The role of social factors in physical activity – using the COVID-19 pandemic as a natural experiment

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Thesis submitted for the degree of Doctor of Philosophy

University College London

I, Verity Hailey, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

COVID-19 created barriers for physical activity. As physical activity is socially patterned, it was vulnerable to the shifting environment created by the pandemic. Using a mixed-methods approach, this thesis investigated how social factors supported physical activity during this period of societal disruption.

Observational data from the COVID-19 Social Study and *Understanding Society* COVID-19 Study was analysed. Ordinal regression was used to evaluate if social factors impacted on sustained physical activity during the first UK lockdown. Multilevel mixed-effects linear regression was used to investigate the association between neighbourhood cohesion and physical activity trajectories during the pandemic. Thematic analysis, with an inductive approach to thematic development, explored the impact of COVID-19 on physical activity. A service evaluation of an online intervention to promote physical activity was undertaken to assess if social support was involved in engagement with the intervention.

Participants with high social support had 64% increased odds of sustaining physical activity during lockdown compared to those with low social support. Higher neighbourhood cohesion was related to higher physical activity, this was maintained throughout suggesting that higher neighbourhood cohesion was protective to physical activity. Several themes were identified from the qualitative work, these included perceived risks/threats to participation in physical activity and the use of technology to aid physical activity which directed studies. The digital physical activity intervention had low engagement.

Community, at individual and group level are important for the maintenance of physical activity, continuing through periods of social restrictions. Neighbourhood cohesion is important and may become more so as hybrid working continues long term. While digital

interventions were utilised during the pandemic, engagement and use appears to have dropped. Effective collaborations between public health and urban planning are required to develop spaces and environments that build communities supportive of physical activity.

Impact Statement

Prior to the COVID-19 pandemic the World Health Organisation reported that 25% of adults and more than 80% of adolescents globally do not meet the recommended level of physical activity (Bull et al., 2020). Physical activity is widely recognised to be an important part of a healthy lifestyle, to achieve health benefit people need to participate in regular physical activity (Condello et al., 2017; Cooney et al., 2014; Nazzari et al., 2016; Reiner et al., 2013). The pandemic resulted in a global reduction in daily physical activity and increased sedentary behaviour (Ammar et al., 2020; Tison Geoffrey, 2020) making physical activity a public health priority.

Understanding why some people stayed active, particularly during a period of social restriction e.g., lockdown, 2m social distancing, can help provide information to develop effective, long term, physical activity interventions. Research prior to the pandemic had established that social support is an important factor for physical activity. This thesis looks at social factors, at the individual level (social support) and community level (neighbourhood cohesion), to identify if social support continued to be important for physical activity participation during a time of social restriction. My research also sought to understand the general impact of the pandemic on physical activity, seeking to identify the barriers and facilitators experienced within the UK.

The evidence from this thesis adds to the literature that social support is an integral part of effective physical activity interventions that lead to positive, long-term behaviour change. Physical activity providers, researchers and interventionists should ensure that social support is built into physical activity interventions to maximise effectiveness. Online physical activity providers need to develop strategies to ensure community and social support is delivered remotely to achieve an effective behaviour change. At local and national

government level, prioritising healthy environments which encourage neighbourhood cohesion can positively impact physical activity and subsequently overall health and wellbeing. This can be achieved by joint town planning and public health planning and policy development.

This research provides additional evidence that individual social support, and the wider, community level environment is important for maintaining physical activity. This work specifically highlights that this remained the case during a period of social restrictions. This information can be applied to physical activity interventions during the winter months, when weather creates restrictions similar problems seen during to the pandemic, and physical activity drops. A key facilitator reported during the pandemic for physical activity was being active, outdoors, in greenspace, highlighting the need to build environments with well maintained, accessible greenspace. This information was disseminated to the research community and public via three publications in expert, peer reviewed, scientific journals.

Social factors have an important role in physical activity. It is essential that individual and community level social support are developed, and healthy environments are built to support physical activity leading to long-term improvement in health and wellbeing.

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VH analysed and interpreted the data and was primarily responsible for the drafting of the manuscript. AF and MH contributed to the topic, statistical analysis, interpretation of the findings and revised the manuscript. DF launched the study and contributed to its original concept and design. All authors reviewed, critically appraised and approved the final manuscript.

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VH undertook data cleaning and analysis. VH, AF and AB developed and agreed the themes. VH wrote the first draft, all authors, AF, AB, MH and DF provided critical revisions.

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Chapter 1 – Introduction

Motivation for PhD

During my career as a pharmacist, working in a variety of settings and roles in the NHS and abroad, I observed the impact of lifestyle and health behaviours on health. The NHS encourages a healthy lifestyle with numerous public health campaigns to encourage the general population to have better health by getting enough physical activity and sleep, eating a balanced diet, maintaining a healthy weight, smoking cessation, and reducing alcohol consumption. Physical activity is undertaken as part of our everyday life but is not utilised by many for its numerous well known health benefits, this disconnect led me to pursue the subject in greater depth. Understanding why some people are active and are able to maintain an active lifestyle while others do not, particularly during a period of social restrictions, could lead to improved physical activity interventions. My overarching aim is to improve patient outcomes at individual and population level by increasing consistent and sustained physical activity.

Physical activity

Definition

Physical activity is defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen et al., 1985, page 129) Exercise is a sub-category of physical activity, and defined as 'physical activity that is planned, structured, repetitive and purposeful, in the sense that improvement or maintenance of one or more components of physical fitness is an objective' (Caspersen et al., 1985, page 129). Exercise generally refers to physical activity performed during leisure time with the primary purpose of improving or maintaining physical fitness or health (Bull et al., 2020). Sport is part of physical activity and exercise, and corresponds to any institutionalised and organised

practice, based on rules (Thivel et al., 2018). Individuals can be active while not participating in sport or exercise.

Guidelines

Due to low physical activity levels globally, in both adults and adolescents (Bull et al., 2020), promoting and increasing physical activity is a public health priority. World Health Organisation (WHO) published "Global Recommendations on Physical Activity for Health" in 2010, which mainly focused on primary prevention of non-communicable diseases through physical activity. This has been superseded by new guidance, 'Physical activity and sedentary behaviour' published in 2020. The updated guidance addressed sedentary behaviour and health outcomes.

Current WHO guidelines recommend:

All adults should undertake regular physical activity

- Adults should do at least 150– 300 minutes of moderate-intensity aerobic physical activity (MPA); **or** at least 75–150 minutes of vigorous intensity aerobic physical activity (MVPA);
- **or** an equivalent combination of moderate- and vigorous-intensity activity throughout the week
- Adults should also do muscle strengthening activities at moderate or greater intensity that involve all major muscle groups on 2 or more days a week

Individuals not meeting these recommendations should start with a small amount of physical activity, doing some physical activity is better than doing none, any amount of physical activity will benefit health (Bull et al., 2020). These recommendations are supported by the UK Chief Medical Officers physical activity guidelines (published in 2019),

which advise that adults should take regular physical activity with the same recommended levels of physical activity as WHO (Department of Health and Social Care, 2019). Thus there is a clear and consistent message both nationally and internationally for physical activity.

A meta-analysis conducted in the UK of 196 large prospective studies with >30million participants found evidence of a dose-dependent association between increasing non-occupational physical activity and a wide range of health outcomes (Garcia et al., 2023). It suggests that the greatest population health benefits can be achieved through getting inactive people undertaking small increases in non-occupational physical activity (Garcia et al., 2023), endorsing the WHO recommendation that doing some physical activity is better than doing none.

According to the WHO, 25% of adults and more than 80% of adolescents globally do not meet the recommended level of physical activity (Bull et al., 2020). Insufficient physical activity is a leading risk factor for non-communicable diseases, and as such, a public health problem. However, prevalence of inactivity varies across region and income. Data from 358 surveys, across 168 countries, showed that prevalence of inactivity in 2016 was more than double in high-income countries (36·8%, 35·0–38·0), than in low-income countries (16·2%, 14·2–17·9) (Guthold et al., 2018). Data from the 2017 National Health Interview Survey in America indicated that only half, 53.8% of US adults were meeting physical activity guidelines (Ozemek et al., 2019). In the UK a report published in early 2020 showed 67% of adults (aged ≥16 years) were meeting physical activity guidelines, while 21% were classified as physically inactive (NHS Digital, Physical Activity, 2020). While survey research is a widely used by researchers and is considered an effective and reliable method of enquiry, especially on a large scale, there are limitations. They are particularly prone to participation

biases, the lower the response rate, the greater the likelihood of selection bias as an issue, with a self-selected proportion of the population responding (Suchman, 1962). Respondents could be different from those who did not respond, reducing generalisability due to missing input from different populations. There can also be issues when respondents fail to answer certain questions within the survey, leading to accuracy issues and reduced validity or provide false answers due to social desirability bias (Suchman, 1963., Sedgwick, 2013). There can be issued with the accessibility of the survey e.g., not suitable for individuals with hearing or visual impairment, access to online surveys. Digital poverty can lead to exclusion and non-response to surveys leading to further participation bias. This is of concern as digital exclusion impacts health outcomes directly via reduced access to health services and tools (Stone, 2021).

Health benefits

Regular physical activity is widely recognized to be an important part of a healthy lifestyle with demonstrated benefits for both physical and mental health and an important factor for healthy ageing (Condello et al., 2017; Cooney et al., 2014; Nazzari et al., 2016; Reiner et al., 2013). The health benefits of physical activity are well established, physical activity contributes to reducing the risk of 25 chronic illnesses such as, cardiovascular disease, hypertension, type 2 diabetes, obesity, osteoporosis. Additionally it reduces the risk of some cancers (e.g., breast, colon), mental ill-health (e.g., reduce anxiety and depression), can promote healthy cognitive function and healthy ageing, as well as a reduced risk of all-cause mortality (Nazzari et al., 2016; Reiner et al., 2013; Warburton & Bredin, 2017). Physical activity is an important determinant of cardiorespiratory fitness. A study of 13,344 healthy adults in the USA with eight years of follow up established that those subjects in the lowest quintile of cardiorespiratory fitness had a higher relative risk (RR) all-cause mortality rate

(RR 3.44 for men and RR 4.65 for women) compared to those in the highest quintile (Nazzari et al., 2016). A systematic review of 15 longitudinal studies with at least 5-year follow up, showed that physical activity had positive long-term influence on weight gain, coronary heart disease, type 2 diabetes, and dementia. This supports that physical activity is an important factor that can have beneficial effect on a number of non-communicable diseases (Reiner et al., 2013). Due to the strong link between physical activity and the prevention of a non-communicable diseases, the member states of WHO agreed, as part of the Global Action Plan 2013-2020, to a 10% relative reduction in the prevalence of insufficient physical activity by 2025 as a target to improve the prevention and treatment of non-communicable diseases (World Health Organization, 2013).

