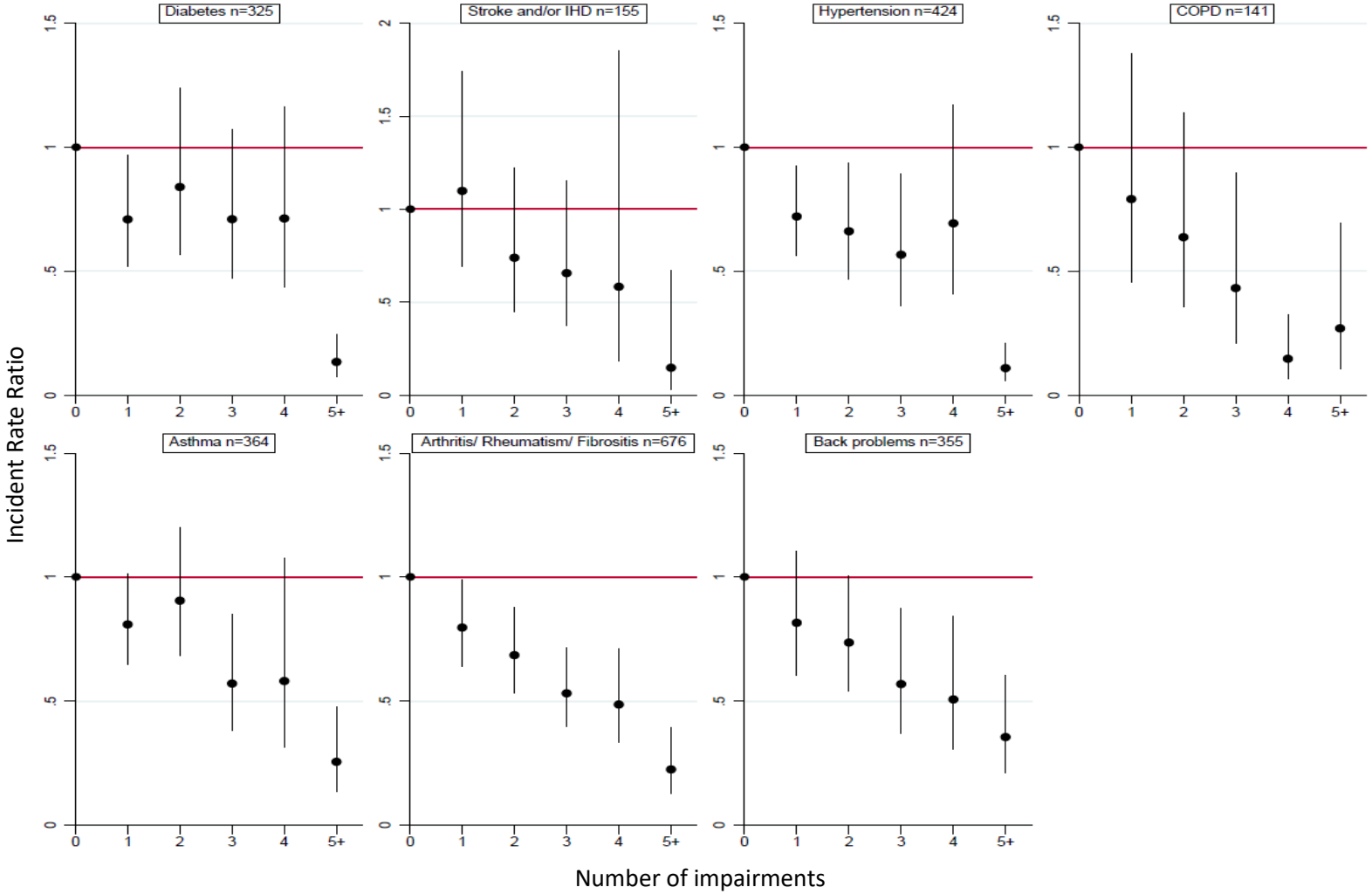

Figure 4.5: Incidence rate ratio and 95% confidence intervals for walking minutes per week, by number of impairments and stratified by chronic condition. Data from the Health Survey for England 2018.

Interpretation: Incident rate ratio less than one indicates lower walking-minutes compared to participants with the same chronic health condition but no impairment.

4.4.4. Objective 4: Relative importance of chronic conditions and impairments as correlates of physical activity

Table 4.3 presents IRRs and 95% CIs indicating the mutually adjusted association of chronic condition and impairment type with physical activity. When adjusting for all other chronic conditions and impairments, having diabetes, COPD, a mobility impairment, a dexterity impairment, or a memory impairment was associated with lower levels of physical activity across both physical activity outcomes, compared to those without these conditions or impairments. For MET-minutes of physical activity, individuals with a hearing impairment (IRR = 0.87, 95% CI = 0.76 – 0.99, *p = 0.04*) or a stamina impairment (IRR = 0.87, 95% CI = 0.77 – 0.97, *p = 0.02*) had lower levels of activity per week compared to individuals with no hearing or stamina impairment respectively.

Table 4.3: Incidence rate ratio (IRR) and 95% confidence intervals (CI) indicating the mutually adjusted association of chronic condition and impairment type with MET-minutes of physical activity and walking-minutes per week. Data from the Health Survey for England 2018.

	MET-minutes of physical activity per week			**Walking-minutes per week**		
	IRR	95% CI	P	IRR	95% CI	P
Diabetes	0.83	0.73 - 0.94	<0.01	0.84	0.75 - 0.96	<0.01
Stroke and/or IHD	0.93	0.77 - 1.13	0.48	1.00	0.83 - 1.21	1.00
Hypertension	0.92	0.83 - 1.02	0.12	1.01	0.91 - 1.12	0.84
COPD	0.76	0.59 - 0.99	0.04	0.80	0.63 - 1.00	0.05
Asthma	1.09	0.97 - 1.23	0.13	1.07	0.96 - 1.19	0.23
Arthritis/rheumatism/fibrositis	1.04	0.93 - 1.17	0.48	1.05	0.95 - 1.16	0.34
Back problems	1.10	0.97 - 1.26	0.15	1.09	0.97 - 1.23	0.16
Vision	1.15	0.99 - 1.33	0.07	1.02	0.88 - 1.18	0.80
Hearing	0.87	0.76 - 0.99	0.04	0.93	0.82 - 1.06	0.29
Mobility	0.63	0.56 - 0.72	<0.01	0.70	0.62 - 0.78	<0.01
Dexterity	0.86	0.75 - 0.98	0.02	0.83	0.73 - 0.95	<0.01
Learning	0.85	0.70 - 1.02	0.08	0.85	0.72 - 1.01	0.07
Memory	0.84	0.72 - 0.99	0.04	0.81	0.70 - 0.94	<0.01
Mental health	0.88	0.77 - 1.00	0.05	0.91	0.81 - 1.02	0.10
Stamina	0.87	0.78 - 0.97	0.02	0.91	0.82 - 1.02	0.09

4.5. Discussion

The aims of this study were to describe the differing types of impairment reported by people with chronic conditions and to explore the association of chronic conditions and impairments with levels of physical activity. The types and number of impairments reported by participants varied substantially within and between different chronic condition groups, as did reported levels of physical activity. We observed an inverse association between the number of reported impairments and levels of physical activity, but the association of specific types of impairment with activity levels varied between condition groups.

Our study highlights the wide range of impairments that can be experienced by individuals with the same chronic condition, indicating that people with the same chronic condition can be impacted in different ways; this is likely due to variation in the severity of the condition and/or how well it is managed. Across the seven chronic health conditions studied, mobility was the impairment type most frequently associated with lower levels of physical activity. This supports previous research that also found individuals with a mobility impairment to have lower levels of physical activity compared to those with a hearing, vision, cognitive, or no impairment.(136) There is evidence that energy expenditure requirements for a given activity may differ for people with a mobility impairment compared to non-disabled people, making physical activity more demanding for people with a mobility impairment compared to other impairment types.(137) Consequently, it is important to understand which population groups are at greatest risk of experiencing mobility impairments, due to the implications this may have on their levels of physical activity.

Alongside impairment types, there were also differences in the number of impairments experienced by people with the same chronic condition. Across all studied conditions, we observed an approximately linear negative association between the number of reported impairments and MET-minutes of physical activity and walking-minutes per week. This is consistent with findings from previous research,(138) including Sport England's Active Lives Survey (November 2020-21), which found that just 38% of participants with three or more impairments were achieving 150 minutes of physical activity per week, compared to 54% with one impairment.(127) These findings suggest that categorisation in physical activity

research based on chronic condition only, may be inappropriate, as the number of impairments a person experiences has a significant influence on their physical activity level.

After mutually adjusting for all other chronic health conditions and impairments, the only two chronic conditions found to be associated with lower physical activity levels were diabetes and COPD. Conversely, several impairments were associated with lower MET-minutes of physical activity and walking-minutes, with the strongest associations being for mobility, dexterity, and memory impairments. This is consistent with previous research showing that mobility and dexterity are the impairment types more likely to affect a person's physical ability,(66,139) such as through restrictions on a person's physical movements and actions.(140) While physical activity has been shown to reduce the risk of cognitive decline,(141) for individuals with a memory impairment, such as dementia patients, research has shown them to be less physically active compared to people without a cognitive/memory impairment.(142) This emphasises the importance of promoting physical activity among people with a memory impairment, as well as those with a mobility and dexterity impairment to help with the prevention and management of chronic health conditions and other forms of impairment.

The current study shows that similar types of impairment can be experienced by people with different chronic health conditions, and that impairment appears to be a more consistent correlate of activity level than health condition per se. Future physical activity research and surveillance should aim to capture both health conditions and impairments (including number and type) to facilitate an improved understanding of the functional barriers that individuals experience to participation, as well as the inter-relations between physical activity engagement and health outcomes.

A key strength of this study is the examination of both chronic conditions and impairments as influences on physical activity participation. This is an advancement on previous research which has typically focused solely on chronic conditions. This study therefore makes an important contribution towards improving knowledge and understanding of the diversity in the number and types of impairments experienced by people with the same chronic condition, emphasising the importance of assessing both chronic health conditions and impairments in future physical activity research.

There are also limitations that need to be acknowledged. A lack of data on impairment severity meant we were unable to account for this in our analyses; we advocate for future research to take this into consideration. The IPAQ-SF is one of the most widely used self-report physical activity questionnaires among general populations(132), though there is some evidence that it may be less suitable in some sub-groups, such as those with intellectual disabilities(143) or progressive muscular diseases.(144) These conditions were not identified within the HSE categorisation, thus we cannot rule-out their presence amongst some participants in the current analysis. In addition, some chronic health conditions were grouped at the data processing stage by the central HSE team (for example, arthritis/rheumatism/fibrositis); this may have masked condition specific variations in impairment type/number and associations with activity. We opted to use time spent walking as an outcome measure in our analyses as it is one of the most accessible forms of physical activity; however, we acknowledge that this would not be an appropriate for people with certain health conditions and impairments, including wheelchair users. Our analyses entailed the conduct of multiple hypothesis tests; we acknowledge the potential for increased type 1 error for null associations but opted not to adjust for multiple comparisons as advised by Rothman(145). Additionally, the data were cross-sectional, and caution needs to be taken in interpretation of the results due to some small sample sizes and differences in sample sizes across chronic condition groups.

4.6. Conclusion

When considered simultaneously, impairment type was more strongly and frequently associated with physical activity than chronic condition. We call for future physical activity research to account for the number and types of impairments that individuals experience, in addition to assessing chronic health conditions. This will facilitate an improved understanding of the functional barriers that individuals experience to participation, as well as the inter-relations between physical activity engagement and health outcomes.

Chapter 5. Physical activity type and duration in disabled and non-disabled adults

5.1. Chapter summary

Study 1 (Chapter 3) explored methods for measuring disability and impairment and Study 2 (Chapter 4) identified the conditions and impairments that have the most negative effect on a person's activity levels. However, there are other factors than can affect a person's physical activity levels, such as lack of accessible facilities, transportation, and financial costs.(99) This can have implications on the types of physical activities that are available and accessible to disabled people compared to the non-disabled population. Subsequently, Study 3 examines the duration and types of physical activity that disabled people participate in compared to non-disabled people.

The manuscript is presented here, the full reference for which is:

Carr, S., Atkin, A. J., & Milton, K. (2025) Physical activity type and duration in disabled and non-disabled adults. *Disability and Health*, https://doi.org/10.1016/j.dhjo.2025.101786

5.2. Introduction

There is clear evidence that being physically active reduces the risk of noncommunicable diseases (NCDs), including heart disease, stroke, diabetes, and certain types of cancer.(65) However, more than a quarter of the world's adult population are insufficiently active.(12) Consequently, an estimated 500 million people are expected to develop NCDs attributable to physical inactivity between 2020 and 2030, at an estimated annual cost of US$27 billion to health care systems.(14)

Maintaining a physically active lifestyle is particularly important for people with chronic conditions and disabilities. In addition to improving symptoms and management of chronic conditions,(124,146) psychological benefits include enhanced self-esteem and self-perceptions, as well as improvements in mood and energy.(147–149) However, disabled people are more likely to be physically inactive than non-disabled people,(127) and report barriers to physical activity over and above those faced by the non-disabled population. For example, Rimmer et al.(103) identified barriers related to the built and natural environment as well as equipment-related barriers, such as insufficient space between gym machines for wheelchair access. Disabled people also report a lack of opportunity to be

physically active and feel less likely than non-disabled people that they can be as active as they would like.(150)

Physical activity promotion is an important component of public health policy.(151) To inform physical activity-related policy for disabled people, it is valuable to understand the types of physical activity that they do and do not participate in, for how long and in what context. This will help with the identification of gaps in provision and inform specific areas for development. The limited available evidence indicates that walking is one of the most common activities in disabled adults.(152,153) Gymnastics and swimming have also been reported to be among the most common activities undertaken by young adults with developmental disabilities, due to their assistance with rehabilitation and physical therapy.(154) Of those less commonly undertaken, Hollis et al.(153) found that using an exercise bike, weightlifting, and swimming were carried out by just over 2% of adults with a mobility disability. However, their research focused on individuals with a serious difficulty walking or climbing stairs, thus the findings may not be generalisable to individuals with a mild or moderate mobility disability, or other types of disability.

Further evidence on the activity choices of disabled people would enable better understanding of where the greatest inequities in access exist and could help to inform future investment of resources and actions to support participation among this population. Therefore, the aims of this study were to describe the types of physical activities that disabled adults participate in and to compare activity frequency and duration to those without a disability.

To note, we use the term ‘disabled people’ throughout the paper, as this is typically preferred among the UK disability community (where the authors are based),(155) however we acknowledge that other terminologies (such as ‘people with disabilities’) are preferred by some individuals, groups and organisations.

5.3. Methods

5.3.1. Data source

This study involved secondary analysis of the 2018/19 Sport England Active Lives cross-sectional survey.(156) Households were randomly selected to participate using the Address File, a UK address database upheld by Royal Mail.(157) In total, 702,781 addresses were sent an invitation letter between 16th November 2018 and 15th November 2019. Initial invitations included details of how to complete an online version of the Active Lives survey.

For non-responding addresses, a follow-up letter was sent 1-2 weeks later, with a further reminder another 1-2 weeks later with a paper survey also included. A final reminder was sent after a further two weeks. Up to two participants aged 16 years or older from each household could complete the survey. Participants were subsequently identified as completing either the online or paper version of the survey. There were two versions of the online survey, with slight variation in content. The item pertaining to club membership was only asked in one version of the online survey and was not asked in the paper survey, thus analyses on this topic are limited to those who completed the relevant online survey.

5.3.2. Measures

Disability

Participants were asked "Do you have any physical or mental health conditions or illnesses that have lasted or are expected to last 12 months or more?" Response options were 'yes', 'no' and 'prefer not to say'. If participants responded 'yes', they were asked "Do these physical or mental health conditions or illnesses have a substantial effect on your ability to do normal daily activities?", with response options 'yes', 'no' and 'prefer not to say'. If participants responded 'yes' to this second question, they were coded as having a disability that had a substantial effect on daily activities. If participants responded 'no', they were coded as having a disability with a non-substantial effect on daily activities. Participants were categorised into one of three mutually exclusive groups: (1) disability – substantial effect on daily activities; (2) disability – non-substantial effect on daily activities; (3) no disability.

Activity assessment

All participants reported whether they had taken part in 173 types of physical activity over two timeframes: (1) previous 12 months; and (2) previous four weeks. For ease of reporting, activities were grouped into 17 mutually exclusive categories: athletic; artistic; combat; cycle; equestrianism; field and strike; fitness; gym equipment/machine; invasion; leisure; motorsports; net/wall; outdoor/adventure; swimming; target; water sports; and other. The composition of each activity group is described in Appendix 6.

For activities undertaken in the past 12 months, all participants reported whether they carried out the activity indoors or outdoors. Additional classification was undertaken by the authors to group activities as individual, team-based, or both. A sub-sample of participants

(as described above) additionally reported whether they were a member of a club or organisation for each activity reported in the previous year.

For activities undertaken in the last four weeks, participants were additionally asked to indicate frequency (number of days in the past four weeks) and duration of each episode (free-text hours/minutes).

5.3.3. Data analysis

We were interested in the adult population only, therefore participants aged 16-18 years were removed prior to analysis. Participant characteristics, activity duration, activity type (including classification by individual, team and both), activity setting (indoor or outdoor), and club membership (yes/no) are presented as frequencies and percentages, stratified by disability status. Activity duration is reported as median and interquartile range (IQR) as the data were not normally distributed. Chi-squared tests were used to compare demographic characteristics between analytical subsamples (disability – substantial effect on daily activities, disability – non-substantial effect on daily activities, and no disability), and between those included and excluded from the analysis. A chi-squared test was also used to compare the proportion of participants reporting participation in each activity type (including classification as individual, team or both), activity setting, and club membership between analytical subsamples. Multivariable linear regression was used to compare weekly activity duration between the analytical subsamples. Regression diagnostics were reviewed and assumptions for the use of linear regression were met. Models were adjusted for age (19-34, 35-54, 55-74, 75+ years), sex (male, female, other), ethnicity (White British, White other, South Asian, Black, Chinese, Mixed, Other ethnic group), and education (Level 4 or above - for example, higher education/degree level; I Level 3 and equivalents - for example, A level, NVQ level 3; Level 2 and equivalents - for example, GCSE grade A*-C or 4-9, NVQ level 2; and Level 1 and below - for example, GCSE below level C or 4). All analyses were conducted using Stata 17.(134)

5.4. Results

As shown in Figure 5.1, from 702,781 invited households 176,260 people aged 19 or over completed an online or paper-based survey. Due to missingness of covariate and disability data, 17,265 participants were removed, resulting in an analytical sample of 158,995 participants. Of our analytical sample, 55% were female (n=88073) and 48% were aged 55

years or older (n=76808). In total, 29057(18%) participants had a disability that had a substantial effect on daily activities, 33004 (21%) had a disability with a non-substantial effect on daily activities, and 96934 (61%) had no disability. Demographic information for the analytical sample is displayed in Table 5.1. Among the three groups, participants with a disability that had a substantial or non-substantial effect on daily activities were generally older ($p<0.01$) and more likely to be white-British ($p<0.01$). Participants with a disability that had a substantial effect on daily activities were more likely to be female ($p<0.01$) and less likely have a qualification at level 4 or above ($p<0.01$).

Based on available data, participants excluded from the analyses were more likely to be 35-54yrs ($p<0.01$), female ($p<0.01$), non-white British ($p<0.01$), and have a qualification lower than level 4 ($p<0.01$), compared to those included within the analytical sample.

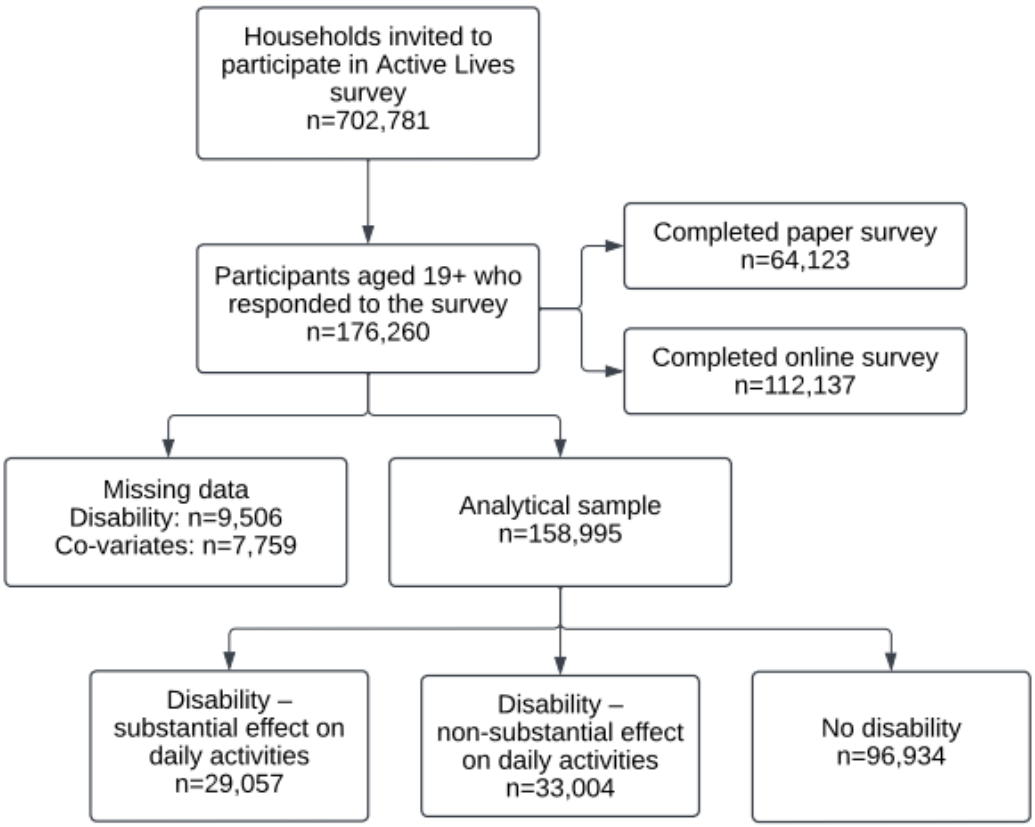

Figure 5.1: Flow chart for selection of the analytical sample

Table 5.1: Participant characteristics

	Analytical sample N= 158,995 n (%)		**Disability – substantial effect on daily activities N= 29,057 n (%)**		**Disability – non-substantial effect on daily activities N= 33,004 n (%)**		**No disability N= 96,934 n (%)**		***P for difference****
Age									p<0.01
19-34	28,137	(17.7)	3,563	(12.3)	3,616	(11.0)	20,958	(21.6)	
35-54	54,050	(34.0)	7,513	(25.9)	8,991	(27.2)	37,546	(38.7)	
55-74	61,884	(38.9)	12,629	(43.5)	16,177	(49.0)	33,078	(34.1)	
75+	14,924	(9.4)	5,352	(18.4)	4,220	(12.8)	5,352	(5.5)	
Sex									p<0.01
Male	70,711	(44.5)	11,731	(40.4)	15,469	(46.9)	43,511	(44.9)	
Female	88,073	(55.4)	17,239	(59.3)	17,504	(53.0)	53,330	(55.0)	
Other	211	(0.1)	87	(0.3)	31	(0.1)	93	(0.1)	
Ethnicity									p<0.01
White British	137,910	(86.7)	26,305	(90.5)	30,183	(91.5)	81,422	(84.0)	
White other	8,841	(5.6)	1,118	(3.8)	1,304	(4.0)	6,419	(6.6)	
South Asian	6,285	(4.0)	747	(2.6)	668	(2.0)	4,870	(5.0)	
Black	2,086	(1.3)	268	(0.9)	301	(0.9)	1,517	(1.6)	
Chinese	885	(0.6)	68	(0.2)	93	(0.3)	724	(0.7)	
Mixed	1,835	(1.2)	344	(1.2)	269	(0.8)	1,222	(1.3)	
Other ethnic group	1,153	(0.7)	207	(0.7)	186	(0.6)	760	(0.8)	
Education									p<0.01
Level 4 or above	84,322	(53.0)	11,641	(40.1)	18,434	(55.9)	54,247	(56.0)	
Level 3 and equivalents	23,993	(15.1)	4,250	(14.6)	4,432	(13.4)	15,311	(15.8)	
Level 2 and equivalents	26,677	(16.8)	5,514	(19.0)	5,201	(15.8)	15,962	(16.5)	
Level 1 and below	3,468	(2.2)	938	(3.2)	691	(2.1)	1,839	(1.9)	

Another type of qualification	7,965	(5.0)	2,109	(7.3)	1,852	(5.6)	4,004	(4.1)
No qualification	12,570	(7.9)	4,605	(15.8)	2,394	(7.3)	5,571	(5.7)

*Chi-square test for difference in demographic characteristics between limiting disability, non-limiting disability, and no disability sub-groups.

5.4.1. Frequency of activity type

Activity participation over the previous 12 months, stratified by disability status, is presented in Table 5.2. For all studied groups, participants took part in more indoor than outdoor activities, and individual-based activities were more common than team-based. 'Leisure' activities, which included walking and gardening, was the most commonly reported activity type. For all other activities, less than 40% of participants reported participation in the past 12 months. For the whole analytical sample, activity participation ranged from 1% (motorsports) to 98% (leisure). In the majority of cases, between group differences in activity participation were significant at $p<0.05$, with those with a disability that had a substantial effect on daily activities having lower participation than the other two groups.

Table 5.2: Activity types undertaken over the past 12 months, by disability status (n, %)

	Disability – substantial effect on daily activities N= 29,057 n (%)		**Disability – non-substantial effect on daily activities N= 33,004 n (%)**		**No disability N= 96,934 n (%)**	
Athletic	2,087	(7.2)*	5,118	(15.5)*	22,735	(23.5)
Artistic	3,890	(13.4)*	6,445	(19.5)*	19,465	(20.1)
Combat	922	(3.2)*	1,403	(4.3)*	3,753	(3.9)
Cycle	722	(2.5)*	1,638	(5.0)*	7,649	(7.9)
Equestrianism	606	(2.1)*	890	(2.7)	2,579	(2.7)
Field and strike	420	(1.4) *	798	(2.4) *	3,748	(3.9)
Fitness	6,983	(24.0) *	11,952	(36.2) *	36,589	(37.7)
Gym equipment/ machine	5,765	(19.8) *	9,701	(29.4) *	31,169	(32.2)
Invasion	1,173	(4.0) *	2,275	(6.9) *	11,064	(11.4)
Leisure	25,006	(86.1) *	32,288	(97.8) *	94,285	(97.3)
Motorsports	221	(0.8) *	379	(1.1) *	1,782	(1.8)
Net/wall	1,687	(5.8) *	3,786	(11.5) *	14,685	(15.1)
Outdoor/adventure	4,123	(14.2) *	9,616	(29.1) *	32,433	(33.5)
Swimming	3,633	(12.5) *	6,571	(19.9) *	24,027	(24.8)
Target	3,542	(12.2) *	6,679	(20.2) *	21,764	(22.5)
Water sports	1,497	(5.2) *	2,888	(8.8) *	10,112	(10.4)
Other	427	(1.5) *	711	(2.2) *	3,800	(3.9)
Indoor	2226	(7.7) *	4478	(13.6) *	16,080	(16.6)
Outdoor	1193	(4.1) *	2953	(8.9) *	10,910	(11.3)
Individual	25,645	(88.3) *	32,537	(98.6)	95,417	(98.4)
Team	1,357	(4.7) *	2,595	(7.9) *	12,421	(12.8)
Both	4,165	(14.3) *	7,888	(23.9) *	25,961	(26.8)

N may exceed sample size, and cumulative percentages may exceed 100 as participants could report participation in multiple activities.

**p* value <0.05, difference in activity type compared to participants with no disability

5.4.2. The ten most frequent activities undertaken

Table 5.3 presents frequencies for the ten most commonly reported activities undertaken in the previous 12 months. Across all three groups, ‘walking for leisure’ (leisure), ‘walking for travel’ (leisure) and ‘gardening’ (leisure) were the most frequently reported individual activities undertaken. In those with a disability that had a substantial effect on daily activities, participants frequently undertook leisure and gym-based activities, including using an exercise bike (11%; gym equipment/machine) and swimming (11%; swimming). The top ten activities were largely similar across the three sub-samples, with the addition of ‘running or jogging’ (23%; athletic) and ‘free weights’ (17%; gym equipment/machine) for the no disability sample.

Table 5.3: The ten most frequently reported activities undertaken in the previous 12 months.

Disability – substantial effect on daily activities N= 29,057 n (%)			**Disability – non-substantial effect on daily activities N= 33,004 n (%)**			**No disability N= 96,934 n (%)**		
Walking for leisure	19,068	(65.6)	Walking for leisure	28,441	(86.2)	Walking for leisure	82,289	(84.9)
Leisure			*Leisure*			*Leisure*		
Gardening	17,125	(58.9)	Gardening	24,678	(74.8)	Gardening	67,525	(69.7)
Leisure			*Leisure*			*Leisure*		
Walking for travel	13,516	(46.5)	Walking for travel	19,704	(59.7)	Walking for travel	58,806	(60.7)
Leisure			*Leisure*			*Leisure*		
Exercise bike	3,159	(10.9)	Cycling for leisure	5,617	(17.0)	Cycling for leisure	22,688	(23.4)
Gym equipment/machine			*Leisure*			*Leisure*		
Dancing (other)	3,149	(10.8)	Hill or mountain walking or hiking	5,550	(16.8)	Running or jogging	22,629	(23.3)
Artistic			*Outdoor/adventure*			*Athletic*		
Swimming – indoors	3,151	(10.8)	Swimming – indoors	5,465	(16.6)	Hill or mountain walking or hiking	20,409	(21.1)
Swimming			*Swimming*			*Outdoor/adventure*		
Body weight exercises	2,783	(9.6)	Body weight exercises	5,407	(16.4)	Swimming – indoors	20,248	(20.9)
Gym equipment/machine			*Gym equipment/machine*			*Swimming*		
Other exercise machine	2,752	(9.5)	Dancing (other)	5,194	(15.7)	Body weight exercises	19,119	(19.7)
Gym equipment/machine			*Artistic*			*Gym equipment/machine*		
Cycling for leisure	2,714	(9.3)	Exercise bike	5,113	(15.5)	Treadmill	18,100	(18.7)
Leisure			*Gym equipment/machine*			*Gym equipment/machine*		
Treadmill	2,665	(9.2)	Treadmill	5,093	(15.4)	Free weights	16,239	(16.8)
Gym equipment/machine			*Gym equipment/machine*			*Gym equipment/machine*		

5.4.3. Activity duration

Table 5.4 presents weekly duration for each of the 17 activity groupings, based on those who reported undertaking the activity in the last four weeks. Compared to participants with no disability, activity duration was lower for participants with a disability that had a substantial or non-substantial effect on daily activities across fitness and net/wall activities (such as badminton and tennis). For participants with a disability that had a substantial effect on daily activities, the duration of artistic activities and swimming activities was higher compared to participants with no disability. The highest median duration of activity across all three samples was for leisure activity (disability – substantial effect on daily activities: 315 (120-700); disability – non-substantial effect on daily activities: 390 (180-750); no disability: 375 (165-750), mins/week).