Sustained physical activity

To achieve the greatest benefits of physical activity, people need to participate in regular and consistent physical activity (Aaltonen et al., 2012; Moholdt et al., 2018; Warburton & Bredin, 2017). Although regular physical activity is an important part of maintaining good physical health and well-being, consistent engagement in physical activity remains challenging for many (Bull et al., 2020). Maintenance of behaviour is defined as; a continued behaviour shown during a given period, or after an intervention complying with a threshold believed to improve well-being or health (Kahlert, 2015). For physical activity, successful maintenance is usually defined as participants who are still active at least six months after a program has finished (Amireault et al., 2013). Sustained physical activity is not a linear behaviour, it is a process that can include multiple episodes of sustained physical activity that can be discontinued for short or longer periods of time and then resumed after a setback e.g., injury or illness (Huffman et al., 2020; Kahlert, 2015). In the physical activity literature 'maintenance' can mean different things, it can be intervention induced change

(intervention duration usually 12-26 weeks), it can relate to individuals who have increased physical activity on their own, or have always been active (Huffman et al., 2020). The majority of self-reported physical activity interventions report individuals achieving temporary behaviour change, relapsing back to a less active or inactive state when intervention support and techniques are finished (Amireault et al., 2013; White et al., 2016). A systematic review of 29 device-measured, randomized controlled physical activity interventions, and meta-analysis of 22 of the studies, found that the majority of these device measured interventions (60-80%) were effective at three months, equivalent to an additional 45 min/week MVPA (Madigan et al., 2021). While these results are promising, further research is required to see if participants have remained active or have relapsed back to less active, or inactive state, at six months, the defined duration for maintenance of physical activity (Amireault et al., 2013).

There is an ongoing need to identify and design interventions that help people to adopt long-term physical activity behaviours. Current evidence, discussed above, suggest that current interventions work at getting people active, but few participants remain active at three-six month follow-up. Identifying and understanding which factors influence behaviour is complicated as these can vary among individuals and populations. Identifying the determinants for maintenance of physical activity behaviour is essential for sustained physical activity. While the majority of physical activity interventions range from 12-26 weeks in duration (Huffman et al., 2020), there is the possibility of interventions being brought in without an end point. As noted above successful maintenance is usually defined as participants who are still active at least six months after a program has finished (Amireault et al., 2013), there is no current definition for those in long term interventions. In order to use the results of these interventions I would accept those that were active at 12

months after the start of the intervention could be described as maintaining physical activity long term.

There are multiple health benefits associated with sustained activity. Table 1. Has a summary of studies looking at health outcomes associated with sustained physical activity. A systematic review of 54 studies (RCTs and prospective observational) looking at community-acquired respiratory infections (viral or bacterial) prior to Coronavirus disease (COVID-19), demonstrated regular physical activity (via an intervention), was associated with a 31% risk reduction of infection, and 37% risk reduction in infection related death. This study also identified that after vaccination, antibody concentration was higher in active individuals, suggesting regular physical activity increases potency of vaccination (Chastin et al., 2021). While this study is promising, only six studies (N=497) investigated the effect of physical activity interventions on vaccine outcomes. Due to the small number of studies, and small overall sample size, there are limitation on the generalisability of this outcome. Further studies with larger samples are needed to provide additional evidence to support these findings.

Looking at COVID-19 specifically, a retrospective observational study of 48,440 adults living in the USA, who were diagnosed with COVID-19, showed that people who consistently met physical activity guidelines prior to the pandemic were associated with a reduced risk of severe COVID-19 outcomes (hospitalisation, admission to intensive care) and death (R. Sallis et al., 2021). This study used an electronic integrated healthcare system that links visits and diagnosis in both inpatient and outpatient settings. Self-reported physical activity was recorded at every outpatient encounter and participants were required to have at least three outpatient visits with exercise measurements between 19th March 2018 and 19th

March 2020, in an attempt to capture regular physical activity habits. Three categories of physical activity were created for the study, consistently meeting physical activity guidelines (active in all assessments, 3/3), consistently inactive (active in no assessments, 0/3), and some activity (active in some assessments, 1-2/3). The use of self-reported physical activity can introduce biases, such as recall and desirability bias. The categorisation of physical activity was not validated which could reduce the validity of the results. Patients had to have at least 3 outpatient visits with a healthcare provider within the 2 years prior to the start of the pandemic. Regular outpatient visits could suggest these patients have outstanding health conditions that require regular monitoring. Those who are already ill are less likely to engage in physical activity due to ill health, and therefore have worse outcomes. Alternatively, as this study was based in the USA, the participants may be healthier and wealthier as they were able to afford regular medical attendance provided by insurance. It is possible that the relationship between physical activity and better COVID-19 outcomes reflects underlying better health among those who are able to afford better health care, thereby reducing the generalisability of the results.

A further retrospective nationwide cohort study in South Korea, of 76,395 adults also found that adults who achieved physical activity guidelines had decreased likelihood of COVID-19 infection, severe infection, and COVID-19 related death (S. W. Lee et al., 2021). Self-reported physical activity data was used from the national general health examination (January 2018 to December 2019). Physical activity was categorised according to metabolic equivalents tasks (MET) score, and a weighted MET-mins/week calculated. Physical activity was categorized into four levels, inactive, insufficiently active, active, and highly active. The limitation of the study include, the use of self-reported physical activity, which has risk of recall and desirability bias, and physical activity was based on a single cross-sectional report,

showing no pattern of activity. The benefits of this study were its large sample size and the nationally representative sample with all individuals who took a COVID-19 test included and linked to their national general health examination data. These findings suggest there are benefits of physical activity and COVID-19 infection and death but they are unable to say if it is sustained activity.

Prior to the pandemic it was known that maintaining any level of activity compared to be inactive led to a lower risk of all-cause mortality and cardiovascular disease mortality (Moholdt et al., 2018). This study followed 3,307 individuals over a period of 30 years who reported a diagnosis of either coronary heart disease or angina pectoris. Physical activity was self-reported and assessed at three time points. Participants were grouped into three categories – inactive (no physical activity), low physical activity (below recommended levels) and high physical activity (achieving recommended levels). Participants needed to have at least 2 waves of data to be included. Changes in physical activity were categorised into 9 categories (inactive-inactive, inactive-low, inactive-high, low-inactive, low-low, low-high, high-inactive, high-low, and high-high) for analysis. As discussed before, self-reported physical activity has problems with bias, both recall and social desirability. The long time period of the study is a strength, however, the guidance on physical activity may have changed over the time period. Categorising participants as achieving/not achieving recommended levels of physical activity could have led to people changing category while maintaining the same level of physical activity which could skew the results.

Physical activity could help prevent numerous non-communicable diseases and age-related diseases such as cognitive decline (Reiner et al., 2013; Weuve et al., 2004). Regular physical activity is also associated with a reduction in symptoms of common mental health disorders (De Moor et al., 2006), and better quality of life (Alzahrani, 2022).

Table 1: Studies looking at sustained physical activity (PA) and associated health outcomes

First author (year) country	Study type	Population	Health outcome	Summary
Chastin (2021) UK (Chastin et al., 2021)	Systematic review and meta-analysis (54 studies) 42xRCTs 7x prospective observational 5xvaccination	Adults (n=557,487)	Community acquired infection, infections disease mortality, CD4 count, IgA, vaccine response	Regular MVPA is associated with 31% risk reduction of community-acquired infectious diseases and 37% risk reduction of infectious disease mortality. It enhances the immune system, and antibody concentration is higher after vaccination.
Lee (2021) South Korea (S. W. Lee et al., 2021)	Retrospective longitudinal – 2 years	Adults diagnosed with COVID-19 (n=212,768)	COVID-19 severity and mortality	Patients who engaged in recommended levels of PA were associated with decreased likelihood of infection (2.6% vs 3.1%; aRR, 0.85; 95% CI 0.72 to 0.96), severe COVID-19 illness (0.35% vs 0.66%; aRR 0.42; 95% CI 0.19 to 0.91) and COVID-19 related death (0.02% vs 0.08%; aRR 0.24; 95% CI 0.05 to 0.99) than those who engaged in regular MVPA
Sallis (2021) USA (R. Sallis et al., 2021)	Retrospective longitudinal – 3 years	Adults diagnosed with COVID-19 (n=48,440)	COVID-19 severity and mortality	Patients with COVID-19 who were consistently inactive prior to diagnosis had an increased risk of severe COVID-19 outcomes compared to active: risk of hospitalisation (OR 2.26; 95% CI 1.81 to 2.83), admission to intensive care (OR 1.73; 95% CI 1.18 to 2.55) and death (OR 2.49; 95% CI 1.33 to 4.67)
Stevens (2020) UK (Stevens & Cruwys, 2020)	Longitudinal – 14 years	Older adults (n=3896)	Physical activity	MVPA tended to decline more quickly in those who were not member of a sport or exercise group. Sports and exercise groups membership is beneficial for supporting sustained PA and health in older people

Moholdt (2018) Norway (Moholdt et al., 2018)	Longitudinal – 30 years	Adults from Norwegian health study (n=3307)	All-cause mortality, CVD mortality	There was a lower risk of all-cause mortality in participants who maintained MVPA compared to inactive (adjusted HR: 0.64; 95% CI: 0.50 to 0.83) CVD mortality was similar as all-cause mortality.
Reiner (2013) Germany (Reiner et al., 2013)	Systematic review of longitudinal studies (min 5 years) (18 papers)	Healthy adults (n=288,724)	Weight gain, obesity, coronary heart disease, type 2 diabetes, Alzheimer's disease and dementia	The reviewed studies have shown that physical activity could help in the prevention of non-communicable and age-related diseases, it appears to have a positive long-term influence on all selected diseases
De Moor (2006) Holland (De Moor et al., 2006)	Longitudinal	Netherlands Twin Registry (n=19,288)	Anxiety, depression	Regular exercise reduced symptoms of anxiety (-0.18 SD), depression (-0.29 SD) and social problem than non-exercisers
Weuve (2004) USA (Weuve et al., 2004)	Longitudinal	Older women (n=766)	Cognitive impairment	Long-term regular physical activity is associated with significantly better cognitive function and less cognitive decline in older women. Compared to the least active, the most active had a 20% lower risk of cognitive impairment and less cognitive decline over time

Sport England

Monitoring national trends in physical activity participation is essential to evaluate progress in reducing inactivity as per the WHO Global Action Plan goals. Laterally, it has provided data to track the impact of the pandemic on physical activity. Part of the role of Sport England is to measure the leisure time physical activity level of people across England through the 'Active Lives Adult' survey, providing a comprehensive and representative view of how many adults engage with sport and physical activity. These reports provide reliable and up-to-date information on physical activity patterns in England and the impact of the pandemic on physical activity.