Table 5.4: Descriptive statistics (minutes / week) and between-group differences in activity duration for those who reported participation in the previous four weeks

	Disability – substantial effect on daily activities					Disability – non-substantial effect on daily activities					No disability		
	n	**Median**	**(IQR)**	**β**	**(95% CI)**	**n**	**Median**	**(IQR)**	**β**	**(95% CI)**	**n**	**Median**	**(IQR)**
Athletic	1,174	60	(22.5,120)	-2	(-9,5)	3,327	60	(30,120)	**-7**	**(-11,-2)**	15,305	60	(30,120)
Artistic	1,948	60	(30,135)	**14**	**(3,24)**	3,274	60	(30,120)	-3	(-11,6)	9,786	60	(30,120)
Combat	428	60	(30,120)	10	(-16,36)	749	60	(40,120)	-1	(-22,20)	1,907	60	(30,150)
Cycle	350	120	(60,300)	18	(-14,50)	856	120	(60,270)	-20	(-42,1)	4,007	120	(60,270)
Equestrianism	189	180	(60,450)	-95	(-193,4)	335	210	(68,480)	**-104**	**(-183,-25)**	1,024	240	(90,566)
Field and strike	111	90	(30,240)	-26	(-113,62)	207	60	(23,280)	-7	(-74,60)	1,085	90	(30,360)
Fitness	4,477	140	(70,300)	**-36**	**(-47,-24)**	8,872	165	(90,300)	**-25**	**(-34,-16)**	27,904	180	(90,350)
Gym equipment/machine	3,018	60	(28,158)	-5	(-15,4)	5,449	60	(30,150)	-1	(-9,6)	17,716	60	(30,150)
Invasion	504	103	(40,225)	17	(-13,46)	1,108	90	(45,180)	-20	(-41,1)	5,722	113	(45,225)
Leisure	21,679	315	(120,700)	**-35**	**(-44,-25)**	30,178	390	(180,750)	-5	(-14,3)	87,269	375	(165,750)
Motorsports	28	60	(15,135)	6	(-112,123)	46	34	(15,90)	120	(27,213)	213	45	(15,150)
Net/wall	666	120	(60,240)	**-10**	**(-11,-9)**	1,828	130	(60,315)	**-3**	**(-4,-2)**	6,735	120	(60,270)
Outdoor/adventure	1,723	180	(90,405)	-15.4	(-41,11)	4,283	188	(90,450)	**-35**	**(-53,-17)**	14,098	210	(90,450)
Swimming	1,495	60	(30,120)	**7**	**(1,14)**	2,883	45	(23,95)	-4	(-9,2)	10,781	45	(23,90)
Target	1,399	150	(45,480)	**-53**	**(-81,-24)**	3,087	225	(60,600)	-19	(-40,2)	9,431	135	(30,473)
Water sports	280	60	(30,233)	**50**	**(7,92)**	686	60	(30,180)	18	(-12,48)	2,398	60	(30,150)
Other	62	30	(15,45)	-9	(-48,29)	103	30	(15,50)	-7	(-38,23)	630	30	(15,60)

Bold text indicates a significant difference ($p<0.05$), in activity duration compared to participants with no disability.
IQR, inter-quartile range; 95% CI, 95% confidence interval

5.4.4. Club membership

Table 5.5 presents frequencies and percentages of participants who reported to be a member of a club or organisation for each activity type reported in the previous year. This question was only asked of a sub-sample of participants, as described above (n=8221 disability – substantial effect on daily activities; n=9633 disability – non-substantial effect on daily activities; n=34230 no disability). Overall, club or organisation membership was lowest in those with a disability that had a substantial effect on daily activities (n=1890, 23% disability – substantial effect on daily activities; n=3756, 39% disability – non-substantial effect on daily activities; n=13692, 40% no disability). For all groups, the largest membership was for fitness, which included activities such as pilates, dance, and weight-based and water-based exercise classes. For all activity types except motorsports, membership was lowest in those with a disability that had a substantial effect on daily activities. Participants with no disability were significantly more likely to be club members compared to participants with a disability that had a substantial effect on daily activities; the only exceptions were equestrianism, motorsports and swimming.

Table 5.5: Club membership, by disability classification

	Disability – substantial effect on daily activities N= 8,221 n (%)		**Disability – non-substantial effect on daily activities N= 9,633 n (%)**		**No disability N= 34,230 n (%)**	
Athletic	101	(1.2)*	295	(3.1)*	1,372	(4.0)
Artistic	47	(0.6)*	96	(1.0)	342	(1.0)
Combat	76	(0.9)*	155	(1.6)	535	(1.6)
Cycle	102	(1.2)*	204	(2.1)*	965	(2.8)
Equestrianism	23	(0.3)	35	(0.4)	139	(0.4)
Field and strike	36	(0.4)*	62	(0.6)*	411	(1.2)
Fitness**	1,082	(13.2)*	2,140	(22.2)*	8,310	(24.3)
Invasion	130	(1.6)*	298	(3.1)*	1,566	(4.6)
Leisure	268	(3.3)*	564	(5.9)	1,994	(5.8)
Motorsports	17	(0.2)	16	(0.2)	86	(0.3)
Net/wall	153	(1.9)*	386	(4.0)	1,396	(4.1)
Outdoor/adventure	70	(0.9)*	184	(1.9)*	798	(2.3)
Swimming	21	(0.3)	27	(0.3)	108	(0.3)
Target	220	(2.7)*	511	(5.3)*	1,377	(4.0)
Water sports	50	(0.6)*	135	(1.4)*	382	(1.1)
Other	21	(0.3)*	21	(0.2)*	160	(0.5)

*p value <0.05, difference in activity club membership compared to participants with no disability.

***This also includes gym equipment/machine*

5.5. Discussion

The purpose of this study was to describe the types of physical activities that disabled people participate in and to compare activity frequency and duration to people without a disability. We found that activity types were largely similar in disabled and non-disabled people, however participation rates and duration were typically lower among disabled people, particularly for those with a disability that had a substantial effect on daily activities.

Leisure activities, such as walking and gardening, were the most common activity type across all three participant groups, as well as the activity type that individuals spent the greatest amount of time doing. However, engagement and duration were lower for disabled people compared to non-disabled people. Walking and gardening have been consistently found to be among the most common activities undertaken by adults,(158–160) including those with a mobility impairment.(153,161) Walking is a common form of activity for medical professionals to prescribe, as it requires no specialist skills or facilities.(162) In addition, walking, as with gardening and other leisure activities, is adaptable to lifestyles and can be undertaken at a convenient time for each individual. Walking has been shown to have many benefits for disabled people, including the management of certain health conditions and improvements in wellbeing and pain management.(163–165) Gardening is also associated with a range of health benefits, including reduced risk of depression and improved cognitive function.(166) Although these activities are both popular among disabled people and health enhancing, the lower participation rates suggest a need for continued efforts to enhance access and participation levels. For example, activity supportive infrastructure, such as pavements and curb cuts, are often lacking or not maintained, meaning there is an environmental disincentive to walk even amongst those able to do so.(99) Improvements to infrastructure (such as pavement surfaces) and increased provision of community-based initiatives (such as communal gardening projects) would provide greater opportunities and support for disabled people to engage in physical activity.(103)

In this study, the only activity types for which reported duration was highest in those with a disability were swimming and artistic activities, such as dancing and gymnastics. Artistic activities are an accessible activity for people with different impairments and have been shown to have many benefits including improved social inclusion and self-

esteem/(167,168) Swimming also has many benefits for disabled people including reductions in joint pain and functional limitations,(169) and is a common recommendation of physical therapy. In this study, although time spent in artistic activities and swimming was higher among people with a disability that had a substantial effect on daily activities, the proportion of people taking part in artistic activities and swimming was lower than that of non-disabled people (artistic activities: 13% of participants with a disability that had a substantial effect on daily activities compared to 20% of non-disabled participants; swimming: 13% of participants with a disability that had a substantial effect on daily activities compared to 25% of non-disabled participants). This suggests that whilst uptake of these activities is relatively low compared to non-disabled people, they are a valuable source of activity for those who do them. A lack of appropriate facilities, information about suitable classes, and instructor knowledge, can restrict a disabled person's ability to participate in activities such as swimming(170) and artistic activities.(171) Addressing the barriers to these activities, as well as other facility-based activities, would support access and uptake.

Of the sub-sample of participants who reported on club membership, 23% of participants with a disability that had a substantial effect on daily activities and 39% of participants with a disability with a non-substantial effect on daily activities were members, compared to 40% of participants with no disability. Existing research is limited, but these values are higher than those reported in a study in Northern Ireland, where 11% of disabled people were a member of a sports club, compared to 23% of non-disabled people.(172) Variation in question formatting and the proportion of participants who were asked if they were members of a sports club may account for some of the differences observed in percentages across studies, though the overarching trend is the same. Sports clubs provide an opportunity for social integration; however, this is only possible if clubs(173) and national governing bodies(174) provide appropriate provision for disabled people. We encourage sport governing bodies to enhance the availability and quality of training opportunities to support the development of inclusive coaches. We encourage sports clubs to improve the marketing of activities that cater for disabled people, as well as increasing the number of accessible opportunities. Carty et al(86) emphasised the need to advance disability inclusion, not as a niche and distinct area, but through universal design and mainstreaming. Consultation with disabled people will be important in shaping the provision of physical

activity opportunities, including the types of activities and sessions provided, as well as addressing preferences for distinct versus integrated activities.

5.5.1. Research/policy implications

To support participation in physical activity among disabled people, action is needed across multiple levels - from policy to practice, and across a range of sectors, including sport, health, urban design and transport. France is an example where disability inclusion is being addressed through a wide range of strategies. Between 2012 and 2015 France established an additional 400 sports clubs for disabled people and an additional 18,500 disabled people became active sports club members.(175) This has also risen in more recent years, with Pierre et al(176) in 2019 reporting 26% of clubs to have had an increase in uptake of members with disabilities over the previous three years. France has been supporting the promotion of physical activity among disabled people through the National Unit for Resources on Sport and Disabilities within the Ministry for Sports, which funds employment of dedicated disability sport professionals in disability sport federations, and subsidised employment provided through the French Disabled Sports Federation, the Federation for Adapted Sport, and the French Paralympic Sport Committee.(175) It also publishes an online guide which lists sports clubs that provide activities and facilities suitable for disabled people. The approach taken in France provides a useful case study and may serve as a model for other countries to follow.

5.5.2. Strengths and limitations

Strengths of this study include the use of data from a large nationally representative sample, which included a comprehensive assessment of activity participation and participants' disability status - something which is often omitted in epidemiological studies and surveillance.(177) However, this study is based on self-reported measures of physical activity which have not been formally tested for their psychometric properties. In addition, this study did not explore differences in physical activity preferences and levels by health condition or impairment type. Previous work has shown that physical activity levels differ between and within people with the same health condition, influenced by the nature and extent of impairment.(120) Collecting more comprehensive data on health conditions in large scale physical activity surveys would facilitate a detailed analysis of physical activity preferences in people with different conditions; this is an important area for future research. Additionally, the analyses involved conducting multiple hypothesis tests. We

recognize the possibility of an increased risk of type 1 error for null associations; however, we chose not to adjust for multiple comparisons, as advised by Rothman.(145)

5.6. Conclusion

Activity choices were largely similar among disabled and non-disabled participants, but participation rates and activity duration were generally lower in those with a disability. There is a clear need to reduce inequalities in physical activity participation in disabled people by improving access, opportunities, and support. This could be facilitated through qualitative research with disabled people to understand the barriers and facilitators to participation, and co-production of strategies and actions to better support disabled people to be active.

Chapter 6. ‘You have to make it accessible and it's really not’: priority actions to support disabled people to be physically active

6.1. Chapter summary

Study 3 (Chapter 5) identified similarities in the activities disabled people undertake compared to non-disabled people, however activity levels were much lower among the disabled population. It is therefore important to explore this matter by speaking with disabled people to identify the actions needed to help support this target population to be active, which was the aim of Study 4.

The manuscript is presented here, the full reference for which is:

> Carr, S., Atkin, A. J., & Milton, K. (2024). ‘You have to make it accessible and it's really not’: priority actions to support disabled people to be physically active. *Disability and Rehabilitation*, 1-7. https://doi.org/10.1080/09638288.2024.2417032

6.2. Introduction

Physical activity has many benefits for adults, including the prevention and management of chronic diseases and improved mental health, sleep, and cognitive function.(65,146,178) However, 26% of adults in the United Kingdom (UK) were reported to be physically inactive in 2023.(179) Of particular concern is that disabled people are more likely than non-disabled people to be physically inactive, placing them at increased risk of ill-health.(179,180) Disability prevalence is rising, with 24% of the UK population reporting to have a disability in the 2021/22 financial year - an increase of 5% points over a ten-year period.(7) For disabled people, physical activity is an effective rehabilitative method of improving symptoms of health conditions, as well as enhancing quality of life and life satisfaction.(181,182) Disabled people are therefore an important target group for physical activity promotion.

The ecological model depicts the relationships between the individual, social, and environmental factors that combine to influence human behaviour.(183) The framework suggests that health behaviours (including physical activity) are shaped by factors at five levels: intrapersonal, interpersonal, institutional, community, and policy. A systematic review by Martin Ginis et al. (2016) identified a range of factors aligned to the ecological

model that can influence disabled people's participation in physical activity.(99) The most common barriers to physical activity include a lack of disposable income, inadequate professional support, and a lack of specialised/adapted equipment.(103,184) There are also a range of factors that can improve disabled people's adherence to physical activity, including social support, feedback from instructors, aspirational role models, and developing behavioural skills such as goal setting.(185,186)

Whilst the barriers to physical activity faced by disabled people are relatively well understood, insufficient action has been taken to overcome these barriers. In the UK, 76% of a nationally representative sample of disabled people stated that they wanted to be more physically active but felt there was insufficient support to do so.(187) Barriers previously reported by disabled people in the UK included the cost of activities and transport, ineffective communication methods, and a lack of self-esteem.(188) Recent policy developments in the UK, such as the sport and physical activity strategy 'Get Active' released in August 2023,(189) have helped to raise awareness of the importance of improving physical activity provision for disabled people; however the actions are somewhat ambiguous and disabled people were not consulted in its development. A better understanding is therefore needed of the actions that disabled people feel are required to support them to be physically active. Therefore, the aim of this study was to explore with disabled people the key actions that would best support their participation in physical activity.

6.3. Methods

6.3.1. Study sample

Following ethical approval from the University of East Anglia Faculty of Medicine and Health Sciences Research Ethics Subcommittee (ETH2223-2695), participants were purposively sampled via Activity Alliance,(190) (a national charity and leading voice for disabled people in sport and activity in England) and Active Norfolk(191) (the active partnership for the county of Norfolk, UK). Both organisations had connections to disabled people through previous work. An initial invitation to take part was sent via email from Activity Alliance and Active Norfolk. These organisations compiled a list of respondents who expressed interest, and their contact details were subsequently shared with the first author (SC). SC led the communication from that point; sharing the participant information sheet, consent form, and further information about the study with all potential participants.