Sport England is a non-departmental, public body, of the UK Government; its main role is to increase the number of people being active and sustain participation levels. The 'Active Lives Adult' survey, which is used to assess the activity level of people in England, is sent out to a random sample of households from across England selected from the Royal Mail's Postal Address File (gold standard for population surveys) and weighted to Office for National Statistics population measures for geography and key demographics to collect representative data from the adult population in England. Survey data weighting is a statistical technique used to adjust survey results to accurately represent the broader population, this is done to increase reliability and validity of the survey results (Biemer et al., 2012). Two people (aged ≥16 years) per household are invited to take part, they can complete the survey either online, paper version, or via telephone (if English not a first language). The overall sample is approximately 198,000 people, minimum 500 sample size for each English local authority (with boosting in some local areas) and is published twice a year in April and October. A limitation of Sport England surveys is that physical activity is self-reported, as discussed previously, this can lead to recall and desirability bias.

Participants are asked to report the time and intensity of participation in any type of activity. Activity data is reported at three levels, 'Inactive" classified as achieving less than 30 minutes a week of MVPA, 'fairly active' 30-149 minutes of MVPA/week and 'active' 150+ minutes of MVPA/week, as per WHO guidance. The UK Government base their adult physical activity reports on data from two main sources, Sport England Active Lives survey and the Health Survey for England (Office for Health Improvements and Disparities, 2022). The Sport England survey is carried out twice a yar rather than annually, so it can capture change in physical activity quickly. A report published just prior to the pandemic using Active Lives Survey data reported 67% of adults (aged ≥16 years) were meeting physical activity guidelines, while 21% were classified as physically inactive (<30minutes on average per week) (NHS Digital, Physical Activity, 2020).

COVID-19 Pandemic

Coronavirus disease (COVID-19), an infection caused by the SARS-CoV-2 virus, was identified December 2019 in Wuhan, China. The virus infects the lungs and respiratory tract causing respiratory type symptoms (WHO, 2021) . In severe cases, infection can lead to respiratory failure or complete organ failure requiring hospital admission, intensive care, and ventilation. People at greatest risk of developing serious COVID-19 infection are the already vulnerable population; older adults, people with serious underlying medical conditions and those who are immunocompromised (Ainsworth & Li, 2020). Despite attempts to isolate the outbreak, COVID-19 spread across the world with the WHO declaring the outbreak a Public Health Emergency of International Concern on 30th January 2020 and a global pandemic on 11th March 2020. Strategies to manage COVID-19 were put in place, many involved restrictions on freedom of movement. Within the UK measures included lockdown, people

were ordered to stay at home, permitted to leave for essential purposes only, such as buying food or for medical reasons, and 2m social distancing rule. Despite these restrictions time outside to exercise was allowed, engaging in daily exercise was encouraged, and meeting recommended daily activity levels was possible for many. The exception was for those who were classified as shielding/sheltering in place, and those who were resident with them, who were advised to stay inside and shield in their homes, making in-home physical activity the only option. The pandemic restrictions provided a unique 'natural experiment' to explore the social factors associated with sustained physical activity through challenging times.

Restrictions

Initially gyms, parks, community centres and other public spaces used for social activities and physical activity were closed in response to COVID-19. These closures resulted in a disruption and change to routines for work, commuting, social engagements and physical activity. The change in access to sport/exercise groups and a strict time limit, changed the dynamics of physical activity. While some sports/exercise groups and facilities have returned as before, some have not returned to their pre-COVID-19 format and others have not returned at all (Sport England, 2022). This can be seen both in a group and individual context with access to sport and exercise groups limited (due to closure and social distancing) from March 2020 through to the removal of all restrictions in April 2022, and the end of the pandemic in May 2023. Table 2. provides a timeline of COVID-19 restrictions across England, Scotland, Wales and Northern Ireland. The home nations introduced the first lockdown at the end of March 2020 with only minor differences in their approaches. At points during the pandemic the devolved governments have taken a slightly different approach e.g., some green spaces, such as Snowdonia, were closed due to the high visitor

numbers when restrictions were lifted. However, there is limited scope for significant policy differences (Brown & Kirk-Wade, 2021; Sport England, 2021b).

Table 2. Timeline of COVID-19 restrictions in England, Scotland, Wales and Northern Ireland 2020 to 2023 (Institute for Government, 2020; Brown and Kirk-Wade, 2021; Sport England, 2021b; Senedd Wales Research, 2022; SPICe Spotlight, 2023; WHO news, May 2023;

Date	**COVID-19 restriction**
2020	
Mid-March to mid-May	National restrictions (**lockdown 1**) People told to stay at home Sports facilities closed, restrictions applied to all indoor activity and organised outdoor activity. Single daily allowance of activity allowed
Mid-May	People can go outside more than once a day to exercise Meeting one person outside your household outdoors allowed
June	Schools reopened in England for limited ages groups (year 1 and year 6). In Wales, for all age groups. Groups of 6 people allowed to meet outdoors (rule of 6). Indoor gatherings of two people from different households permitted. Outdoor training sessions allowed Scotland and Wales, 'stay at home' changed to 'stay local' e.g. five miles
Early July	Local Lockdown regulations introduced and used Northern Ireland, outdoor sport restarted but keep indoor facilities, such as dressing rooms and gyms closed
Mid-July	Playgrounds and outdoor pools reopened. Organised sports restarted
End- July	Gyms, indoor pools and leisure centres reopened
Aug	Pupils returned to Scotland's schools, all year groups Schools in Northern Ireland reopened to all pupils since lockdown
Sept	Schools in England and Wales reopened to all age groups Tightening of rules on social meeting in Wales (rule of 6)
Mid-Sept to Oct	Restrictions reintroduced for meeting indoors, including indoor sports Reintroduction of maximum of 6 people allowed to meet outdoors Three tier system introduced based on location Wales, 'firebreak' lockdown (23/10/2020 to 09/11/2020) Northern Ireland, schools closed for two weeks (19/10/2020 to 02/11/2020), physical education classes to be held outdoors
November	National restrictions (**lockdown 2**) Schools remained open Restrictions applied to all recreational indoor activity and organised outdoor activity. People could leave home to meet 1 person outside their support bubble
December	New fourth tier added to the system

	First vaccinations are carried out Travel and visiting restriction over the festive period
2021	
January to March	National restrictions (**lockdown 3**) People told to stay at home Schools to use remote learning except in the case of vulnerable children and those of key workers Can exercise within household or one other person
April to July	Lockdown restriction lifted Roadmap out of lockdown introduced
July	Most legal limits on social contact removed e.g., social distancing and limits on gatherings
December	Temporary restrictions introduced - facemasks and 2m rule in shops and public transport, working from home advised
2022	
January	All temporary restrictions lifted Masks continue to be recommended in crowded and enclosed spaces
April	All restrictions lifted
2023	
May	WHO declare COVID-19 is no longer a pandemic

Impact on physical activity

The COVID-19 pandemic resulted in major disruption to physical activity levels, with a global reduction in all intensities of daily physical activity and increased sedentary behaviour reported (Ammar et al., 2020; Tison Geoffrey, 2020). A systematic review and multilevel meta-analysis of 173 observational studies with 320,636 participants, identified that COVID-19 restrictions resulted in a moderate reduction in total physical activity (SMD -0.65, 95% CI -1.10 to -0.21, p= 0.004) and walking (SMD -0.52, 95% CI -0.29 to -0.76, p= <0.001), and a large increase in sedentary behaviour (SMD 0.91, 95% CI 0.17 to 1.65, p= 0.02), reductions in physical activity affected all intensities (Wilke et al., 2022). In the UK, a national survey of ~2000 adults, reported 41% respondents doing less physical activity in the first week of April 2020 (lockdown 1) compared to before the restrictions, although 31% reported doing more (Sport England, 2020). As noted above, the 'Active Lives' survey is a representative,

repeated, survey of physical activity participation in the English population. The November 2019/2020 report showed there were 1.9% (700,000) fewer active adults compared to 12 months earlier, and 2.6% (1.2million) more inactive adults (Sport England, 2021a). Activity levels were affected the most during lockdown 1, with a drop of 7.1% (3million) active adults in the UK (Sport England, 2021a). Worryingly, this reduction in activity continued past lockdown, coming out of the pandemic there were still 1.9% (600,000) fewer active adults and 2.6% (1.3million) more inactive English adults in 2020-2021 compared to pre-pandemic (Sport England, 2022). This suggest that activity has stabilised since the beginning of the pandemic when we saw a dramatic reduction in activity, numbers are recovering slowly but remain below pre-pandemic levels. While these reports only represent England, due to similar pandemic restrictions across the UK it is thought they are likely to be similar results across the UK.

A systematic review of 66 studies (45 self-reported; four device-based) looked at changes in physical activity during COVID-19 (Stockwell, Trott, Tully, Shin, Barnett, Butler, McDermott, et al., 2021). The majority of the studies found that physical activity declined, and sedentary behaviour increased during lockdown, although a proportion of participants reported no change in physical activity. The tools used to measure physical activity were different across the studies making direct comparison of results difficult, however, the overarching outcome of the review showed that physical activity decreased during lockdown compared to pre-lockdown. An additional limitation was the relatively poor quality of the studies, self-reported measures were used which brings a risk of bias such as recall, social desirability, and measurement bias (Sylvia et al., 2014). Many asked participants to retrospectively report physical activity (pre-lockdown) and current behaviour (during lockdown) leading to potential recall bias and reporting accuracy issues. All studies were cross-sectional, taking

measurements of physical activity at a single time point during the pandemic, allowing comparison of different population groups at that time point only. Longitudinal studies can establish sequences of events, repeated measures on the same participants shows change in measures, such as physical activity, over time (Rindfleisch Aric et al., 2008). Although ethnicity, age, level of education, socioeconomic position, urban living and good health status are all well-known predictors of physical activity (Bauman et al., 2012; L. Smith et al., 2015) demographic information was limited and therefore not included in the analysis so residual confounding cannot be discounted. Information on the level of lockdown was also not reported making it difficult for comparison between studies (Stockwell, Trott, Tully, Shin, Barnett, Butler, Mcdermott, et al., 2021). A rapid review of 61 quantitative studies concluded that COVID-19 was linked with a significant negative impact on physical activity and increase in sedentary behaviour with differential effects across sub-populations (Park et al., 2022). The following studies looked at the impact of the pandemic on daily physical activity in adult populations and provide further information on which groups were most affected and in which way.