Participants were eligible for inclusion if they were aged 18 years and over, had a disability or chronic health condition which affected their daily activities, spoke English, and had sufficient communication skills to contribute to a group discussion. We sought to recruit participants with a variety of impairments, including physical, sensory, mental health, and speech and language.

A total of 21 participants were recruited, of which 10 (48%) were male, 13 (62%) were aged 45 years or older, 17 (81%) were of white ethnicity, and 7 (33%) were working either full- or part-time. Participants reported experiencing a variety of impairment types, most commonly mobility (n=13, 62%) and mental health (n=10, 48%).

6.3.2. Data collection/ procedure

Focus groups were used in place of individual interviews to allow participants to feel empowered and share their beliefs and observations among other disabled people.(192) The focus group guide was developed by the authors. No formal pilot testing was undertaken; however, the draft schedule was shared with Activity Alliance in advance, who provided feedback and suggestions to inform the final focus group guide. During the focus groups, participants were asked open questions related to the barriers and facilitators to physical activity for disabled people, to help set the scene for the discussion, followed by questions related to the main aim of the study, to identify actions that would help support disabled people to be more physically active. Questions included “What do you think encourages you or other disabled people to be active?”, “What do you feel might prevent you or other disabled people from being active?”, and “What do you feel governments need to do to support disabled people to be active?” Prompts included “Are there any examples you can give from your own experience?” and “For each action, what might this look like?”

Written consent was obtained prior to the focus groups commencing. Six focus groups were undertaken, with between two and six participants in each. All focus groups took place online; five via MS Teams and one via Zoom. This enabled reach to participants across the UK and minimised accessibility restrictions. Prior to the focus groups commencing, participants were reminded that a recording would be taken, their data would be kept securely, and they did not have to answer any questions they were not comfortable with.

Once all participants were happy to proceed, recording was started. The focus groups were mixed gender and lasted an average of 51 minutes (ranging from 44 to 57 minutes).

In the days following the focus groups, participants were sent an email thanking them for their participation and providing website links for further information about how to become more active. The email also signposted participants to sources of advice and support relating to mental health, education, and disability equipment. Participants received a £35 voucher as a token of appreciation for their time.

6.3.3. Data analysis

Thematic analysis was used to identify common themes and recurring patterns of conversation across the focus groups. In line with the six-step procedure proposed by Braun and Clarke(193), the focus group recordings were transcribed verbatim, and participants names were removed. Transcripts were read thoroughly by SC and KM to immerse the researchers in the data. Initial codes were generated to describe the content of the discussion, which were grouped into themes. This was first undertaken by SC and KM separately, before comparing. Following agreement of the codes and themes, these were grouped by SC to reflect the different levels of the ecological model(96) (except for the intrapersonal level, for which no codes or themes were identified), which was verified by KM.

6.4. Results

The results are presented in line with the levels of the ecological model. See Figure 6.1 for the coding structure. We identified recommended actions across four levels of the ecological model - interpersonal, institutional, community, and policy. No codes or themes were identified for the intrapersonal level, suggesting that the actions disabled people perceive are needed are not those aimed at changing disabled people's attitude and motivation, but rather actions that address the external barriers to their participation.

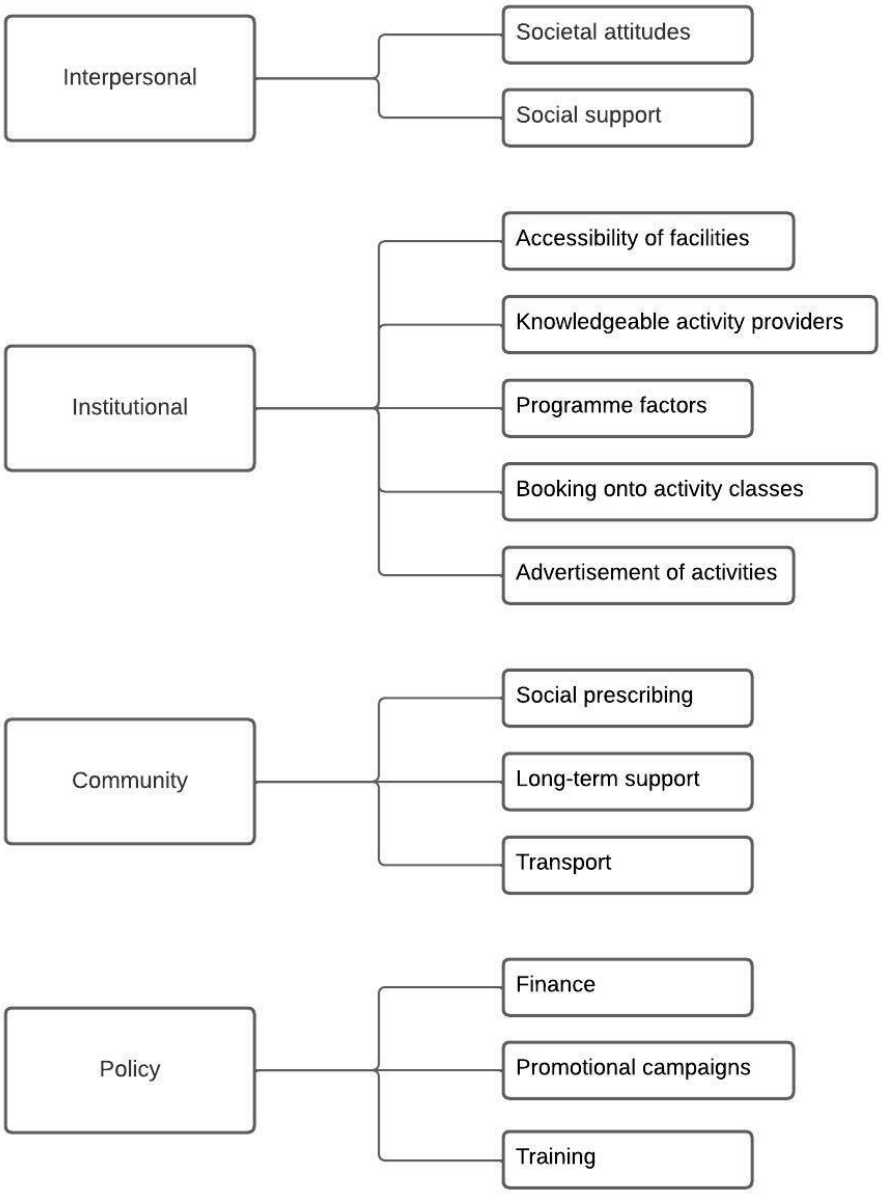

Figure 6.1: Coding structure

Interpersonal

At the interpersonal level, two themes were identified: societal attitudes and social support.

Societal attitudes

Discrimination towards disabled people was mentioned during the focus groups as having an impact on participants' self-confidence and motivation to take part in physical activity. One participant mentioned the positive shift in societal attitudes towards homosexual

individuals through national campaigns and promotion of the rainbow flag. It was suggested that something of similar scale for disabled people may contribute to improvements in societal attitudes and disabled people's own beliefs about how they are perceived in society, which in turn would help disabled people to feel more welcome and confident participating in physical activity opportunities.

> *I was on my bike a couple of years back and some kids sort of shouted 'out the way fatty' erm and that's the first time, because I've never used to put on weight, and it was the first time somebody had ever said anything like that to me, and… that's only because I'm, I'm less active than I used to be, which is to do with my MS. (FG2; Male; 45-54yrs; Long term pain, Mobility, Dexterity, Mental health, Visual, and Memory impairment)*

Social support

Taking part with friends and family made participants feel more motivated to do physical activity, and in some cases made them feel more comfortable to attend an activity class. Support from carers was also a key factor to enabling disabled people to take part. Participation in the activity by carers was felt to be important; if support workers attend but do not participate in an activity, this can feel patronising to disabled people. However often carers or support workers were not able to join or support the disabled person. Participants gave examples of how their carers have been required to pay to attend an activity, even though they were attending for the primary reason of supporting the disabled person to take part. Therefore, better systems are required to enable support workers to take part in physical activity alongside disabled people.

> *It feels quite patronising then, doesn't it? I mean it's like, oh, come on, come on. You know rather than kind of sweating alongside then going, oh my God, this is killing me, when, you know, work harder because you're going to beat me, you know, that's the sort of encouragement that you need. (FG6; Female; 18-24yrs; Mental health impairment)*

Some participants mentioned that since the COVID-19 pandemic there is a reduced number of staff available at leisure centres to support disabled people, for example, to use the hoist to get in and out of the swimming pool. This means that disabled people are even more reliant on carer support to facilitate their participation in physical activity. However, often this means their opportunities to participate are limited to the number of times they

receive carer support throughout the week and the duration of time the carer has with the individual. Increased availability of staff at leisure facilities is therefore necessary to support disabled people's access to physical activity provision, without the need to provide their own carer.

Institutional

At the institutional level, five themes were identified: accessibility of facilities; knowledgeable activity providers; programme factors; booking onto activity classes; and advertisement of activities.

Accessibility of facilities

Infrastructure and accessibility of equipment were among the most common reported barriers throughout all focus groups. For one participant, some activity venues and gym equipment were not accessible for their wheelchair.

> *I can't really use gym equipment because it's really hard to transfer from my chair onto the gym equipment, because usually you have to kind of contort yourself into erm like difficult positions. Like you can't, you can lower bike seats to a certain extent, but not low enough so that I can just transfer onto them. (FG6; Female; 18-24yrs; Mobility, and Dexterity impairment)*

Due to variation in the accessibility of leisure facilities and the provision of appropriate equipment for disabled people, participants often have to contact leisure facilities in advance, which creates an additional barrier to being active. Participants may also be limited in their choice of activities, depending on what equipment and/or support staff the centre has available.

> *I was in another session with a lady who was in a wheelchair and again, from my point of view you don't think do you, she'd have to ring ahead to say is the, is the hoist available to get into the swimming pool but, you know surely she should just be able to go and the hoist is available but no they have to put it all in and you know, oh we need two members of staff because of, so you're like straight away you feel, you've got a pressure that you're causing. (FG4; Female; 55-64yrs; Mental health impairment)*

Improvements are therefore needed to the accessibility of facilities, and to the information provided about accessibility, including the level of support that facility staff can provide.

Knowledgeable activity providers

Knowing that staff at leisure centres would be friendly, supportive, and accommodating of any accessibility requirements was crucial to participants feeling supported and able to attend local physical activity opportunities. Within the activity classes provided, having knowledgeable instructors who are accommodative and supportive of disabled peoples' needs was also considered important.

> *I'm lucky now, I've got a personal trainer that wants to work with what I actually want to do, because barriers vary in terms of psychologically, you don't want to go over and feel like you're failing, you want somebody that's going to help you achieve by doing the things that you can do well and then building from that. (FG4; Male; 45-54yrs old; Long term pain, Mobility, Dexterity, Mental health, Breathing, Memory, Speech, and Behavioural impairment)*

Partnering with disability organisations was a suggested approach to help leisure centres and activity providers to better understand the needs of their disabled clients.

> *It's like getting other people involved, like maybe who I work for, like MENCAP, who work with people who've got the learning disabilities side and seeing what they can come up with, ….just like third parties involved, speaking to other people who work with people like us on a daily basis and see what we're dealing with because its ok somebody sitting in their office, but not seeing actually what's happening on the shop floor all the time. (FG3; Female; 45-54yrs old; Long term pain, Mental health, and Breathing impairment)*

Programme factors

Participants felt that there were limited classes that they were able to attend, compared to non-disabled people. People with certain impairment types, such as sensory impairments, require specific adaptations or additional support. Several solutions were suggested, such as having a pre-recorded interpreter displayed on a screen to the side of the activity class; this would be particularly easy for activity classes that are already video recorded. Alternatively, having a screen displaying a ball that bounces with the rhythm of the music would help people with a hearing impairment to step in time. For people with sensory impairments, often the background music or level of noise within activity classes can be too loud, and the lighting in the activity room can also be too bright, thus quiet times at leisure centres or gym classes were recommended. It was suggested that adjusting some of the

classes to accommodate these requirements would not hugely alter non-disabled people's experience of the class, but would improve the opportunity for disabled people to participate.

> *The feedback that comes back is that they don't put quiet hours in or sessions that are signed. So, if you have sensory needs and you can't cope with bright light or or loud, loud noise, it can be quite difficult to use places, like gyms and swimming pools because they're just, it's just too much to, for some people to take. (FG6; Female; 18-24yrs old; Mobility, and Dexterity impairment)*

Booking onto activity classes

Often classes at leisure centres must be pre-booked, with spaces filling very quickly, especially now with fewer leisure facilities. However, disabled people can experience irregular changes in their severity of pain and symptoms, meaning they often do not know how well they will feel in a week's time. This can make some people hesitant to book onto activity classes and pay in advance. The opportunity for disabled people to cancel a booking at short notice and receive a refund would mitigate this problem.

> *I think another thing is we often have to, have to cancel late and obviously normally, you have to give 24 or 48 hours' notice. Well, I don't know in 24 hours' time what state I'm going to be in and whether I'm going to be able to do a class or not, and it would be nice if there was a little bit more understanding. (FG4; Male; 45-54yrs old; Long term pain, Mobility, Dexterity, Mental health, Breathing, Memory, Speech, and Behavioural impairment)*

Advertising of activities

Advertisement of activity classes and opportunities that are suitable for disabled people to attend was felt to be lacking. Participants reported a lack of information about whether facilities are accessible for disabled people and which classes are suitable for people with different types of disabilities. Clear and readily available information about the accessibility and support that activity centres and classes provide would help disabled people to feel encouraged to take part in physical activity.

> *If you're going to look for a holiday, for instance. So I was just looking for some information for a friend and it's like, you know, dog, smoking… maybe it should be local government, ticking the box for do you provide this facility for disabled people, that should be an automatic tick, you know yes you've got it for females, yes you've*

got it for males, yes you have only female sessions, but have you got, just have you got disabled only. (FG4; Female; 55-64yrs old; Mental health impairment)

Community

At the community level, three themes were identified: social prescribing; long-term support; and transport.

Social prescribing

Social prescribing involves the referral of patients to a range of community-based services to help with the prevention and management of chronic disease. This can include physical activity and weight-loss programmes. Participants in this study felt that these opportunities were depleting and that the connections between health professionals and the activities that individuals were referred onto was weak.

GP's, when someone has a health problem, whether it's blood pressure, weight, or anxiety, or depression, they're at the front line of those sorts of things, and general ill health, sort of health acute and chronic conditions. That they're the place, well one of the best places where people come into contact, and somebody has that in-depth knowledge about you, erm and therefore can actually recommend the best sorts of course of action, where it may not just be medication. And other, other options might be just as helpful and more helpful, but they're just not, it's not there, really at all. It's not, it's not joined up, I guess there's no. There's no formal link at all between my GP and any activity services. (FG2; Male; 45-54yrs old; Long term pain, Mobility, Dexterity, Mental health, Breathing, Memory, Speech, and Behavioural impairment)

One participant mentioned that they had been signposted to activity classes by their health professional, but some of the programmes did not feel appropriate for them. Thus, rather than the health professional being viewed as a source of support and reassurance, this was lost, which led to reduced motivation to undertake physical activity. Improved communication between health professionals and activity providers is required to ensure activities are suitable and are still taking place.

People signpost you to things, they don't check actually the signpost is doing what it says at the other end and if it is actually right for you, you have to experience that negativity of it not being what you need, and then it feels a bit childish to go, oh,

you know, it doesn't do what you think it does. (FG4; Female; 55-64yrs old; Mental health impairment)

Long-term support

Related to social prescribing, but also to other physical activity programmes, was a lack of ongoing support. Participants felt well supported whilst attending an activity programme but wanted further support after completing the 'prescribed' course to help them to continue doing an activity, or to obtain information on other activities they could access.

Having that legacy of whether it's a program or something like that, then, because quite often you can find that you get like erm, so a bit like social prescribing, you can get physical activity programmes that people are signed onto for six weeks. But for me, I don't know whether there's anything after that for people in terms of their being this legacy to carry on. (FG4; Female; 55-64yrs; Mobility impairment)

Transport

Participants highlighted the need for leisure facilities to be well connected with public transport. The location of fitness centres and gyms can often be outside of city centres and for some disabled people who are unable to drive, this can be problematic and limit their ability to use such facilities. For many participants, improved public transport links to the physical activity provision would make them feel more encouraged and able to undertake physical activity.

Going out in the country or going to the beach, you know, they're difficult because they're not very wheelchair accessible, whereas gyms are, but because I can't drive and a lot of disabled people can't drive and the public transport isn't great, having them in more, so in city centres, and in accessible places that I would be going anyway, that is really great for me. (FG6; Female; 18-24yrs old; Mobility, and Dexterity impairment)

Policy

At the policy level, three themes were identified; finance; promotional campaigns; and training.

Finance

The cost of activity sessions, travelling to an activity, and for support workers to assist, are often prohibitive factors for disabled people to take part in physical activity. Adaptive sports equipment can also be more expensive than non-disabled equipment. Making activity classes and adaptive equipment more affordable would improve the opportunities available for disabled people to access physical activity provision.

> *For someone who's blind for example, playing football er it's so much money to like, to buy a football when a sighted person can go to sports direct and buy a ball for £10, sometimes even less, and someone who's blind has to go out and get a blind football, which is like 50, £60, depending like where, got it from and like the quality of it. So it's a massive difference. (FG3; Male; 18-24yrs old; Visual Impairment)*

Promotional campaigns

Campaigns were considered important in the promotion of physical activity for disabled people. Advertisement of elite disabled athletes is often lacking compared to that of elite, non-disabled athletes. It was also expressed however, that hearing about elite disabled athletes, or disabled people who have accomplished an outstanding sporting achievement, can be unmotivating. Instead, advertisement of people at a recreational level who are more relatable would help to encourage participation.

> *You see people disabled people in the media speaking about sport, normally they've done something absolutely incredible, like, you know, they've climbed a mountain or they've, I don't know, they've run a marathon or or 12 marathons... and then people, I don't know why people do this, but people turn to me, or turn to someone with a disability and go oh, you could do that… somebody doesn't climb Everest and then you turn to your neighbour and say, oh, you could do that. You know, nobody does that, but for some reason because they have a disability, they do. So again, kind of trying to show, kind of normal people, disabled people doing exercise…putting more of an emphasis on normal exercise and not just focusing on, you know, extreme feats of incredible athleticism. (FG6; Female; 18-24yrs old; Mobility, and Dexterity impairment)*

Training

It was commonly mentioned that disabled people did not feel that activity providers were adequately aware of the multitude of different disabilities, nor trained in how to adapt an activity and support disabled people to participate. From the participants' perspective,

there also appeared to be differences in instructor training across sporting activities, with some sports providing training on how to support disabled people, and others not. Similarly, whilst some sports provide disability training, this may be online, meaning no real-life experience is gained on how to work with and support disabled people. Online training does not provide hands on experience in assisting disabled people to use fitness equipment or a hoist, for example. Therefore, in-person training is needed for all activity instructors and anyone working at an activity centre on how to support disabled people.

> *I don't believe there is any for swimming. However, I work as a football coach and I coach disabled people and for that I have had to pass a few courses, which are, erm it's on the FA website and it's specifically for coaching for disabled people. (FG3, Male, 25-34yrs old, Mobility; Long term pain; Mental health impairment)*

> *The other thing for me would be also making sure that staff are trained… from doing a lot of our reviews, they may do an online course but they may never ever meet a person with a disability face-to-face. (FG6, Female, 18-24yrs old, Mobility; Dexterity impairment)*

6.5. Discussion

The aim of this study was to identify the key actions that would best support disabled people to be physically active. The findings highlight a range of recommended actions across multiple levels of the ecological model. Below we discuss some of the tangible actions needed and the roles of different stakeholders.

Highly trained centre staff and activity instructors are critical for enabling disabled people to feel supported to be physically active. There is a need for improved training for activity providers, including education on the variety of different disability and impairment types, and how to adapt activities to meet varying needs. This should be mandatory for anyone delivering activities. A review of existing training content across the range of available courses (for facility staff and instructors) would highlight examples of good practice and gaps in the current training provision. Continued Professional Development should also be provided through on-site workshops and seminars on how to support disabled people and improve the accessibility of activity sessions.(103) There is evidence of policy developments in this area. For example, the new UK sport and physical activity strategy, 'Get Active', released in August 2023,(19) identifies the need to improve the promotion of disability

sport, ensure activity providers and facilities are able to adapt and provide a warm welcome to disabled people with varying needs, challenge discrimination, and increase diversity among the sport and physical activity sector.(189) Actions to address the strategy's aims were specified, such as investing over £300 million to improve existing and provide new facilities, as well as establishing a national physical activity taskforce which will bring together government departments and stakeholders from across the activity sector to develop a clear consensus on what and how improvements should be made. However, the impact is yet to be determined.

The need for improvements to the accessibility of activity facilities and equipment was frequently mentioned during our focus groups and is consistent with previous research.(103,184) To address this issue, Riley et al.(2008) recommend that activity providers conduct an accessibility assessment of their centres, review the findings with individuals experienced in accessibility and disability, and develop an action plan for improvements, with a nominated person or persons accountable for implementing the plan.(194) This would hold providers accountable for improving their activity provision for disabled people. Consulting with disability organisations and disabled people would encourage an enhanced understanding of the required improvements to facilities. At the policy level, minimum standards for the accessibility of activity centres may be necessary to ensure that disabled people with varying impairment types have equitable access. With improved accessibility of facilities and an upskilled workforce, activity providers would be well positioned to increase the number and variability of physical activity opportunities available to disabled people.

Public transport to activity centres is essential to supporting disabled people to access activity provision. Disabled people are less likely to drive or live in a household with access to a car,(195) and are more likely to use local bus services than non-disabled people.(196) The use of public transport can facilitate disabled people's participation in a variety of activities including visiting friends and doing exercise;(197) however, it is not mandatory for leisure facilities to be accessible by public transport. The leisure sector needs to work closely with the transport sector and local government planning departments to ensure there are regular public transport services to current and future facilities, and that the timetabling of these services aligns with the scheduling of activities and classes. This will

support disabled people, and others reliant on public transport for travel, to access activity provision.

The cost of activity classes and gym memberships can limit both disabled and non-disabled people's capability to be physically active. Disabled people, in particular, are more likely to be unemployed,(198) with those who are employed typically being on lower-than-average incomes, resulting in less discretionary spending.(199) Some leisure facilities offer free or discounted activities and memberships to disabled people and individuals who may not otherwise be able to afford it, however there is no statutory requirement for councils to provide these discounts.(200) Support workers can positively influence a disabled person's participation in an activity,(201) however this usually comes at a cost to either the disabled person or the carer's work organisation, which can restrict support workers participation. Activity providers and governments need to consider reduced or free activity classes for disabled people, support workers of disabled people, and people on low income, to help widen activity choices and support participation.

Societal attitudes have a widespread influence on disabled people, including their confidence to take part in physical activity, which is consistent with previous research.(99) Knowledge and understanding of disability among the general public, as well as contact with disabled people, can influence public attitudes.(202) Improvements to disability campaigns is one method of improving people's knowledge and awareness of different disabilities and health conditions. The 'We are Undefeatable' campaign(203) developed by 15 leading health and social care charities, aims to encourage people living with a range of long-term health conditions to be active. As part of this campaign, a television advert has been created showing people with different health conditions doing activities that suit their needs. The impact of this campaign is yet to be determined; therefore, a rigorous evaluation is needed to assess its impact and inform future physical activity campaigns targeting disabled people.

We acknowledge the following strengths and limitations of this study. We recruited disabled people with a variety of impairments to gain a range of perspectives and experiences of physical activity participation. We used open questions, with minimal prompts, to enable participants to have open discussions. In addition, undertaking focus groups online meant we were able to reach individuals from across the UK and minimise

accessibility restrictions. However, online focus groups can restrict the flow of conversations and participants can become distracted by other activities taking place in their home or surroundings. Although we recruited participants with different impairments, the findings and actions identified might not be appropriate for all disabled people. Moreover, participants were recruited through two sports organisations and have been previously involved in focus group discussions about physical activity. It is possible that this group is more active or has greater interest in the topic than the average person, thus their views may not reflect the wider disabled community. Recruitment through non-sport related organisations may provide different perspectives on the actions required to support disabled people to be active. Lastly, whilst this study focused on the views of disabled people; future research should engage with other key stakeholders, such as activity providers and policymakers, to explore their thoughts on the proposed actions, and the barriers and facilitators to implementation.

6.6. Conclusion

Findings from this study highlight a range of actions aligned to the ecological model to support disabled people to be physically active. Actions identified include mandatory training for activity centre staff and instructors on how to support disabled people, advancements to the accessibility of activity/exercise facilities and equipment, better access and frequency of public transport to activity centres, reduced cost of activity classes and gym memberships, and actions to improve societal attitudes towards disabled people. These actions highlight the need for a systems-based approach, combining actions across multiple levels of the ecological model, to ensure equitable access to physical activity for disabled people.

Chapter 7. Discussion and conclusion

7.1. Chapter summary

This thesis comprises four interlinked studies that advance the scientific evidence on physical activity in disabled people. Firstly, a scoping review was undertaken to explore the assessment of disability in prospective and cross-sectional studies that included a device-based measurement of physical activity. This was followed by two analyses of cross-sectional data; one examining the associations of chronic conditions and impairment with self-reported physical activity, and the other describing physical activity levels and the activity types undertaken by disabled people compared with non-disabled people. Lastly, focus groups with disabled people were carried out to explore barriers to physical activity and the actions needed to help support this population to be active. This concluding chapter presents a summary of the key findings from each study and across the thesis as a whole. It also includes an interpretation of the thesis findings in the context of previous research and policy, and provides recommendations for future research. The chapter closes with discussion of the strengths and limitations of the thesis, and a personal reflection on my PhD journey.

7.2. Summary of thesis study findings

The objectives and findings for the four studies conducted are presented in Table 7.1. Study 1 revealed substantial differences in the assessment of disability in the reviewed studies. In particular, there was considerable diversity in the number of questions and level of detail obtained about health conditions and disability, and how these impact a person's daily activities. Study 2 explored the association of chronic conditions and impairments with self-reported physical activity using the HSE 2018 dataset. In this study, having diabetes, COPD, a mobility impairment, a dexterity impairment, or a memory impairment were associated with lower levels of physical activity compared to other health conditions and impairments, such as hypertension, asthma, and learning or visual impairments. This builds from Study 1 and suggests that attempts to improve the measurement of disability in physical activity research should consider both health conditions and impairment types. Studies 3 and 4 examined the types of activity that disabled people engage in, and explored the actions needed to support disabled people to be active. Using the Active Lives 2018/19 dataset, Study 3 identified similarities in activity choices between disabled and non-disabled people, but activity levels and club membership were lower among disabled people. Study 4

identified several actions, recommended by disabled people, to help support them to be active, such as better training for activity providers, improved accessibility of facilities and equipment, and improved societal attitudes towards disabled people.

Bringing together the findings of the four studies, I have identified three cross-cutting themes from this thesis: [1] the assessment of disability in physical activity research, [2] disentangling health conditions and impairments to advance understanding of physical activity in the disabled population, and [3] advancing physical activity policy and practice for this population. In Sections 7.3 – 7.5 of this chapter, I discuss these themes in more detail and provide corresponding recommendations for future research.

Table 7.1: Study objectives and findings

Study	Objectives	Findings
Study 1 A scoping review of disability assessment in prospective and cross-sectional studies that included device-based measurement of physical activity	Explore whether disability has been assessed within epidemiological studies that included accelerometer-based measurement of physical activity in adults, and if so, what information on disability was captured.	75% of studies (n=51) captured whether a person had at least one health condition. 63% (n=43) had questions related to body functions and structures. 75% (n=51) included questions related to activities and participation. Measurement of health conditions, body functions and structures, and/or life activities and participation is often included in physical activity studies, yet there is considerable diversity in how these are measured.
Study 2 The cross-sectional associations of chronic conditions and disability with self-reported physical activity among adults in England	Describe the number and types of impairments reported by people with selected chronic conditions. Describe the levels of physical activity participation in people with different chronic conditions. Examine the association of type and number of impairments with physical activity levels in people with a chronic condition. Examine the relative importance of chronic conditions and impairments as correlates of physical activity.	Mobility and stamina impairment were the most common impairment types (n=1074, 48%; n=892, 40% respectively). Twenty-eight percent (n=620) of participants with a chronic health condition reported having none of the impairments listed. Sixty-six percent (n=2004) of participants reported up to two impairments. There was an inverse association between number of impairments and activity levels. Physical activity levels were highest in individuals with asthma and lowest in individuals with chronic obstructive pulmonary disease. Adjusting for all other chronic conditions and impairments, having diabetes, a mobility impairment, a dexterity impairment, or a stamina impairment was associated with lower levels of physical activity.

Study 3 Physical activity type and duration in disabled and non-disabled adults	Describe the types of physical activities that disabled people participate in and compare activity frequency and duration to non-disabled people.	Activity choices were similar among disabled and non-disabled people. Across disabled and non-disabled people, 'walking for leisure', 'walking for travel' and 'gardening' were the most frequent activities undertaken. Participation rates and activity duration were typically lower among disabled people compared to those with no disability. Participants with no disability were significantly more likely to be club members compared to participants with a limiting disability.
Study 4 'You have to make it accessible and it's really not': priority actions to support disabled people to be physically active	Explore the barriers and facilitators to physical activity for disabled people and identify the key actions that would best support this population to be active.	Thirteen themes were identified across four levels of the ecological model - interpersonal, institutional, community, and policy. Priority actions included mandatory training for activity providers on how to support disabled people, improvements to the accessibility of facilities and equipment, improved frequency of public transport to activity centres, and actions to improve societal attitudes towards disabled people. A systems-based approach is needed, combining actions across the levels of the ecological model to ensure equitable access to physical activity for disabled people.

7.3. Disability assessment in physical activity research

This thesis highlights the complexity of measuring disability in physical activity research. As identified in the general introduction (Chapter 1), disability has many definitions, and no single definition will likely ever meet multiple societal needs.(2,3) The complexity of disability poses challenges for its measurement. Study 1 identified a wide diversity of disability measurement tools, and different disability assessments were used in Studies 2 and 3. For example, the Health Survey for England 2018 assessed disability through asking participants to report their health conditions and impairments, whilst Active Lives focused solely on impairments. Inconsistencies in the conceptualisation and measurement of disability have implications for the accuracy and comparability of national prevalence estimates, as well as the comparability of research findings from etiological studies and subsequent understanding of the relationships between disability, physical activity, and health. In addition, there is a tendency in research to focus solely on a person's health condition rather than considering differences in severity and impairment types. This assumes homogeneity within condition specific groups and fails to recognise the variability in impairment and functioning in people with the same health condition.