A study of 490 adults in Northern Italy reported that 35% performed less, 28% did no activity, 22% performed more, and 15% reported an unchanged level of physical activity during COVID-19. Of those who were active prior to COVID-19 (>2hrs MVPA/week), 32% continued their habitual exercise or increased it, and 27% of the subjects who were previously inactive increased their activity (Cancello et al., 2020). This study demonstrates that while the majority of participants reduced their physical activity, there was a proportion who were able to positively navigate lockdown and continue to be active or even increase activity levels. Being ≥30 years old and having positive pre-lockdown habits of physical activity were the main determinants of physical activity. Data was collected via self-

reported survey, participants were asked report their physical activity prior the pandemic and the change that occurred during the pandemic. Bias cannot be excluded due to the use of self-reported responses and the use of a non-validated question regarding physical activity. However, this study does provide insight into how people perceived their physical activity behaviour during this time.

A UK based study of 5395 smartphone users showed a reduction in physical activity during the lockdown however, there were differences in the populations affected. This showed that younger people were more active prior to lockdown but dropped to the least active after lockdown, those aged >65 years were more likely to remain active during lockdown and increase activity as soon as lockdown finished. Those who were physically active pre-pandemic showed the largest reduction in physical activity (McCarthy et al., 2021). A limitation of this study was that only outdoor physical activity was tracked, indoor activity that may have substituted outdoor physical activity was not collected. The study was prone to selection bias due to data coming from those who subscribed to a physical activity app suggesting they were interested and participating in physical activity prior to the pandemic.

A study using Active Lives data compared data from 2016-19 and May 2020 (n=725,257), showed population physical activity declined substantially after COVID-19 restrictions were introduced. Compared to pre-pandemic levels of activity, the odds of reporting any activity were 30% lower during the first lockdown. The decline was not uniform across demographics with the largest declines seen in non-white ethnicities, the young and old age groups and the unemployed (Strain et al., 2022).

A longitudinal study of 759 adults in New Zealand looked at pre-, during-, and post-lockdown physical activity. This showed that those individuals who were highly active pre-

lockdown, their MVPA dropped during lockdown and remained at this level post-lockdown, although their walking behaviour stayed the same throughout. Individuals who undertook moderate activity pre-lockdown, their MVPA increased, post lockdown the increase in vigorous activity remained while moderate activity returned to pre-lockdown levels. Walking was higher during lockdown before returning to pre-lockdown levels (Hargreaves et al., 2021). A further online study of 1098 Canadians indicate that while 40.5% of inactive individuals (<149mins/wk MVPA) became less active, reporting a drop in the average number of minutes of physical activity, only 22.4% of active individuals became less active. Comparatively, 33% of inactive individuals became more active while 40.3% of active individuals became more active (Lesser & Nienhuis, 2020). While there is evidence that that the pandemic changed physical activity, there is less evidence looking at what factors supported those who stayed active during this period. While there is some demographic data available about those who remained active, there is little published research looking at what social factors were associated with physical activity through lockdown and the pandemic.

There are few COVID-19 and physical activity qualitative or mixed methods studies that have been conducted and published to date. These add to what is known and allow researchers to gain insight to the lived experience and challenges faced to stay active during the pandemic. Quantitative research allows us to identify who, and how many stayed active. Qualitative research allows us to understand the everyday experience in its complexity and its natural settings. It is concerned with how the social world is interpreted, understood, experienced, or constructed and can be used to identify what empowered and supported people to stay active and what where the barriers (Cleland et al., 2018).

One study in India aimed to understand 22 adults attempts to maintain an active lifestyle during the COVID-19 pandemic (Kaur et al., 2020). Participants described how during the initial lockdown they had a lack of motivation for exercise, however there was a gradual increase in motivation and participation in fitness exercises at home (Kaur et al., 2020). This study recruited only previous regular gym attenders, so findings may not be transferable. A qualitative study of 12 adults in Canada, with a range of physical activity levels, found that physical activity that could not be undertaken due to COVID-19 restrictions were often replaced by other types of activity. For those who required access to specific sports facilities, some did not find an appropriate alternative activity (Petersen et al., 2021). Both studies were specific in their focus and had a small sample size so do not allow comparison across demographic groups.

The reduction in physical activity during the pandemic could have both short and long-term impact on the health and wellbeing of the population. As described above, there are lots of studies looking at the changes in physical activity during the pandemic, the demographics of those who changed, and which groups were most affected. In these studies, the majority of participants reported a reduction in physical activity, however, there was a minority of people who maintained their pre-pandemic levels and some who increased their physical activity. By maintaining physical activity habits people demonstrated resilience to a change in environment e.g., working from home, being furloughed, and the ability to adapt quickly to the lockdown environment. My studies looked specifically at the people who were able to achieve physical activity targets during the pandemic, and try to understand what helped them navigate this changing environment while remaining physical active.

Theoretical models are often used to develop physical activity interventions which are aimed at initial behaviour change (Howlett et al., 2019b). There is a distinction between initial behaviour change and behaviour change maintenance (Howlett et al., 2019b). Using a theoretical model to capture maintenance behaviour is a way of synthesizing successful approaches.

Theoretical Perspectives

Social Cognitive Theory (Bandura. 1986), Theory of Planned Behaviour (Ajzen.1985), Social-Ecological Model, and Health Belief Model (Arafat. 2018) are commonly used to understand health behaviours, including physical activity behaviour. All the theories listed include the importance of social factors (social support and social connection) as a construct for the initiation and maintenance of behaviour change (Lindsay Smith et al., 2017). Cognitive-behavioural theories and models focusing on social relationships, stress, and coping have been used to understand the link between social support and health for many years. They are also commonly used to understand the link between the social environment, such as social support and neighbourhood cohesion, and behavioural indicators of health, such as diet and physical activity, and in the development of physical activity interventions (Scarapicchia et al., 2017). Some of the exercise psychology literature recommend increasing motivation for physical activity by shifting the decision balance by creating a belief that there are more benefits to becoming active than barriers. This can be achieved by bolstering self-efficacy, and creating social environments that promote perceptions of autonomy, competence, and relatedness (Brand & Cheval, 2019). Having social support or supportive social relationships can aid in engaging in physical activity and are commonly used to develop interventions (Cohen & Wills, 1985; Scarapicchia et al., 2017). The evidence for the sustainability of behaviour change in response to theory based

interventions is limited with many theories not explicitly addressing the issue of behavioural maintenance (White et al., 2016, Howlett et al., 2019b). It is thought that motivations for maintenance could be different from those that prompted individuals to make initial changes (Huffman et al., 2020). For example, there is evidence to support that extrinsic motives (getting fitter, weight loss) dominate during the start of physical activity adoption while intrinsic motives (competency and enjoyment) are important for the maintenance of physical activity (Aaltonen et al., 2012; Huffman et al., 2020), however, there are still gaps in our understanding of the factors and motivations associated with adoption versus maintenance. This lack of understanding is mainly due to the limitation in study design, both in methodology and reporting. The Theoretical Domains Framework aims to provide a theory-informed approach to identify determinants of behaviour, while the domains cover the physical and social environment, the majority relate to individual motivation and capability factors (Atkins et al., 2017). This has been linked to a simpler model of behaviour, the Capability, Opportunity, Motivation behaviour model (COM-B). This model was developed as a framework to use for intervention development and reporting to address some of these issues (Michie et al., 2011).

COM-B model

A theory or model guides an intervention, ensuring that the target behaviour and predicted mechanism of action are identified and analysed (Michie et al., 2011). However, Michie et al. reviewed existing interventions and identified that even when models or theories were used, important aspects of behaviour change were often being missed. The COM-B model was developed to rectify this and specifies capability, opportunity, and motivation as the drivers of behaviour change (Michie et al., 2015). The COM-B framework can be used to highlight barriers and facilitators predictive of physical activity, allowing identification of

which behaviours should be targeted for intervention development (Howlett et al., 2019; Michie et al., 2015). The COM-B model maps directly onto the intervention and specifies, capability (*social* and *physical*) and motivation (*reflective* and *automatic*), as the drivers of behaviour (Howlett et al., 2019a). The constructs of capability and motivation have been found to explain a large variance in moderate to vigorous physical activity, while opportunity (*physical* and *social*), weakly predicted motivation (Howlett et al., 2019a). Although cognitive-behavioural theories and models are commonly used to develop physical activity interventions (Scarapicchia et al., 2017), they are used less often used in qualitative research. Theoretical frameworks can be utilized to guide qualitative research by suggesting concepts to explore and relationships, effectively providing a map for qualitative exploration. A theoretical framework can be useful where there is an abundance of data by helping to direct the research to a particular area of interest (Garvey et al., 2021).

In order to inform intervention design, it is useful to map qualitative findings onto a theoretical intervention development framework. The COM-B posits that both capability and opportunity influence motivation making it the central mediator of the model (Howlett et al., 2019a). Mapping qualitative work to the COM-B model has been utilised in pre-pandemic studies (Howlett et al., 2019a; Willmott et al., 2021) and in a study of adherence to government guidelines during the pandemic (Burton et al., 2022).

The use of the COM-B model to map the themes identified in study 2 guided the second half of my PhD. As noted above capability and opportunity influence motivation making them important qualities to build into interventions. Using study 2's themes mapped to the COM-B model provided guidance to explore concepts which contained capability and opportunity leading to study 3 and 4.

Social-Ecological model

The Social-Ecological Model (SEM) constructed by Bronfenbrenner (1977), proposed that health behaviours are affected by a range of variables. The social-ecological approach to physical activity puts forward a multidimensional approach, it posits that individual characteristics, the social environment and physical environment alongside the political environment all play an important role in health behaviours and outcomes which are interrelated and embedded in a complex system. Individual level factors include demographic characteristics such as age and sex. The social environment considers how supportive the people around an individual are of physical activity participation. The physical environment considers factors such as access and quality of facilities. Finally, the political environment describes the laws and policies of the central and local governments for engagement in physical activity. Using the SEM approach in the promotion of physical activity helps to examine the multiple factors that might be determinants of physical activity (Mehtälä et al., 2014). The model helps us to identify opportunities to promote physical activity by recognizing the individual, the behaviour (e.g., physical activity), the social environment (e.g., social support, neighbourhood cohesion) and the physical environment (e.g., facilities) that may influence one's ability to be sufficiently physically active (Mehtälä et al., 2014). Research has established the individual level attributes that contribute to an active lifestyle; younger age, male gender, white ethnicity, prior fitness level, higher education and higher socioeconomic position (Seefeldt et al., 2002). Older adults with physical disabilities, low education attainment, Black, Asian and minority ethnic (BAME) background, women, workers from lower socioeconomic strata and undernourished individuals are less likely to adopt and maintain physical activity (Seefeldt et al., 2002). Previous research has shown that the social environment may influence physical activity,

this thesis primarily considers social support and sustained physical activity at both the individual level and the group level.

Social Factors

The influence of social factors is widely recognised in health behaviour research and is considered an important determinant of health. Most health behaviours, including physical activity, are socially patterned, positively impacting those in resource-high social and physical environments, conversely negatively impacting those that live in resource-deficient social and physical environments (McNeill et al., 2006). Physical activity is particularly responsive to the social environment as most activities happen within the bounds of families, communities, and neighbourhood making it vulnerable to the shifting environment created by the COVID-19 pandemic.