It is interesting to note that there have been previous attempts to develop standardised tools for disability assessment in research, such as the Washington Group measurement tool(51) and the WHODAS 2.0,(52) as previously discussed in Chapter 2. In 2017, the Washington Group tool had been included in 69 national censuses and was due to be added to a further 29.(204) Meanwhile, between 1999 and 2015, 810 studies had reported to use the WHODAS 2.0 across all research areas, not solely physical activity.(59) These tools were developed to improve disability measurement in population based studies and to provide a unified scale for measuring disability across diseases, countries, and cultures.(51,52) However, Study 1 showed that, to date, these tools have not been widely adopted in physical activity research. Both measurement tools ask questions related to daily activities, which would be relevant for understanding a person's physical activity levels; for example, their ability to walk a long distance. Neither are extensive (a minimum of six-items and 12-items respectively), though they could be considered too detailed if disability is not the primary focus of the research study.

A recent analysis found that less than 5% (n=1235) of articles published in the five highest ranked medical journals between 1999 and 2019 focused on disabled people, with less

than 7% (n=77) of these addressing physical activity and/or health.(89) Possible explanations include a lack of priority for disability measurement within epidemiological studies, less interest in disability research in high impact physical activity journals, and limited policy attention until developments in recent years. In addition, disability assessment might be overlooked in physical activity research if it is not the primary outcome of a study. Efforts to raise the profile of physical activity research in disabled people are therefore necessary to improve our understanding of physical activity and health in this population. This could be undertaken through working with major stakeholders, such as scientific societies and funders, to increase interest in measuring disability in physical activity related research.

7.3.1. Recommendations for future research

Based on the evidence generated in this thesis regarding the measurement of disability in physical activity research, I identify the following future research recommendations:

- Future research needs to investigate why current disability assessment tools, such as the Washington Group measurement and the WHODAS 2.0, are not currently being used in physical activity research. This could be undertaken through qualitative research exploring researchers' awareness of disability assessment tools, and opinions of their use and applicability to physical activity research. Should the need for a new disability assessment tool be identified, further formative work would be required to identify what should be assessed. This could involve discussions with disabled people, physical activity researchers, researchers involved in the development of disability measurement tools, and stakeholders from physical activity organisations working with disabled people.
- Alongside improvements to disability assessment, future research needs to improve the inclusion of disabled people in physical activity studies and analyses. By doing so, we can expand the evidence base and advance our understanding of the implications of physical activity and health in disabled people.

7.4. Disentangling health conditions and impairments in physical activity research

Most conceptual models of disability, and measurement tools such as the Washington Group measurement and the WHODAS 2.0, consider both a person's health condition(s) and impairment type(s). However, this is not reflected in much of the current physical activity literature. As mentioned in Section 7.3, the most common approach to assessing

disability in physical activity research, to date, has been to focus on a single health condition group or disability, tacitly implying that this defines a homogenous population. However, previous research and this thesis demonstrate that experience of impairment can differ greatly in people with the same health condition. By capturing both health conditions and impairments, we can develop a better understanding of their independent and combined influence on a person's activity and associated health benefits. Indeed, the relative influence of health condition and/or impairment may differ depending on the research question. For example, in etiological analyses, health condition may be more important because it can affect biological processes that might impact the dose-response association between physical activity and health. Conversely, impairment may be more important in analyses pertaining to activity levels because that may affect capacity to be active more than condition per se. It is therefore important that physical activity research in disabled people accounts for both a person's health condition(s) and impairment type(s).

Conceptually, and from an analytical perspective, this thesis highlights the importance of identifying a person's health conditions and impairment types, however there are practical considerations that may restrict assessment of both attributes in physical activity research. In the ICD-11(205) there are 26 Chapters, with over 17 000 diagnostic categories, and over 100000 medical diagnostic index terms. Therefore, accounting for all health conditions individually would not be possible. Additionally, for health conditions that have low prevalence, it may not be possible to recruit sufficient participants for a standalone cohort or as a subgroup within existing cohorts. For example, using Biobank data from 96706 participants who had their physical activity measured between 2013 and 2015, 41312 reported having one or more chronic disease, and among these 7040 had CVD, 7863 had cancer, 1066 had respiratory disease, and 854 had endocrine and metabolic disorders (including diabetes).(87) Thus the sample sizes for specific condition groups were relatively small and would reduce further if also stratifying by impairment type. This was also highlighted in Study 2, as 'social or behavioural impairment' was excluded from the analysis due to a small sample size ($n<65$). In addition, individuals are likely to experience multiple impairments and/or health conditions. For example, in the 2022-2023 Annual Disability and Activity Survey, 77% of people with a health condition reported to experience more than one impairment type.(187) This leads to challenges in establishing the impairment type that has the strongest negative or positive association with physical activity levels.

While there are practical limitations to analysing every health condition and impairment in

all physical activity studies, energy costs of activities can differ in certain subgroups of the disabled population compared to non-disabled people. This variation could imply that the relationship between physical activity and health outcomes may differ between these groups. For example, Dibben et al(206) suggested a lower threshold of activity constituted moderate-to-vigorous physical activity for people with heart failure compared to healthy adults. Given that it may not be possible for all physical activity research to account for a person's health condition(s) and impairment type(s) within the analysis, a solution could be to aggregate sub-populations of people with different health conditions and impairments who exhibit relatively similar activity energy costs or associations with health markers. This would facilitate more streamlined reporting processes for the conditions and impairments that have similar dose-response curves and health outcomes.

While not a specific focus of the work presented in this thesis, an additional consideration is the role of aging in the development of chronic conditions and impairments. Disability prevalence and prevalence of multimorbidity increases with age, with the most considerable increase from 70 years and over.(207,208) In addition, physical activity levels decrease with age, with 43% of people in the UK aged 75 years and above achieving 150 minutes or more of physical activity per week, compared to 63% of people aged 55-74 years, and 66% of people aged 35-45 years.(179) Therefore aging is also a key consideration in understanding the complex relationship between chronic conditions, impairments, and physical activity levels.

7.4.1. Recommendations for future research

Building on the knowledge gathered in this thesis, I identify the following recommendations for future research specific to disentangling the complex relationship between health conditions and impairments:

- Future research needs to explore the dose-response relationship between physical activity and health outcomes for people with different chronic conditions and impairment types. This could be undertaken through using existing data, such as Biobank, or through the establishment of new population-based cohort studies of disabled people. Recruiting larger sample sizes of disabled people would enable in-depth analyses on the physical activity levels and health outcomes in people with a variety of different chronic conditions and impairment types. This would help to build the evidence on the energy costs and health outcomes, and support the aggregation of

subgroups in future research.

- Given the links between ageing and disability, further research is needed to explore the relative influence of age, health conditions and disability on physical activity levels and health outcomes. Recruiting a cohort of disabled people with varying disabilities and conditions across the lifespan would enable exploration of the complex interplay between these factors. This would provide clearer knowledge of disabled peoples physical activity levels, and the relative influence of age and health condition on activity levels. This would additionally allow examination of the relative health benefits of physical activity at different ages and the extent to which physical activity may moderate the ageing process and its impact on morbidity and mortality.
- Future research also needs to work towards understanding how we might account for more than one health condition or disability at a time, given the complexity of disability, the myriad of conditions and impairments, and the added complexity of multi-morbidity. Alongside exploring whether there are similarities in physical activity and health outcomes in people with different health conditions and impairment types, it should also explore the associations between multi-morbidity and physical activity and health. Data on disabled people's health status, activity levels, diagnosed conditions, and impairment types would need to be obtained over an extended period of time (for example, more than 10 years). In doing so, we could explore the long-term association of physical activity and health among people with multi-morbidities, and people with different health conditions and impairment types.

7.5. Implications for physical activity guideline development

As mentioned in the literature review, the WHO physical activity guidelines for disabled people are identical to the guidelines for non-disabled people.(65) However, this thesis has identified differences in physical activity levels among disabled and non-disabled people, as well as variation across chronic conditions and impairment types. Therefore, it may be inappropriate to apply the same physical activity guidelines across all condition and impairment groups. It is known, for example, that mobility limitations pose challenges for physical activity, leading to increased energy expenditure for any given volume of activity.(209–211) In a recent update of the Compendium of Physical Activities,(209–211) a tool for classifying different activities based on energy expenditure, the resting metabolic rate of wheelchair users is noted to be lower than other disabled adults.(212) Therefore, it is important to consider the variation in energy expenditure in people with different health

conditions and disabilities compared to the non-disabled population, to account for relative intensity (differences in the threshold at which an activity is considered 'moderate' or 'vigorous' intensity). If the dose-response effect of physical activity differs across health condition and impairment groups, it may be inappropriate to have the same guidelines for all. However, given the multitude of different chronic conditions and disabilities, having separate physical activity guidelines for each would not be viable. This would shift guidelines away from public health guidelines for all, toward clinical/condition-specific guidelines.

Current physical activity guidelines are informed by evidence from studies that focused on participants with a limited number of specific conditions and impairments. For example, the UK physical activity guidelines were informed by evidence on six conditions and impairments (SCI, intellectual disabilities, cerebral palsy, amputees, visual impairment, and hearing impairment), and the WHO physical activity guidelines were informed by evidence on four chronic conditions (cancer, hypertension, type 2 diabetes and HIV) and eight disabilities (MS, SCI, intellectual disability, Parkinson's disease, stroke, schizophrenia, major clinical depression, and ADHD. Discrepancies in the conditions and disabilities considered when producing guidelines, alongside the limited number of conditions and disabilities considered, may limit the generalisability of recommendations to the whole disabled population. However, including evidence on all chronic conditions and disabilities in one set of public health physical activity guidelines may be impractical, and inappropriate if the evidence is limited. It is encouraging that mental health impairments were considered within the WHO physical activity guideline development, as these are more prevalent in disabled people compared to non-disabled people.(213) It may also be important that differences in the mental health benefits of physical activity for people with different chronic conditions and disabilities are emphasised in future physical activity guidelines.

Research in this thesis has shown considerable variation in physical activity levels in people with the same health condition, which is likely due to many factors including differences in disease severity or symptoms, functional impairments, personal psychology, and environments and opportunities. Whilst it is not possible for physical activity guidelines to address the myriad challenges that people face to being physically active, the WHO guidelines for disabled people included 'good practice statements' which at least provide space to acknowledge that these challenges exist. For example, it was acknowledged that people with chronic conditions or disabilities may wish to consult a physical activity

specialist or health-care professional for advice on the types and amounts of activity appropriate for their individual needs, abilities, functional limitations/ complications.(65) Providing a wider range of examples on the ways in which the physical activity guidelines can be achieved might be another way to address the practical challenges to physical activity faced by disabled people.

The WHO Physical activity guidelines for non-disabled people are distinct for adults (18-64 years) and older adults (aged 65 years and older), but this is not currently the case for disabled people. Given the links between ageing and disability, as mentioned above, and the reduction in physical activity that is observed with age, it may be appropriate for future physical activity guidelines for disabled people to also distinguish between adults and older adults. This would also allow the guidelines to emphasize the importance of different types of physical activity for older disabled adults, such as including the need to incorporate more strength and balance-based activities to reduce the risk of falls.

7.5.1. Recommendations for future research and guidelines

- As recommended in Section 7.4.1, future research needs to explore the dose-response relationship between physical activity and health outcomes. By undertaking this research, we will build the evidence on the energy costs and health outcomes of physical activity, which may support the aggregation of health condition and/or impairment subgroups in future research, as well as future physical activity guidelines.
- Alongside the above recommendation, there is also a need for a clearer rationale for what chronic conditions and disabilities should be considered in the evidence review(s) used to inform physical activity guidelines. Through a better understanding of the physiological responses to physical activity for people with a variety of different chronic conditions and disabilities, we will have an improved awareness of where similarities and differences lie. This would provide stronger justification for what conditions and disabilities must be reviewed when formulating physical activity guidelines, to account for differences in physiological responses.
- Future physical activity guidelines for disabled people should consider having specific guidelines for different age groups (18-64 years, and 65 years and older). This would allow clearer, and potentially more realistic physical activity recommendations for the older disabled population.

7.6. Implications for physical activity policy and practice

This thesis highlights several areas for improvement in physical activity policy and provision for the disabled population. Sections 2.9 and 2.10 of Chapter 2 explore the barriers and facilitators to activity for disabled people, and current global action for improving physical activity policy and provision for the whole population. Findings from Study 3 and 4 identify the most common activities disabled people participate in, and the actions that are needed to better support this target population to be active. In the UK, there is a history of policy action targeting physical activity that has been operational for several years. One recent example is the Department for Culture, Media and Sport 'Get Active' strategy, released in August 2023.(189) The strategy is underpinned by three core principles: 1) driving participation and addressing inactivity; 2) strengthening the integrity of sport through making sport and physical activity more inclusive; and 3) making sport more sustainable. The strategy is aimed at improving sport and physical activity for all population groups, including disabled people. Whilst it has some similar actions to international frameworks such as the GAPPA (Global Action Plan on Physical Activity 2018-2030, mentioned in Section 2.10 of Chapter 2),(93) the UK strategy is somewhat ambiguous compared to GAPPA, particularly in its actions to improve physical activity support and provision for the disabled population. This is possibly due to the strategy's focus on both physical activity and elite sport. Focusing solely on physical activity, the GAPPA is a global framework for population level physical activity promotion, developed by the WHO to help countries upscale physical activity policy actions.(93) The GAPPA recommends 20 policy actions that are categorised into four objectives; active societies, active environments, active people, and active systems, and provides policy level actions for all population groups. See Appendix 2. Whilst the action plan is inclusive of disabled people, there are learnings from this thesis that could help enhance and inform the application of GAPPA for the disabled community.

Under the GAPPA 'Active societies' objective is the need to implement national and community-based physical activity campaigns. Based on the findings of this thesis, it is critical that such campaigns are inclusive of disabled people, and that they are relatable. In the UK, 'We are Undefeatable', which was developed by a group of 15 leading health and social care charities,(203) is a recent physical activity campaign specifically highlighting people living with a range of long-term health conditions being active. Though the impact is yet to be determined, campaigns such as this aim to encourage more disabled people to be

physically active. Greater promotion and knowledge of campaigns, such as this one, would enhance awareness of activity opportunities and improve societal attitudes of disabled people being active; a barrier highlighted in Study 4 of this thesis.

The GAPPA 'Active societies' objective also suggests strengthened training for professionals on how to create inclusive and equitable opportunities for the whole population to be active. This thesis highlighted variation in current training provision and the importance of introducing mandatory training for activity providers on how to support disabled people with a variety of different disabilities to be active. This could be implemented within current instructor courses or as professional development training.

In the GAPPA 'Active environments' objective is the need to improve the accessibility of physical activity infrastructure. Findings from this thesis showed that disabled people were most likely to undertake leisure-based activities, and activities typically undertaken at an activity centre or gym, such as using an exercise bike or swimming. However, the number of disabled people who undertake these activities was low relative to non-disabled people, and the duration of time spent being physically active was also lower in disabled people; potentially suggesting that the current infrastructure is inadequate. Sport England provide extensive detail and instruction for activity centres on how to create accessible sporting facilities,(214) however the current government building regulations are far less detailed, focusing primarily on ensuring there is suitable access for wheelchair users into and around buildings.(215) There is currently no mandatory legislation in place for accessible provision such as using clear and simple signage, or having induction loops installed to help people with hearing impairments. Retrofitting improvements may be challenging due to a lack of financial resources to adapt current facilities. Developing legislative building regulations on the essential accessibility requirements for new activity centres would ensure inclusivity is considered from the outset.

The GAPPA 'Active environments' objective also highlights the need for integrated transport and urban planning policies. This is particularly important for disabled people, who are often more reliant on public transport than the non-disabled population.(196) In particular, this thesis identified the need for activity facilities to be well connected to public transport, including having public transport stops next to activity facilities and frequent services available throughout the day. This will likely require improved collaborations

between health and public transport operators, but in doing so, would improve access for disabled people to attend activity facilities.