Social support

Lockdown measures taken to counter the spread of COVID-19 disrupted daily routines and influenced health behaviours. Pandemic measures were restrictive, impacting social order and social norms. Social networks that form ties between individuals were challenged by social distancing and lockdown. Social constructs, such as social support were affected, with a potential corresponding effect on physical activity. Social support is itself not a single entity but complex and multidimensional. Despite its complexity it is defined as 'the extent to which individuals perceive those around them are available to them and are attentive to their needs' (Kafetsios & Sideridis, 2006, page 864). Multidisciplinary research in social science has established that positive social support is an important factor for individuals maintaining physical health, mental health, and coping with health challenges (Cohen & Wills, 1985; Kafetsios & Sideridis, 2006; Ozbay & Johnson, 2007).

Social support has two main constructs; structural support and functional social support (Kocalevent et al., 2018). Structural support pertains to the size, type and frequency of social network. Functional support relates to the degree to which these relationships serve a function and provide resources and has five established forms (Golaszewski & Bartholomew, 2019; Stapleton et al., 2015).

a) instrumental or material support, to help to solve practical problems such as, transport or childcare
b) emotional support, can take many forms such as, concern, provision of care, empathy or praise and encouragement
c) cognitive or informational support, refers to information, knowledge and advice such as, feedback from a coach
d) companionship support, refers to other doing similar activities such as, exercise class or group training session
e) validation support, agreement with the recipient's perspective of a situation

Due to the broad definition of social support it is not always clear the type, or where, support is derived from. It has been reported that the primary sources of support, both emotional and practical, are family, friends, peers and partners (Scarapicchia et al., 2017). It is an important distinction to be made between the social support an individual receives, and an individual's perception of that support. Both received and perceived social support are commonly measured variables, however, the relationship between them has been found to be consistently only moderate (Melrose et al., 2015). Received support refers to the quantity of support behaviours received by an individual, perceived social support refers to how individuals perceive friends, colleagues and family members as available to provide functional and overall support during times of need (Ioannou et al., 2019). Only perceived social support is regarded as a sensitive measure in the context of ability to cope with challenges and is related to better physical and mental health outcomes and quality of life

(Kocalevent et al., 2018). As noted above, perceived social support is a more sensitive measure in the context of coping with challenges. And perceived social support was the social support variable collected in the datasets, I decided to focus on perceived social support.

A study of 332 older South Korean adults (>65years), recruited from sports centres for older people, found that perceived social support has a significant positive effect on physical activity (Kang et al., 2018). While this was a small study it illustrates the positive effect of perceived social support. A positive statistically significant association has been shown between social support and physical activity (Bauman et al., 2012; van Luchene & Delens, 2021). A systematic review of 25 papers examined the relationship between social support and physical activity among college and university students. The results suggested there is a positive association between them, although the source of social support is not clear (van Luchene & Delens, 2021). A review of 9 systematic reviews showed consistent positive association with physical activity and social support in adults (Bauman et al., 2012). Limitation of the literature is lack of clarity of which type of social support is being measured, perceived support is consistently associated with positive health outcomes while received support is inconsistent (Melrose et al., 2015). This thesis will concentrate on perceived support.

Although there is a lack of data on the impact of social support on physical activity during the COVID-19 pandemic, eight systematic reviews pre-pandemic looked at the impact of social support on physical activity, table 3. has a summary of the systematic reviews. Five reviews showed a small positive association of social support with physical activity behaviours, although the specific type or source of social support remained unclear

(Bauman et al., 2012; Scarapicchia et al., 2017; Tay et al., 2013a). All the reviews identified limitations reporting a high level of study variability. In particular there was high variability in the type and sources of social support (general or physical activity specific) and the type and reporting of physical activity (self-reported versus objective), making comparison difficult. Studies were predominantly observational and cross-sectional with few longitudinal studies, and therefore at risk of confounding bias which is common in observational studies. Confounding is described as a blurring of effects and happens when simultaneous effects of other factors/exposures occur that could also cause the outcome (Jager et al., 2008). Without controlling for confounding inaccurate association can be identified and obscure the real effect. Another limitation was a lack of experimental studies. Due to research predominately coming from cross sectional studies, further research is needed to understand if changes in social support precede changes in physical activity or vice versa. Looking at longitudinal data will allow for better understanding of the relationship between social support and physical activity and provide evidence of a causal relationship (Bauman et al., 2012).

A 2017 systematic review and meta-analysis of 20 longitudinal studies looked at the direction and strength of the relationship between social support and physical activity in healthy adults (Scarapicchia et al., 2017). The strength and direction of the association between social support and physical activity was inconsistent across the studies. Based on meta-analysis of 4 studies, there was a small positive association between support from friends and physical activity levels, although effect size could not be determined due to the small number of studies (Scarapicchia et al., 2017). All studies used self-reported physical activity, which is a limitation and commonly employed the *Social Support for Exercise Survey*. The scale consists of a 15-item scale regarding family support and 5-item scale with

regarding friends' support. Participants responded on a 5-point Likert scale how often (1, none to 5, very often) in the past 3 months family or friends have said or done what is described in the items (e.g., offered to exercise with me), an average social support score was calculated for friends, family, and combined friends and family. It assesses the frequency of such support and is designed to measure if family members or friends influence physical activity behaviour (Golaszewski & Bartholomew, 2019; J. F. Sallis et al., 1987). The *Social Support for Exercise Survey* is considered reliable and widely used tool with a Cronbach alpha of .90 (family members = .89; friends = .90) (Golaszewski & Bartholomew, 2019). A further systematic review in 2017, including 27 papers (25 observational, two interventional), looked specifically at the association between older adults and physical activity (Lindsay Smith et al., 2017). They reported that people with greater social support specific for physical activity, especially from family members, are more likely to participate in physical activity. When looking at leisure time physical activity, a positive association was found for social support from both friends and family. Those participants who reported being lonely had lower physical activity levels (Lindsay Smith et al., 2017). The two interventional studies in the review showed similar findings to the observational studies, both reported increased support and physical activity in the intervention group compared to control group.

While there were cross-sectional studies looking at the impact of COVID-19 on physical activity, at the beginning of the thesis, there were no longitudinal studies of social support and physical activity during the pandemic. There was only a single, small, cross-sectional study exploring social support specific to physical activity during COVID-19 (Van Luchene et al., 2021). In this study 272 Belgium adults responded to an online survey in the first weeks of lockdown which aimed to explore the impact of COVID-19 lockdown on physical activity

and social support specific to physical activity from friends and family. Although statistical analysis showed no significant difference in the amount of physical activity between before and during lockdown, the participants reported restrictions on social contacts, isolation of people from their networks and therefore social support, resulted in a significant decrease in social support for physical activity from friends across the entire population (students, workers & retirees). Social support for physical activity from family showed increase among students while there was a decrease for workers and retirees. This change in support for students is thought to be related to students returning to families during lockdown (Van Luchene et al., 2021). This study demonstrated that the pandemic restrictions have the potential to diminish or change social support, which could contribute to a reduction in physical activity.

Table 3. Summary of systematic reviews looking at the impact of social support on physical activity

First author (year)	Type of review	Sample type	Type of social support	PA	Results
Van Luchene (2021) (Van Luchene et al., 2021)	Systematic review 25 studies (22 cross sectional, 3 longitudinal)	College students	SSPA	Self-reported	SSPA was positively associated with active behaviours
Lindsay Smith (2017) (Lindsay Smith et al., 2017)	Systematic review 27 studies	Older adults	All types	23 x self-report 4 x accelerometery	People with greater SS for PA are more likely to do LTPA, especially when the SS comes from family members
Scarapicchia (2017) (Scarapicchia et al., 2017)	Systematic review 20 prospective studies	Adults	All types	Self-report leisure time PA	Inconclusive associations between overall SS and the maintenance of PA and a small positive association between support for PA from friends and future PA
Mendonca (2014) (Mendonça et al., 2014)	Systematic review 75 articles (64 cross-sectional, 2 interventional, 9 longitudinal)	Adolescent	All types	Objective (17%), self-report (77%), and combined (6%)	Social support was positive and consistently associated with the physical activity level of adolescents. Those who received more overall social support as well as support from both parents, friends and family showed higher levels of physical activity
Amireault (2013) (Amireault et al., 2013)	Systematic review 31 studies (6 x social support)	Adults	General SS (6 studies)	Self-report	Non-significant result for SS from friends, other types of SS results were inconsistent of too few studies
Tay (2013) (Tay et al., 2013)	51 Studies, 11 PA specific (4 observational studies, 4 narrative review, 2 narrative systematic review)	Adults and children	General SS	unclear	Social support was associated with exercise adherence. Family and social relationships showed an effect on exercise behaviour

Bauman (2012) (Bauman et al., 2012)	Review of reviews 16 reviews (9xadults 7xchildren/adolescents)	Adults and children	All types	Self-report and accelerometer	*Adults*: social supports are correlates of PA but not determinants, family support was positively associated with PA *Children*: Family support was identified as a correlate in children and adolescents, but it was not a determinant in children *Adolescents:* general social support for physical activity was confirmed as a determinant in one review
Trost (2002) (Trost et al., 2002)	Systematic review 38 studies (7x prospective 31 x cross sectional)	Healthy adults	Social support (9 studies) Social integration (29 studies)	Self-report	A significant positive association was found between social support for physical activity

Social isolation and loneliness

During the pandemic, due to lockdown and ongoing social restrictions, there was increased risk of social isolation and loneliness. An increase in either has the potential to influence physical activity behaviour. Social isolation and loneliness are known to have a negative impact on health and increase utilization of health services, especially in older adults (Steptoe et al., 2013; H. Wang, Zhao, et al., 2019). Social isolation and loneliness are distinct from, although related to, social support. While social isolation refers to a lack of social contact with others, loneliness refers to the perception that one's social contact is insufficient to meet one's emotional needs (de Jong Gierveld & van Tilburg, 2010; K. J. Smith et al., 2020).

The 'UK Wellbeing and Loneliness Survey', a household self-completion survey of adults in the England, reported 9% of respondents being lonely in 2020/21, a similar proportion reported in 2019/20 (UK Government, 2021). The Office of National Statistics analysis *Mapping loneliness during the coronavirus pandemic* reported levels of loneliness across the pandemic. In the spring of 2020, during the first lockdown, 5% of adults reported feeling lonely 'often or 'always. Subsequent survey results from October 2020 to February 2021 showed an increase to 7.2%. Areas with higher rates of loneliness were identified as areas with higher numbers of young adults (aged 16-24) and areas with higher rates of unemployment. According to the UK based COVID-19 Psychological Wellbeing Study, a cross-sectional online survey of 1964 adults, reporting that rates of loneliness were higher with a prevalence of 27% during the initial phase of lockdown (Groarke et al., 2020). This data shows an increase in loneliness, with the lockdown measures put in place to combat COVID-19 the risk of social isolation was increased with a corresponding negative impact on physical activity. Pre-pandemic a study of 267 community-based men and women, taking

part in the English Longitudinal Study of Ageing (a longitudinal panel study), wore wrist mounted accelerometers which recorded 24-hour activity for a 7-day period. It was found that social isolation had a negative effect on the amount of light or moderate/vigorous physical activity undertaken, and an increased the amount of time in sedentary behaviour. When looking at loneliness, no association was found with physical activity or sedentary behaviour (Schrempft et al., 2019). This finding was consistent with another large study (N= 3,393) of older people using English Longitudinal Study of Ageing (Kobayashi & Steptoe, 2018). The social isolation measure was created specifically for the study and not validated. Results for isolation status were heavily skewed to 'not isolated' leading to the variable being dichotomised (isolated/not isolated). Loneliness was measured using a known and validated scale (UCLA loneliness scale) which showed high internal consistency. The small sample size, skewed data, and unvalidated social isolation scale could be a serious methodological limitation therefore results from this study should be viewed with caution. Additionally, accelerometers were wrist mounted which is popular due to low participant burden, however, wrist accelerometers capture less sensitive data, detecting upper-body movement, such as household task and are less accurate than waist mounted devices for measuring MVPA (Liu F. et al., 2021).

The systematic review by Smith et al, 2017 (described above) also looked at the association between loneliness and physical activity. Six observational studies were included in this analysis, one low quality paper was removed from the synthesis and four of the studies found a significant negative association, indicating that people who were lonely had lower physical activity levels. High variability in measurements used to assess loneliness and physical activity made it difficult to compare studies. Given the low number of studies included in this review, further research is advised (Lindsay Smith et al., 2017).

A further systematic review of 36 studies, 24 cross-sectional, seven longitudinal and five interventional, looked at the relationship between physical activity and loneliness. Most of the studies addressed adolescent (age 14-19 years) or older samples (≥65 years). Fourteen studies (four longitudinal, nine cross sectional and one experimental) aimed to analyse the influence of loneliness on physical activity. The four longitudinal studies found loneliness to be associated with less physical activity across the study period. Overall, it was found that loneliness was associated with reduced effort and engagement with physical activity. The five interventional studies found that physical activity programs can contribute to a reduction in loneliness, related to the positive change in social support from other physical activity course members (Pels & Kleinert, 2016).

Due to the inconsistent results regarding loneliness and physical activity, it has been suggested that social support could be both a moderator, affecting the direction and strength of the relationship, and a mediator, explaining the influence of physical activity on loneliness. There is little published data on mid-adulthood individuals.

Neighbourhood cohesion

Where we live contributes to the exposures that influence our knowledge, attitudes, behaviours and health. Neighbourhoods can be a source of resources, or a source of stress, which can in turn influence health (McCulloch, 2003). Neighbourhood factors are increasingly recognised as determinants of health and of health behaviours (McNeill et al., 2006; Yi et al., 2016). Neighbourhood cohesion is often used interchangeably with social cohesion and is a construct of the social environment (McNeill et al., 2006). It has been described as the perceived degree of connectedness between and among neighbours and their willingness to intervene for the common good (McNeill et al., 2006, p1016), a sense of

belonging and social connection with neighbours (Buckner et al., 1988, p774) or the solidarity and connectedness within a group of individuals (Sampson et al., 1997, p919). Buckner (Buckner et al., 1988) developed an instrument to conceptualize and measure neighbourhood cohesion as a social construct. Three dimensions were chosen to produce a valid instrument: sense of community, attraction to the neighbourhood and degree of interaction within the neighbourhood. A neighbourhood high in cohesion refers to a neighbourhood where residents, report feeling a strong sense of community, engage in frequent acts of neighbouring, like living there, and plan to remain residents of the neighbourhood (Buckner et al., 1988) .

There is growing evidence, predominately from the USA, that neighbourhood cohesion may influence physical activity behaviours with a number of studies looking at the interaction between neighbourhood cohesion and physical activity. Data from 23,006 participants of the USA National Health Survey (2017), a cross-sectional household interview survey, showed a positive relationship between neighbourhood cohesion and meeting physical activity guidelines. These associations remained after accounting for covariates such as age, sex, ethnicity, income, education, English language proficiency and US native. Respondents who reported having higher social cohesion had 45 minutes/week more of aerobic activity and increased odds of meeting aerobic, strength and combined guidance (Quinn et al., 2019) . Physical activity was based on self-reported MVPA of >10minutes. Moderate and vigorous activity was calculated as minutes completed per week, and binary coded as achieving guidelines or not. Strength training was also binary coded and three outcomes produced; meets aerobic guidelines, meets strength guidelines, meets both. By dichotomizing the variables and combining them sensitivity would have been lost particularly for aerobic exercise outcomes.

A cross-sectional study of 1359 ethnically and socioeconomically diverse adults living in urban neighbourhoods in the USA, showed that poor overall neighbourhood perception, and poor physical and social environment were associated with decreased physical activity after accounting for sex, ethnicity and socioeconomic position (Claudel et al., 2019). Physical activity was self-reported with a subset of only 404 participants who had sedentary behaviour measured via 7-day accelerometery. Use of objective measures to compliment self-reported physical activity and bigger sample size would be beneficial to reduce self-report data bias and increase statistical power.

A retrospective study of changes in physical activity in 449 adults in the USA demonstrated a relationship between physical activity and social cohesion. In this study participants had moved to a 'walkable' community, reporting an increase in physical activity, social interactions and neighbourhood cohesion across the sample (Zhu et al., 2014). This study is cross-sectional and relied on recall of physical activity prior to moving to the community introducing the risk of recall bias. While both physical activity and neighbourhood cohesion increased, it was not possible to assess the causal direction of the relationship. In a UK study of 5,923 adults from income-deprived communities, higher social cohesion and safety had the largest positive effect on the likelihood of walking in the neighbourhood. Participants reporting higher levels of cohesion were nearly twice as likely to walk regularly in their neighbourhood (Sawyer et al., 2017). Limitations of this study were that it was context-specific which limits generalizability. Physical activity was self-reported, introducing recall and social desirability bias, reducing validity and reliability of the measure. The study was cross-sectional, thus it is not possible to assess the casual direction of the relationships.

Investing in the neighbourhood environment can potentially improve residence health, including increasing physical activity. A natural experiment from two low-income urban neighbourhoods in a US city, matched on socioeconomic position, ethnicity, income and education, assessed accelerometery measured physical activity, active transport and neighbourhood satisfaction both before and after neighbourhood investment. The results showed no statistically significant differences in physical activity or neighbourhood satisfaction after neighbourhood investment between the intervention and control neighbourhoods (Dubowitz et al., 2019). Limitations of this study include that follow up was relatively short (three years), potentially the improvements were not extensive enough to generate change in the environment. A greenspace regeneration project was initially planned but did not happen, suggesting that plans changed and items that may have improved physical activity were not implemented.

The majority of studies in this research area are cross-sectional studies, a limitation is they are unable to assess the direction of the relationship between neighbourhood cohesion and physical activity. Longitudinal research can help establish evidence for the temporal order of variables. However, longitudinal research design cannot eliminate competing explanations (e.g., third-variable effects) and, as a result, cannot absolutely establish a causal relationship or allow causal claims.

Physical activity is important for physical and mental health but lots of people are not achieving the recommended amount of physical activity making it a public health priority (Bull et al,. 2020). The COVID-19 pandemic has had a negative impact on physical activity, with levels reported to have dropped and not yet recovered (Sport England, 2022). Social factors such as social support and neighbourhood cohesion have been identified to have a

positive effect on physical activity (Scarapicchia et al., 2017; Quinn et al., 2019) while the reverse is seen with loneliness and social isolation (Lindsay Smith et al, 2017). The pandemic created a unique environment to identify who stayed physically active during periods of social restriction and what supported them. This is important information to take forward for developing interventions in the future especially during winter months which can reflect the restrictions seen during the pandemic. A number of behaviour change theories include the importance of social factors as a construct for behaviour change (Lindsay Smith et al., 2017), however, there are gaps in our understanding of the factors and motivations associated with adoption versus maintenance.

I started writing the proposal for this PhD in March 2020 as the COVID-19 pandemic was starting. I was interested in what supports active people stay active, my original idea were to research endurance athletes and the importance of their communities in staying active. It became clear the pandemic was going to impact my ability to collect primary data, with uncertainty around the duration and level of restrictions both in the UK and globally. Based on my original area of interest and discussion with my supervisors I developed the aims and objectives for study one.

Study aims and objectives

As discussed previously social support has a positive effect on physical activity participant, while loneliness and social isolation had the reverse effect. The COVID Social Study was chosen as the data set for this study because it had captured data from the start of the first COVID-19 lockdown in the UK. This allowed me to look at physical activity participation from week one through to the end of lockdown one. Identifying those who had been active throughout and what had supported them to maintain their physical activity. Study 1 details below.

Study 1

Perceived social support and sustained physical activity during the COVID-19 pandemic

Aim: To identify the proportion of people who successfully sustained adequate physical activity during lockdown and to explore whether social support, loneliness and social isolation were associated with maintenance of physical activity during the first COVID-19 lockdown in the UK.

Research question: Is there an association between social support, loneliness and social isolation and sustained physical activity?

Having completed study 1, I thought it would be helpful to understand what the population were saying about their experience of physical activity during the pandemic. In particular, the impact the pandemic had on the level of physical activity, and peoples lived experiences of physical activity during times of social restriction.

While many of the UK longitudinal studies e.g., Understanding Society, were collecting quantitative COVID-19 data sweeps the Covid Social Study was the only one I found that had a free-text module. This allowed me to undertake a qualitative study to gain more insight to the impact of the pandemic on physical activity. Full detail of study 2 is below.

Study 2

Physical activity during the COVID-19 pandemic in the UK: a qualitative analysis of free-text survey data

Aim: To use large-scale free text survey data to qualitatively gain a more in-depth understanding of the impact of the COVID-19 pandemic on physical activity, map barriers and facilitators to the Capability, Opportunity, Motivation, Model of Behaviour (COM-B) to aid future intervention development.

As part of study 2 I mapped the themes identified from the qualitative analysis onto the COM-B model. This was done in order to identify which themes could be mapped to capability and opportunity which is essential for the motivation to undertake a behaviour, physical activity in this instance.

One theme, use of technology, was identified as mapping to capability and opportunity and was a contributing factor for undertaking study 4. Another theme, perceived risk to participant in physical activity, contributed to the development of study 3. I was interested to see if the perception of our neighbourhood, the behaviours and trust in the area, and therefore risk, changed physical activity participation. This was of particular importance when physical activity was only allowed within local areas.