Under the GAPPA 'Active people' objective is the need for community-wide initiatives to increase physical activity in all population groups. Findings from this thesis highlighted that disabled people felt there were fewer available opportunities and noted that existing activities were not well advertised. It is therefore necessary to improve advertising of activities taking place within the community that are accessible for disabled people. For example, this could include an image or logo on activity advertisements identifying where instructors have attended a disability awareness course. This could provide reassurance to the disabled population that the activity and the instructor can cater for their ability and needs. Social prescribing is a common community-initiative within the UK. This involves referral by a health care provider into community programmes, including physical activity. However, these programmes are typically short-term and are perceived to be depleting. Whilst they can increase physical activity participation, at least in the short-term,(216) a lack of ongoing support following the programme can prevent people from sustaining these increased activity levels. It is therefore important that there are supportive and robust community referral pathways into physical activity for disabled people, and support available for disabled people after completing an activity programme. This could include instructors recommending other classes participants could join following the end of the programme.

Lastly, among the GAPPA 'Active systems' objective is the need for multisectoral partnerships and strengthened finance mechanisms to implement effective action to increase physical activity levels. This thesis identified the need for subsidies and systems to allow support workers to attend activity classes alongside a disabled person at a reduced or no cost. This would encourage disabled people to attend a class and feel supported by someone who they already know and trust. For researchers, there is a strong need for governments and/or research funders to allocate increased resources to physical activity research in disabled people. This would improve opportunities for high-quality research to be undertaken, thereby improving the quality of the evidence base on physical activity and health in this population. For disabled people, it is crucial that we encourage policy makers, and scientific journals and societies to give better attention to research in this target population. This could be implemented through special editions of journal volumes

outlining the gaps in the current evidence base and future research recommendations, with support encouraged by scientific societies, and researcher funders, to advocate for these future research efforts to be undertaken.

It is evident that there needs to be system-wide changes to enhance physical activity policy and practice for disabled people. However, as identified in Section 2.10 of Chapter 2, the GAPPA has experienced limited government support from countries at all income levels,(108) preventing improvements to access and provision for all populations to be more active. It is therefore necessary to continue promoting the importance of physical activity to policymakers to encourage change. By improving the areas highlighted above, we would provide long-term improvements to activity provision and support for disabled people to be physically active.

7.6.1. Recommendations for future research

Based on the findings in this thesis, existing action plans need to be strengthened and implemented better to enable disabled people to be active, including wide scale improvements to physical activity provision for disabled people. I subsequently suggest the following areas for future research:

- In regard to training, we need better evidence on the types of training that are most effective to equip instructors with the skills and confidence to cater for a wide variety of abilities and needs. Small scale intervention studies using a range of training options would help to build this evidence.
- To advocate for changes to the accessibility of facilities, we need to know what types of adaptations have the biggest impact and therefore should be included in any building regulations. Examining usage of existing facilities with different design features might provide initial insights into the types of designs that are most accessible.
- With recent implementation of the 'We are Undefeatable' physical activity campaign targeting disabled people, research is necessary to assess the impact of the campaign on encouraging this target population to be more active. Similarly, future research is needed to assess the impact of local campaigns promoting physical activity for disabled people, to identify what is the most effective approach (messages and delivery formats) for encouraging disabled people to take part in physical activity.

7.7. Thesis strengths and limitations

A discussion of the specific strengths and limitations of each study conducted in this thesis is presented in the relevant study chapters. The commentary that follows focuses on the strengths and limitations that cut across the whole thesis, or that apply to two or more of the thesis studies. A strength of this thesis is its focus on a significant target population for health promotion. Disabled people make up 24% of the UK population,(7) and are an important target group for physical activity promotion due to their increased likelihood of being inactive compared to non-disabled people;(13) however they have received limited attention in the physical activity epidemiology literature to date. As the disabled population is growing,(7) it is crucial that there is appropriate knowledge, government action, and interventions to enable disabled people to access physical activity provision and feel supported to be active. The thesis highlights barriers to participation for disabled people, but also actions to promote participation. Evidence from this thesis can be used to improve research, and future policy actions to increase the activity levels of the disabled population.

Another strength of this thesis is the use of mixed methods. Using quantitative and qualitative methods enables a more comprehensive understanding of physical activity in disabled people. It also allows for richer interpretations of the thesis findings that can lead to informed decision-making and policy formulation.(217) The quantitative studies undertaken in this thesis allowed for large-scale analysis of disabled peoples' physical activity levels in the UK, whilst the qualitative analysis in Study 4 provided an opportunity to delve deeper into what limits this target population from being as active as they would like to be. The surveys used in Studies 2 and 3 also continue to take place annually, which will enable my thesis findings to be compared to future iterations, facilitating monitoring of trends over time.

As mentioned in Section 2.12, 'Thesis rationale, aims, and structure', a steering group was established to help guide the research conducted as part of this PhD. This group consisted of representatives from Sport England, Activity Alliance and the Office for Health Improvement and Disparities. The steering group were involved from the beginning of my PhD journey, allowing them the opportunity to share their feedback and help shape the work I was proposing to undertake. The published manuscripts from the four PhD studies have been shared with the team, although it is too early to know how impactful the findings will be for these organisations and how this work might shape policy and practice

moving forward. However, we have established good working relationships with these organisations, and will remain connected to try to shape future directions in research, surveillance, and physical activity guidelines.

Alongside the strengths of this thesis, there are limitations that need to be acknowledged. A limitation is the use of self-reported physical activity data for Studies 2 and 3. Self-report is the most common method of collecting population level data on physical activity due to being relatively inexpensive to administer and adaptable to different country contexts.(218) However, self-report is widely known to have limitations such as recall bias, and an inability to capture absolute levels of physical activity.(219) Participants are likely to overestimate their activity levels compared to levels identified with a wearable activity tracker.(220) Physical activity researchers and policy makers are now considering the move towards using accelerometer data for physical activity surveillance and for the future development of physical activity guidelines.(93) This being said, accelerometry measurements are inaccurate in detecting activity for people with certain impairment types, such as wheelchair users.(221) As Heath and Levine(90) highlight, international surveys and surveillance systems typically either measure physical activity well, or disability well, but rarely both. This was evident within my thesis research, as to locate datasets that included a person's disability and physical activity levels, the evidence base was limited to cross-sectional surveys. Therefore, as the field debates the future of physical activity measurement, it is critical to consider inclusion and representativeness, alongside measurement properties, such as validity and reliability.

A further challenge of this thesis was complexity and differing perspectives towards disability. Whilst the biopsychosocial model is becoming the more commonly adopted perspective towards disability, there were difficulties in capturing this multifaceted definition and applying this perspective in my research. Though this thesis largely focuses on health conditions and impairments, analysis was not undertaken to assess the influence of environmental and social factors that could impact a person's physical activity levels. Study 4 explored this in more detail, however the quantitative analysis undertaken did not account for this influence and was not assessed within the questionnaires used in Studies 2 and 3. Whilst this thesis is an important step forward in highlighting the associations of health conditions and impairments with physical activity levels, operationalising the biopsychosocial perspective towards disability to its full extent is complex. Additionally, the

data used in Studies 2 and 3 were solely from the UK, and therefore do not account for political, social, and environmental differences in other countries. For example, barriers to participation can vary between people in higher income countries compared to people in lower- and middle-income countries, such as a higher likelihood to experience insufficient resources and lack of facilities.(222) The type of physical activity undertaken is also likely to vary, with individuals in lower- and middle-income countries undertaking lower leisure time physical activity, but higher compulsory activity such as for transport.(223)

A final limitation of this thesis was that none of the studies examined whether there was effect modification by age. Within Studies 2 and 3, I did not assess the potential moderating influence of age in the analyses conducted. For example, it is possible that the association between impairment type and physical activity may differ by age. Within the UK, 42% of adults over 66yrs, and 59% of adults aged 80 years and over, report to have a disability, compared to 21% of working aged people.(6) Levels of physical activity are also known to decrease with age,(224) and symptoms experienced as a result of a person's health condition are likely to worsen.(225) Certain health conditions included in the analyses in this thesis are also more common in older adults; for example in Study 2, 86% of the sample aged 55years or older reported having COPD, whereas a comparatively lower proportion (47%) of the sample aged 55years or older reported to have asthma, which is more common in younger people. In addition, activity levels were lowest in people with COPD, and highest in people with asthma. Whilst older adults were not excluded from any analyses within this thesis, effect modification by age would indicate whether there is an association between health condition and impairment with physical activity based on a person's age.

7.8. Personal reflection

Having had time after my master's degree studies before undertaking a PhD, I was able to gain valuable experience in delivering physical activity interventions in disabled people and evaluating physical activity and public health interventions. I feel that the experiences I gained during this period of my career helped to shape my research interests and knowledge prior to commencing my PhD journey. I feel that I was able to start my PhD journey with some knowledge and skills of writing research papers, carrying out focus groups, and undertaking data analysis. However, this PhD has enabled me to feel much more knowledgeable and confident undertaking research in the future. I feel that I have

been able to enhance and develop skills in research and data analysis, such as learning Stata and using code. I have also found a new appreciation for the use of mixed-methods research and how both quantitative and qualitative methods can help to guide and answer a research question. In particular, I have enjoyed undertaking focus groups with disabled people, to be able to hear first-hand the actions that are needed to help support disabled people to be active. I have also enjoyed undertaking the quantitative analysis and exploring how physical activity levels can vary based upon how disabled people are grouped by their health condition, impairment type, and number of impairments.

My PhD journey began in October 2020, during the COVID-19 pandemic. Consequently, I began my PhD journey working from home and have continued like this for the duration of my PhD. Whilst I have occasionally worked from the university, I have found myself spending a substantial amount of my time working alone. Though this has felt quite isolated at times, when reflecting on my PhD experience, this has enabled me to realise how self-driven I am. Likewise, having the time dedicated to undertaking research that I feel passionate about and interested in has been thoroughly enjoyable, and I hope that I can continue in this research area in the future.

7.9. Conclusion

This thesis aimed to explore relationships between health conditions, impairments, and physical activity levels in disabled people, and identify actions to support this population to be active. The findings from this thesis highlight that disability assessment can often be superficial, and use of established tools is very limited. There is also variation in physical activity levels both between and within people with different health conditions and impairment types. Actions to improve physical activity provision, practice, and policy across the ecological model are identified to increase physical activity uptake in disabled people. The work presented in this thesis provides a foundation of evidence on what future disability measurement should look like, whilst also providing tangible actions to improve physical activity provision suggested by the target population. This thesis also discusses the challenges in future implementation of these actions.

Appendices

Appendix 1: UK Chief Medical Officers' physical activity guidelines infographic for disabled adults(64, p.26)

Appendix 2: Global Action Plan on Physical Activity, whole-of-government solutions for physical inactivity(93, p.44-45)

Appendix 3: Search strategy for MEDLINE

Terms

1. (physical adj2 (activit* or inactivit* or behavio* or exercise).ti.ab
2. (sedentary adj2 (activit* or behavio*). ti.ab
3. (sitting adj2 (time or behavio*). ti.ab
4. accleromet* ti.ab
5. (activity adj2 (monitor* or device). ti.ab
6. motion sensor. ti.ab
7. inclinometer. ti.ab
8. observational adj2 (stud* or cohort). ti.ab
9. cohort adj2 (stud*). ti.ab
10. cross-sectional. ti.ab
11. prospective. ti.ab

Example strategy

1 or 2 or 3
and
4 or 5 or 6 or 7
and
8 or 9 or 10 or 11

Search Limits:

Participants: adult, human
Articles: Journal articles, English, Full-text, Journal articles, published in English, full text available*
Design: Observational studies, not case-control, not trials, not experimental

Appendix 4: Data extraction categories

Study name

Source

Questionnaire

Year

Cohort size

Location

Physical activity measurement device (e.g. Actigraph, GeneActive, ActiPal)

Previous diagnosis of disability/condition/impairment/illness

- Any question asked (tick box)
- State question asked
- Y/N response (tick box)
- List the conditions/ impairment/ illness mentioned

Currently have long term disability/ condition/ impairment/ illness?

- Any question asked (tick box)
- State question asked
- Y/N response (tick box)
- Identify long-term as 12 months or longer/ likely to effect person for rest of life (tick box)
- Specify condition/ impairment/ illness? (tick box)
- List the conditions/ impairment/ illness mentioned

Is ability to do daily activities affected?

- Any question asked (tick box)
- State question asked
- Y/N response (tick box)
- Response options
- List daily activities mentioned

Physical impairment

- Any question asked (tick box)
- Y/N response (tick box)

Breathing or stamina

State question asked

Response options

Dexterity

State question asked

Response options

Mobility

State question asked

Response options

Long-term pain

State question asked

Response options

Other

State question asked

Response options

Sensory impairment

Any question asked (tick box)

Y/N response (tick box)

Hearing

State question asked

Response options

Visual

State question asked

Response options

Other

State question asked

Response options

Cognitive impairment

Any question asked (tick box)

Y/N response (tick box)

Learning or understanding

State question asked

Response options

Memory

State question asked

Response options

Other

State question asked

Response options

Speech and/or language impairment

Any question asked (tick box)

Y/N response (tick box)

State question asked

Response options

Mental health impairment

Any question asked (tick box)

Y/N response (tick box)

State question asked

Response options

Social/ behavioural impairment

Any question asked (tick box)

Y/N response (tick box)

State question asked

Response options

Appendix 5: Study reference number, details and source

Reference number	Study name	Location	Sample	Study website
1	Activity and Function in the Elderly in Ulm (ActiFE ULM) Study	Ulm, Germany	City/local	Denkinger MD, Franke S, Rapp K, Weinmayr G, Duran-Tauleria E, Nikolaus T, et al. Accelerometer-based physical activity in a large observational cohort - Study protocol and design of the activity and function of the elderly in Ulm (ActiFE Ulm) study. *BMC Geriatr*. 2010;10.
2	Australian Longitudinal Study on Women's Health (ALSWH)	Australia	State/regional	https://alswh.org.au/
3	Australian Diabetes, Obesity and Lifestyle (AusDiab) Study	Australia	National	https://www.baker.edu.au/ausdiab/
4	Baltimore Study of Aging	Baltimore, Maryland, USA	State/regional	https://www.blsa.nih.gov/
5	1970 British Cohort Study	UK	National	https://cls.ucl.ac.uk/cls-studies/1970-british-cohort-study/
6	Belgian Environmental PA Study (BEPAS- IPEN)	Ghent, Belgium	City/local	https://www.ipenproject.org/Belgium.html
7	British Regional Heart Study	England, Wales and Scotland	National	https://www.ucl.ac.uk/epidemiology-health-care/research/primary-care-and-population-health/research/brhs
8	Canadian Health Measures Survey	Canada	National	https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=1195092
9	Coronary Artery Risk Development in Young Adults (CARDIA)	Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA	National	https://www.cardia.dopm.uab.edu/
10	Cancer prevention Study 3	United States and Puerto Rico	National	https://www.cancer.org/research/cps3-cancer-prevention-study-3.html