Study 3

Association between neighbourhood cohesion and physical activity trajectories during the COVID-19 pandemic.

Aim: to determine if physical activity change during COVID-19 pandemic. Does neighbourhood cohesion contribute to differences in physical activity?

Study 4

The influence of perceived social support on participation in a physical activity digital health intervention

Aim: To determine if social support is associated with online physical activity program participation and maintenance.

Methods

Due to the use of different cohorts and methodologies in each chapter, methods are expanded in each individual data chapters for ease of reading.

Chapter 2 – Study 1

Perceived social support and sustained physical activity during the COVID-19 pandemic

A version of this chapter has been published as:

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Background

As discussed in chapter one, strategies such as lock-down, restriction on non-essential travel and social distancing were implemented in response to COVID-19 (Füzéki et al., 2020). These strategies have impacted the level and patterns of physical activity (Ammar et al., 2020; Chtourou et al., 2020; Constant et al., 2020). In the UK, gyms, leisure facilities and sports clubs were closed, affecting usual leisure time exercise behaviours (UK Government, 2020). The pandemic led to major changes in commuter patterns, with many people working from home, furloughed or losing work, reducing active commuting and changing routines (Office for National Statistics, 2020). Identifying factors associated with successfully sustaining sufficient levels of leisure time physical activity despite significant barriers could help inform interventions and future pandemic responses.

Being consistently active, achieving recommended levels of physical activity prior to the pandemic was associated with reduced likelihood of COVID-19 infection, reduced risk of severe illness and reduced risk of COVID-19 related death (Janssen et al., 2014; S. W. Lee et al., 2021; R. Sallis et al., 2021), demonstrating the importance of the maintenance of physical activity during the pandemic.

To date, several studies have focused on *individual predictors* of decreases in physical activity during COVID-19 pandemic. A UK smartphone-based observational tracking study

(n=5395) found a larger reduction in physical activity during the first lockdown amongst younger people and those who had been active prior to lockdown (McCarthy et al., 2021); a finding echoed in an observational study of 532 Australian students (Gallo et al., 2020). However, other studies have found different results. A cross sectional online study in Belgium (n=13,515) reported that those aged <55 years and were inactive prior to lockdown were likely to exercise more (Constandt et al., 2020). Of note, the mode of usual exercise appeared to be a key factor, with those who usually exercised with friends/sports clubs and who did not engage with online exercise tools reporting a reduction in exercise (Constandt et al., 2020). A study in the UK, using the COVID-19 Social Study (n=35,915) looked at trajectories of physical activity in relation to lockdown measures, this found that although 62% experienced little change, nearly 29% reduced physical activity and 12% of those who did not change were consistently inactive (Bu, Bone, et al., 2021). The majority of studies exploring predictors of changes in physical activity during the COVID-19 pandemic have been cross-sectional in nature and used a limited number of variables as predictors.

There is a lack of data to date exploring how individual social factors could have affected changes in physical activity during the pandemic. *Social support* is multi-layered and complex, it has been associated with positive physical activity participation (Scarapicchia et al., 2017) and physical activity prior to the COVID-19 pandemic (Lindsay Smith et al., 2017., Kocalevent et al., 2018; Stapleton et al., 2015).

Stressful events may require multiple resources and types of support (Cohen & Wills, 1985). The effect of social support can be explained by two major hypotheses. The stress-buffering hypothesis, where it is thought social support can buffer the negative impact of stressful life events, and the direct-effect hypothesis, where social support has a positive effect on

health, independent of stress levels (Cohen & Wills, 1985). People with high social support show overall better health in their daily lives (Buchwald, 2016).

As described in chapter 1 there is a distinction between actual support received in the past and perceived availability of support. Perceived social support has been found to have a significant positive effect on physical activity (Kang et al., 2018) and is used in this study. A limitation could be that perceptions of support are different between pandemic and non-pandemic times, however, in this study all measures are taken during the pandemic so this should be limited. Compared to the general UK population there

Social support may be particularly important during the pandemic as it has been shown to play a key role in physical activity participation, general well-being and is a strong predictor of resilience following disasters e.g., Hurricane Katrina and exposure to trauma (Saltzman et al., 2020). Specifically, social support may serve as a 'buffer' as per the stress-buffering hypothesis, providing emotional and psychological support, which is considered a major factor in maintaining well-being and coping with health challenges (Zysberg & Zisberg, 2020). The importance of social support in relation to physical activity is well understood, (Lindsay Smith et al., 2017; Molloy et al., 2010; Scarapicchia et al., 2017) with research indicating a positive relationship between social support, intention to be active, and participation in physical activity (Golaszewski & Bartholomew, 2019; Kang et al., 2018). People with either general social support or physical activity specific social support are more likely to be participate in leisure time physical activity (Lindsay Smith et al., 2017). The greater the perceived social support the less isolation and loneliness experienced, supporting increased intention and participation in physical activity.

There is evidence that social support might influence other health behaviours. For example, a cross sectional study of changes in alcohol consumption in 1958 US university students (after COVID-19 related campus closure) showed those with greater perceived social support reported less alcohol consumption than those with lower social support (Lechner et al., 2020).

Social factors, such as *social isolation* and *loneliness*, have also been related to physical activity pre pandemic (Pels & Kleinert, 2016; Schrempft et al., 2019), levels of both may have increased as a result of lockdown restrictions. Social isolation has been shown to have a negative effect on the amount of overall physical activity, with an increase in social isolation directly related to reduced physical activity (Schrempft et al., 2019; Steptoe et al., 2013). Loneliness has also been identified as an independent risk factor for a reduction in activity and discontinuation of physical activity (Hawkley et al., 2009).

During the COVID-19 pandemic, social factors such as social isolation, loneliness and social support have all been affected. Quarantine and social distancing had led to elevated levels of loneliness and social isolation (Hwang et al., 2020). Whether changes in individual-level experiences of social factors such as isolation, loneliness and social support have affected physical activity remains unknown.

In social epidemiology research, social isolation is the lack of meaningful social contacts, perceived isolation and having minimal people to interact with regularly (Cornwell & Waite, 2009). In this study social isolation was conceptualised differently, it measures 'isolation' as defined by the UK Government during the first COVID-19 lockdown. The definition was 'staying at home and avoiding contact with any people inside or outside the household' (Covid Social Study - Userguide, 2020). This change from individual choice to isolation

enacted by Government, may have exposed different people to isolation and therefore changed the response.

The aim of the study was to identify the proportion of people who successfully sustained physical activity during lockdown and to explore whether social support, loneliness and social isolation were associated with maintenance of physical activity during this period. I hypothesised that high social support would be positively associated with physical activity, but loneliness and social isolation would have a negative impact on sustained activity.

Method

Data was used from the Covid Social Study (CSS).

The CSS is a large scale, longitudinal, panel, observational study of adults (age ≥18 years) living in the UK during the COVID-19 pandemic (Fancourt et al., 2021). The participants from the study are not randomly selected and therefore not representative of the UK population but contains a heterogeneous sample (Fancourt et al., 2021). Study inclusion criteria; aged ≥18 years, living it the UK, with a valid email address and internet access. Recruitment was undertaken using three primary approaches to make the study as inclusive and representative as possible. Firstly, the study was promoted through the senior study researchers existing networks including large databases of adults who had previously consented to be involved in health research in the UK, such as UCL BioResource, HealthWise Wales, and through the UKRI Mental Health Research Networks. To ensure good heterogeneity and stratification over demographic groups, targeted recruitment was undertaken using advertising and recruitment companies focusing on a) low-income backgrounds b) no, or low qualifications c) unemployed. Finally, promotion via partnerships with third sector organisations to vulnerable groups was undertaken. Compared to the

general UK population there were more women, people aged 30-59, educated to degree or above, living in Wales enrolled in the study (Covid Social Study – Userguide, 2020).

The study was approved by UCL Research Ethics Committee (12467/005) in March 2020, with all participants giving informed consent.

Data collection started on 21st March 2020 via a weekly online questionnaire, subsequently reduced to monthly in September 2020. The survey had baseline data captured when a participant started (week 0), then weekly repeated questions, and standalone modules designed to capture specific data.

The CSS was chosen for this study because it was set up early in the pandemic and data was available from the beginning of the first COVID-19 lockdown. This allowed me to assess physical activity across the duration of the first lockdown period. Variables were measured weekly which provided multiple data points allowing for physical activity behaviour to be viewed across the duration of lockdown rather than cross sectionally. This allowed me to identify those who had sustained physical activity throughout.

Dependent Variable

Physical activity in the Covid Social Study was self-reported on a weekly basis. Self-report questionnaires are the most common method of physical activity assessment: they are easy to administer, cost effective, and relatively accurate at measuring intense activity although less robust at measuring light to moderate activity (Sylvia et al., 2014). Planned and structured MVPA is easier to remember and therefore report than light or moderate activity which is often incidental movement e.g., walking. A '*stylised questions*' and '*time diaries*' approach was used to measure 'time use' of a specific set of activities including physical activity (Bu, Steptoe, et al., 2021; Seymour et al., 2017). A study comparing time diary data

with camera and accelerometer records strongly supports the use of diary methodology at sample and individual level, with time diaries providing accurate and unbiased estimates of time in different activities, including physical activity (Gershuny et al., 2020). Participants were asked to focus on the last weekday, and report how much time they spent on physical activity. Data prior to COVID-19 suggested that patterns of physical activity could be different between weekends and weekdays, with physical activity lowest on Sunday and highest on Saturday in some studies (Racette et al., 2008),however, the average amount of time spent in moderate physical activity was not found to be significantly different between weekdays and weekends (Buchowski et al., 2004).

Respondents were asked, focusing on the last weekday (i.e. Monday to Friday), this may be yesterday (Mon-Thurs), or it may be before the weekend (Fri). How much time did you spend 1) going out and walking slowly or other gentle physical activity 2) going out for moderate or high intensity activity (e.g brisk walking, running, cycling or swimming) 3) exercising inside your home or garden (e.g., doing yoga, weights or indoor exercise). Time spent doing the different activities was reported as; none, <30 mins, 30mins-2 hours, 3-5 hours and 6+ hours.

As described in Chapter 1, the current WHO and UK physical activity guidelines recommend adults ≥18 years should aim to be active daily and achieve 150 minutes of moderate activity per week (NHS, 2021). Benefits of physical activity are seen at even moderate levels of activity, such as brisk walking and gardening, for 30min/day on most days of the week. Taking the description of moderate activity into account, the moderate/high intensity and in-home categories were combined to identify all those who would achieve any kind of moderate activity level. Those who reported <30minutes on the last weekday were

categorised as ‘inactive’ as it was assumed they were unlikely to achieve the recommended 150minutes/week of moderate activity, those who reported >30minutes were categories as ‘active’. This assumption has not been tested against another data set and potentially allows for those who perform 75mins of vigorous physical activity to be missed. The lack of a validated physical activity questionnaire and testing of assumptions reduces the validity of the results.