11	CoLaus	Lausanne, Switzerland	City/local	https://www.colaus-psycolaus.ch/professionals/colaus/
12	COMO VAI (How are you) study	Pelotas, Southern Brazil	City/local	Barbosa-Silva TG, Bielemann RM, Gonzalez MC, Menezes AMB. Prevalence of sarcopenia among community-dwelling elderly of a medium-sized South American city: Results of the COMO VAI? Study. *J Cachexia Sarcopenia Muscle*. 2016;7(2):136–43.
13	Danish Physical Activity cohort with Objective Measurements (DPhacto)	Denmark	National	Jørgensen MB, Korshøj M, Lagersted-Olsen J, Villumsen M, Mortensen OS, Skotte J, et al. Physical activities at work and risk of musculoskeletal pain and its consequences: Protocol for a study with objective field measures among blue-collar workers. *BMC Musculoskelet Disord.* 2013;14.
14	Danish Observational Study of Eldercare work and musculoskeletal disorders (DOSES)	Zeeland in the larger Copenhagen area, Denmark	City/local	Karstad K, Jørgensen AFB, Greiner BA, Burdorf A, Søgaard K, Rugulies R, et al. Danish Observational Study of Eldercare work and musculoskeletal disorderS (DOSES): A prospective study at 20 nursing homes in Denmark. *BMJ Open*. 2018;8(2).
15	The European group for the study of insulin resistance: relationship between insulin sensitivity and cardiovascular disease risk (EGIR-RISC)	Pisa, Italy. London, UK. Villejuif, France. Amsterdam, The Netherlands. Newcastle-upon-Tyne, UK. Padova, Italy. Lyon, France. Odense, Denmark. Dublin, Ireland. Perugia, Italy. Geneva, Switzerland. Frankfurt, Germany. Malmö, Sweden. Rome, Italy. Glasgow, UK. Vienna, Austria. Madrid, Spain. Athens, Greece. Milano, Italy. Belgrade, Serbia	International	http://www.egir.org/

		and Montenegro. Kuopio, Finland		
16	EPIC-Norfolk	Norfolk, UK	State/regional	https://www.epic-norfolk.org.uk/
17	Epidemiology and Human Movement (EPIMOV) Study	Santos, São Paulo, Brazil	City/local	De Sousa TLW, Di Paschoale Ostoli TLV, Sperandio EF, Arantes RL, De Toledo Gagliardi AR, Romiti M, et al. Dose-response relationship between very vigorous physical activity and cardiovascular health assessed by heart rate variability in adults: Cross-sectional results from the EPIMOV study. *PLoS One*. 2019;14(1).
18	EVIDENT3	Salamanca, Valladolid, Cuenca, Palma de Mallorca, and Zaragoza	City/local	https://clinicaltrials.gov/ct2/show/NCT03175614
19	Fenland Study	Fenland, Cambridgeshire, UK	State/regional	https://www.mrc-epid.cam.ac.uk/research/studies/fenland/
20	FINRISK Study	North Karelia, Northern Savo, Turku and Loimaa, Helsinki and Vantaa Northern Pohjanmaa and Kainuu, Lapland - Finland	National	https://thl.fi/en/web/thlfi-en/research-and-development/research-and-projects/the-national-finrisk-study
21	Finnish Retirement and Aging study (FIREA)	South-West Finland	National	https://sites.utu.fi/firea/en/about-firea/
22	Framingham Study	Framingham, Massachusetts, USA	City/local	https://www.framinghamheartstudy.org/fhs-about/
23	Healthy Aging in Neighbourhoods of Diversity across the Life Span study (HANDLS)	Baltimore, Maryland, USA	City/local	https://handls.nih.gov/
24	Health 2011. Finland	Mainland Finland	National	https://thl.fi/en/web/thlfi-en/research-and-development/research-and-projects/health-2000-2011

25	Health of the Nation (HotN)	Barbados	National	https://www.uwi.edu/cdrc/barbados-health-nation-survey
26	Health Survey for England	England, UK	National	https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england
27	Helsinki Birth Cohort	Helsinki, Finland	City/local	https://thl.fi/en/web/thlfi-en/research-and-development/research-and-projects/helsinki-birth-cohort-study-hbcs-idefix
28	Hispanic Community Health Study / Study of Latinos (HCHS/Sol)	Miami, San Diego, Chicago and the Bronx area of New York, USA	City/local	https://sites.cscc.unc.edu/hchs/StudyOverview
29	Hisyama Study	Hisayama, Japan	City/local	https://www.hisayama.med.kyushu-u.ac.jp/en/
30	Hunt4 (The Trøndelag Health Study)	Trøndelag, Norway	State/regional	https://www.ntnu.edu/hunt
31	Inuit Health in Transition Study. Greenland	Greenland	National	Bjerregaard P. Inuit Health in Transition Greenland survey 2005-2010: Population sample and survey methods. 2nd ed. 2011.
32	SPACEs of Curitiba - Understanding the physical activity practices in the community (IPEN Brazil)	Curitiba, Brazil	City/local	http://www.gpaq.com.br/
33	Irish Longitudinal Study of Aging	Ireland	National	https://tilda.tcd.ie/
34	Longitudinal Aging Study. Amsterdam	areas in and around the cities of Zwolle, Oss and Amsterdam	National	https://lasa-vu.nl/
35	Maastricht Study	South of The Netherlands	State/regional	https://www.demaastrichtstudie.nl/research
36	The Cork and Kerry Diabetes and Heart Disease Study	County Kerry and County Cork, Ireland	State/regional	https://clinicaltrials.gov/ct2/show/study/NCT03191227

	(Phase II) Mitchelstown Cohort			
37	The Osteoporotic Fractures in Men (MrOS) Study	USA, Hong Kong and Sweden	International	https://mrosonline.ucsf.edu/
38	National Social Life, Health and Aging Project	USA	National	https://www.norc.org/Research/Projects/Pages/national-social-life-health-and-aging-project.aspx
39	Neighbourhood QoL Study (inc Snr NSHAP)	32 neighbourhoods from the Baltimore, Maryland-Washington, DC, and Seattle King County, Washington metropolitan areas	State/regional	https://www.drjimsallis.com/neighborhood-quality-of-life-study-nqls
40	National Health and Nutrition Examination Survey (NHANES)	USA	National	https://www.cdc.gov/nchs/nhanes/about_nhanes.htm
41	Northern Finland Birth Cohort 1966	Northernmost provinces in Finland (Oulu and Lapland)	State/regional	https://www.oulu.fi/en/university/faculties-and-units/faculty-medicine/northern-finland-birth-cohorts-and-arctic-biobank/research-program-health-and-well-being
42	Physical Activity Cohort Scotland	Tayside, Scotland	Regional	McMurdo MET, Argo I, Crombie IK, Feng Z, Sniehotta FF, Vadiveloo T, et al. Social, environmental and psychological factors associated with objective physical activity levels in the over 65s. *PLoS One.* 2012;7(2).
43	Physical Activity in Public Space Environments (PHASE)	Rotterdam and Maastricht, Netherlands	City/local	Jansen M, Kamphuis CBM, Pierik FH, Ettema DF, Dijst MJ. Neighborhood-based PA and its environmental correlates: A GIS- and GPS based cross-sectional study in the Netherlands. *BMC Public Health*. 2018;18(1).
44	Pelotas	Pelotas, Southern Brazil	City/local	http://epidemio-ufpel.org.br/site/content/coorte_1982-en/index.php

45	The Raine Study	Western Australia	State/regional	https://rainestudy.org.au/
46	REasons for Geographic and Racial Differences in Stroke (REGARDS) Study	continental United States	National	https://www.uab.edu/soph/regardsstudy/
47	Rotterdam Study	Ommoord district of Rotterdam, Netherlands	City/local	http://www.epib.nl/research/ergo.htm
48	Swedish CArdioPulmonary bioImage Study (SCAPIS)	Sweden (Uppsala, Umeå, Linköping, Malmö/Lund, Gothenburg and Stockholm)	National	https://www.scapis.org/
49	Singapore Health Study 2	Singapore	National	https://blog.nus.edu.sg/sphs/population-studies/singapore-health-study-2-sh2/
50	Southampton Women's Study	Southampton, UK	City/local	https://www.mrc.soton.ac.uk/sws/
51	The Attitude, Behavior and Change study (ABC)	Sweden	National	https://ki.se/en/nvs/the-abc-study-attitude-behavior-and-change#:~:text=The%20Attitude%2C%20Behavior%20and%20Change,questionnaire%20and%20physical%20activity%20monitoring.
52	The Tromsø Study	Tromsø, Norway	City/local	https://uit.no/research/tromsoundersokelsen
53	Whitehall II/Stress and Health Study	London, UK	National	https://www.ucl.ac.uk/epidemiology-health-care/research/epidemiology-and-public-health/research/whitehall-ii
54	Women's Health Initiative	USA (regional centres in Buffalo, NY. Boston, MA. Winston-Salem, NC. Columbus, OH. Stanford, CA. Seattle, WA)	National	https://www.whi.org/

55	FinHealth2017	Finland	National	https://thl.fi/en/web/thlfi-en/research-and-development/research-and-projects/national-finhealth-study/the-finhealth-2017-follow-up-study
56	Lothian Birth Cohort	Lothian region of Scotland, UK	State/regional	https://www.ed.ac.uk/lothian-birth-cohorts
57	Adult Changes in Thought	Seattle area, USA	State/regional	https://actagingresearch.org/about
58	British Women's Health and Heart	United Kingdom	National	https://www.ucl.ac.uk/british-womens-heart-health-study/
59	Mil Familias	Santa Barbara County, America	Regional	https://clinicaltrials.gov/ct2/show/NCT03830840
60	BioBank	United Kingdom	National	https://www.ukbiobank.ac.uk/
61	IPEN Columbia	Bogotá, Columbia	City/local	http://www.ipenproject.org/Colombia.html
62	Moveability Study in Danish Cities - IPEN	Roskilde and Kolding, Denmark	City/local	http://www.ipenproject.org/Denmark.html
63	Physical Activity in Localities and Community Environments Study (PLACE) - IPEN	Adelaide, Australia	City/local	http://www.ipenproject.org/Australia.html
64	Active Lifestyle and the Environment in Chinese Seniors (Hong Kong ALECS) Study	Hong Kong, China	City/local	Cerin E, Sit CHP, Zhang CJP, Barnett A, Cheung MMC, Lai PC, et al. Neighbourhood environment, physical activity, quality of life and depressive symptoms in Hong Kong older adults: A protocol for an observational study. *BMJ Open.* 2016;6(1).
65	Understanding the Relationship Between Activity and Neighbourhoods (URBAN) study	4 New Zealand cities—Christchurch and Wellington and Waitakere and North Shore in the Auckland metropolitan area	City/local	Badland HM, Schofield GM, Witten K, Schluter PJ, Mavoa S, Kearns RA, et al. Understanding the relationship between activity and neighbourhoods (URBAN) study: Research design and methodology. *BMC Public Health.* 2009;9.
66	Japan Multi-Institutional Collaborative Cohort Study	Japan	National	https://jmicc.com/

67	Modeling the Epidemiologic Transition (METS) Study	Ghana, South Africa, Seychelles, Jamaica and the United States	International	https://clinicaltrials.gov/ct2/show/NCT02925156
68	Age, Gene/Environment Susceptibility (AGES)-Reykjavik Study	Reykjavik, Iceland	City/local	https://clinicaltrials.gov/ct2/show/NCT03269656

Appendix 6: Activity classification used within this research, based on activity types identified within the Active Lives Survey.

Athletic

Running or jogging	Track and field athletics

Artistic

Cheerleading	Other types of dancing	Hula hooping
Creative or artistic dance	Gymnastics	Trampolining

Combat

Aikido	Ju-Jitsu	Other martial arts
Boxing (traditional)	Karate	Taekwondo
Fencing	Martial Arts	Tai Chi
Judo	Chinese martial arts	Wrestling

Cycle

BMX	Mountain biking	Track cycling
Cyclo-cross	Road cycling or racing	

Equestrianism

Dressage	Hacking or pony trekking	Schooling
Eventing	Other horse riding	Show jumping

Field and strike

Baseball or Softball	Cricket nets or practice	Rounders
Cricket	Other cricket	
Long form cricket match (e.g. 40-50 overs)	Short form cricket match (e.g. 20:20)	

Fitness

Bootcamp (e.g. drill sergeant military fitness)	Dance-based class	Water-based class
Boxing class	Fitness class	Weights-based class
Cardio class	Gym session	Cross fit

Circuit training	High intensity	Cross training
Core strength class	Other fitness or exercise class	Yoga
Cycle class	Pilates	

Gym equipment/machine

Body weight exercises	Resistance weights machines	Treadmill
Exercise bike	Rowing machine	Weightlifting or powerlifting
Other exercise machine	Skipping	Cross training machine
Free weights	Step machine	

Invasion

Basketball	Handball	15 a-side rugby union
Football	Hockey	Rugby sevens
11 a-side football	Ice hockey	Rugby Union
Other football	Lacrosse	Tag or other rugby union
Small sided football	Netball	Touch rugby union
Walking football	13 a-side rugby league	Wheelchair Basketball
Frisbee or ultimate frisbee	Tag or other rugby league	Wheelchair Rugby
Futsal	Touch rugby league	
Goalball	Rugby League	

Leisure

Active Travel	Cycling for travel	Walking for leisure
Angling	Gardening	Walking for travel
Cycling for leisure	Garden trampolining	

Motorsports

Karting or go-karting	Motorcar racing	Motorcycle racing

Net/wall

Badminton	Squash	Tennis
Racket sports	Table Tennis	Volleyball

Outdoor/adventure

Abseiling	Hill and mountain walking hiking mountaineering	Rollerskating inline skating rollerblading
Caving or pot holing	Hill or mountain walking or hiking	Skateboarding
Climbing or bouldering	Mountaineering and scrambling	Skiing
Climbing or bouldering wall	Obstacle course (e.g. Tough Mudder)	Sledding luge tobogganing
Fell running	Orienteering	Snowboarding
Gliding paragliding or hang gliding	Parkour or free running	Snowsport
High ropes	Rock climbing or bouldering	

Swimming

Diving	Swimming - Indoors	Swimming - Outdoor pool
Scuba diving or snorkelling	Swimming - Open water	Water polo

Target

Airgun (including pistol)	Flat green bowls - Indoors	Short course golf par 3 pitch and putting
Archery	Flat green bowls - Outdoors	Pool
Boccia	Short mat bowls	Rifle
Boules petanque deck bowls	Croquet	Shooting
Bowls	Darts	Shotgun
Bowls or boules	Driving range	Skittles
Carpet bowls	Golf	Snooker
Crown green bowls	Adventure or crazy golf	Ten-pin bowling
Flat green bowls	Full course golf	

Water sports

Canoeing	Rowing (on water)	Surfing board, body boarding, kite surfing
Life-saving	Sailing	Waterskiing

Other

Dodgeball	Modern Pentathlon	Triathlon
Ice skating		

Glossary

ADHD	Attention Deficit Hyperactivity Disorder
CI	Confidence Intervals
CMO	Chief Medical Officers
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular Disease
DDA	Disability Discrimination Act
GAPPA	Global Action Plan on Physical Activity
HSE	Health Survey for England
ICD	International Statistical Classification of Disease and Related Health Problems
ICF	International Classification of Functioning, Disability and Health
ICIDH	International Classification of Impairments, Disabilities and Handicaps
IHD	Ischemic Heart Disease
IPAQ-SF	International Physical Activity Questionnaire – Short Form
IQR	Interquartile Range
IRR	Incidence Rate Ratio
METS	Metabolic Equivalents
MS	Multiple Sclerosis
NCD	Noncommunicable Disease
PRISMA-ScR	Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews
SCI	Spinal Cord Injury
UK	United Kingdom
UN	United Nations
UNCRPD	United Nations Convention on the Rights of Persons with Disabilities
UPIAS	Union of the Physically Impaired Against Segregation
WHO	World Health Organization
WHODAS	World Health Organization Disability Assessment Schedule
WWI	World War One
WWII	World War Two

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