When deciding how to categorise sustained physical activity I searched the literature to see how this had been done in previous studies. There was limited literature however, there was a study looking at correlates of sustaining physical activity in middle-aged women (Janssen et al., 2014) . This study explored autonomous motivation and self-efficacy with long-term patterns of physical activity using a physical activity pattern index (Janssen et al., 2014). The study collected data at 6 time points and the participants were classified as ‘low physical activity’ or ‘high physical activity’ at each assessment. Those who never met the criteria for high physical activity (0/6) were classified as sedentary, women who reported being active between 1 and 3 week (1-3/6) were classified as sporadic, those who reported high physical activity on at least 4 assessments (4-6/6) were considered consistent (Janssen et al., 2014). This definition of sustained physical activity was chosen as there were similar number of data/time points and similar classification of levels of activity to that used by Sport England.

Due to the CSS data being heavily skewed to being inactive, a similar approach to Jansson et al was adopted with a description of physical activity engagement generated using a Physical Activity Pattern Index. This consisted of three ordered categories: inactive, intermittently active, and active. Sustained physical activity is not a continuous behaviour, it

is a process that includes episodes of sustained physical activity that can be discontinued for short or longer periods of time and resumed after setback e.g., injury, or illness (Huffman et al., 2020; Kahlert, 2015; White et al., 2016). In lieu of specific guidance in the literature on how to define sustained physical activity, there was extensive discussion with my supervisors and a decision was taken to base the categories in a similar structure to the paper by Janssen et al. Therefore, those who did not report active behaviour at any time point were classified as 'inactive'. Those reported as 'active' 1-5weeks of the 8 weeks of the study (lockdown 1), were classified as 'intermittently active'. Those reported as 'active' 6-8/8 weeks (≥75%) were classified as 'active'. As the 8-week study period matched with lockdown 1 there were no changes in restrictions during this time.

There is potential that an 'active' person was allocated as 'inactive' if they had not undertaken physical activity on the previous working day. However, to achieve the WHO guidelines of 150min MVPA/week, regular participation in physical activity would be required such as ≥5 days/week of ≥30mins MVPA. Participants could complete the survey on any day within the allocated 7-day period, it was thought unlikely that a participant would be incorrectly coded for all 8 weeks. There is potential that participants were achieving guideline through 75mins of VPA/week which puts them at risk of being mis-categorised and is a limitation of the variable. 'Active' participants were those coded as active 75% of the time, this took into account that sustained physical activity is not a continuous behaviour, allowing for incorrect coding and low activity weeks e.g., illness, work/family pressure, lack of activity on the previous weekday.

Independent variables

Social support was measured using the Perceived Social Support Questionnaire (F-SozU K-6) adapted for use in COVID-19 and reported weekly, see Table 4 for the original and adapted questions (Kliem et al., 2015). This is a 6-item questionnaire with a 5-point Likert scale ranging from 1=not at all, to, 5=very true. The scores for each measure were then summed to give a total ranging from 6 to 30, the higher the score, indicates higher levels of social support. The variable used in this in this study was the sum score of social support at baseline (week 1). The questionnaire was reported in other studies to have excellent construct validity and reliability for perceived social support (Kliem et al., 2015),with internal consistency of 0.89 (Lin et al., 2018) and a Cronbach's alpha of 0.86, they did not report on other relevant metrics such as face validity (Labrague & de los Santos, 2020). Research looking at the predictive role of social support among 325 front-line nurses in reducing COVID-19 anxiety (Labrague & De los Santos, 2020) grouped people into three levels of perceived social support, scores of 6-17 = low social support, 18-25 = normal social support and 26-30 = high social support. Categorisation into three levels of social support was used due to the skew towards normal/high social support, this helps with the assumptions of the model and interpretation. Ordered logistic modelling explores whether the odds of being in a 'higher' category is associated with an explanatory variable, the odds ratio calculates the direction of the relationship and the likelihood of the event occurring.

Table 4. Original and revised Perceived Social Support Questionnaire (F-SozU K-6) (Kliem et al., 2015)

Original	**Adapted for COVID-19** **In the past week, I feel…**
I experience a lot of understanding and security from others	I have experienced a lot of understanding and support from others
I know a very close person whose help I can always count on	I have a very close person whose help I can always count on
If necessary, I can easily borrow something I might need from neighbours or friends	If necessary, I can easily borrow something I need from neighbours or friends

I know several people with whom I like to do things	I have people with whom I can spend time and do things together
When I am sick, I can without hesitation ask friends and family to take care of important matters for me	If I get sick, I have friends and family who will take care of me
If I am down, I know to whom I can go without hesitation	If I am feeling down, I have people I can talk to without hesitation

Loneliness was measured using the UCLA-3 loneliness scale, a short form of the Revised UCLA Loneliness Scale (UCLA-R) and reported weekly. It is designed to measure subjective feelings of loneliness as well as feelings of social isolation, it has demonstrated adequate test-retest reliability and good construct validity (Tull et al., 2020). This is a 3-item scale, respondents were asked how often they felt (1) they lack companionship (2) left out (3) isolated from others. Frequencies ranged from hardly ever (assigned a score of 1), some of the time (assigned a score of 2) and often (assigned a score of 3). The scores of each scale were summed to give a score ranging from 3 to 9, the sum score for loneliness was based on data at baseline (week 1), A higher score of ≥6 indicates higher risk of loneliness. Researchers in the past have grouped people into categories (Steptoe et al., 2013), score of 3-5 = low risk of being lonely and scores of 6-9 = indicative of greater loneliness. Due to the data being heavily skewed towards the low risk of being lonely end of the scale, categorisation was used in this study which helps with the assumptions of statistical models and interpretation.

Social Isolation Due to the fast-moving nature of the lockdown and the time involved with the survey setup, social isolation variable was only added to the weekly questions and collected from week 4. The scale was developed specifically to identify participants isolating in line with Government COVID-19 guidelines. Participants were asked to choose their current isolation status, options were 1) I am in full isolation, not leaving my home at all

(11%) 2) I am staying at home, only leaving for exercise, food shopping, accessing medication, or essential activity permitted by government guidelines (68%) 3) I am staying at home, only leaving for exercise, food shopping or accessing medication or other essential activity AND work (19%) 4) I am NOT following the stay-at-home recommendations (leaving the house for more reasons than those listed above) but am adhering to social distancing when out in public (2m rule) (2%) 5) I am NOT following the stay-at-home recommendations and NOT following social distancing when out in public (0.14%).

Social isolation was coded as a binary variable where 0 = not currently isolating (21%), and 1 = fulling isolation (79%) in line with Government COVID-19 guidelines. Those who indicated their status as, full isolation (answer 1), or staying home except for essential activities (answer 2), were classified as fulling isolating. Those who were leaving their home for work or not following the stay-at-home order were classified as not currently isolating.

Covariates

Covariates were selected due to their potential to interact (confounding) and a theoretical interaction due to lack of previous reported exposure e.g., frontline worker. Being white, male, well educated, a high earner, urban living and good health status are all well-known predictors of physical activity (Bauman et al., 2012; Smith et al., 2015). Any form of health condition, physical or mental health and older age, are associated with a lower likelihood of being active (Smith et al., 2015). There was no previous work published on key worker status or carer status which theoretically could be confounders of physical activity. This was due to the pandemic changing/creating these roles leading to no published data.

Some variables were available in the dataset already dichotomized, this was where there were small numbers within the sub-variable or where there was no benefit in the level of

data collected. For example urban living variable was created by merging living in a city or town (urban), versus village or hamlet (rural), which is of more use in physical activity research. For the purpose of this study a number of the dichotomized covariables were used and indicated below. Covariates included demographics: sex (male/female), age (18-29, 30-45, 46-59, 60+), ethnicity (dichotomised to white versus BAME [black, Asian and minority Ethnic]), household income >£30,000 p/a (ONS UK median salary 2020 = £31,461) (dichotomised to yes/no), university education (dichotomised to degree or above versus high school or none), employment (dichotomised to full-time, part-time employment or self-employed versus in education, unable to work, unemployed, homemaker or retired). Data were also collected on living alone (yes/no), urban living (dichotomised to living in a city or town versus living in a village or hamlet), physical health condition (dichotomised to yes/no), having a diagnosed mental health condition including depression, anxiety or any other mental health problem (dichotomised to yes/no), carer status (yes/no), key worker (those whose work is critical to the COVID-19 response) (dichotomised to yes/no), active the week prior to lockdown, undertaking moderate to vigorous physical activity for ≥15 minutes on 5-7 days (dichotomised to yes/no) (to achieve 150mins of MVPA recommended by WHO and UK guidelines). Due to the pre-lockdown physical activity question asking about MVPA ≥15 minutes on 5-7 days, rather than ≥30 minutes, therefore being non-compatible, this data was used for descriptive purposes only and not for the main analysis.

Statistical analysis

Analysis was carried out using STATA 14.0 (StatCorp, College Station, TX). Multiple imputation was used to account for missing data. There is no clear guidance on a cut-off for multiple imputation, so in discussion with my supervisors a pragmatic decision was made that participants should have at least 5 weeks (60%) of data in order for imputation to be

less than half of the data. Complete case analysis was also conducted to allow for comparison with those who provided data for the entire 8 weeks.

Potential confounders were identified by running logistic regression with physical activity (inactive/intermittently active/active) as the outcome and the covariables as exposures, this included demographic (sex, age, ethnicity, income, education level and employment status), health (physical health condition, mental health condition, active prior to lockdown), living condition (lives alone, urban living) and other (carer or key worker). Those that did not have a significant effect on physical activity were not included in the main analysis.

The main analysis used ordinal logistic regression in which physical activity with loneliness, was regressed on 3 models to identify if loneliness influenced physical activity behaviour. The use of sequential models was to see which set of covariates had the most influence on the model. Model 1 adjusting for age and sex, model 2 additionally adjusting ethnicity, employment, income and education, model 3 additionally adjusting for physical and mental health conditions. The analyses were repeated with the same 3 x model structure but performed between physical activity and social support. The final analyses repeated the same 3 x model structure but performed between physical activity and social isolation. alternative methods of analysis were considered. However I was familiar with the logistic regression approach and after discussion with my supervisors we thought it the most appropriate approach with the 3 ordered categories of the physical activity pattern index.

Missingness

There are a number of hypothesis tests that can be carried out to test for missingness. Little's test can be used if the overall mechanism of missing data is of interest, logistic regression can be used if the missing data mechanism at a particular assessment is of

interest. Logistic regression for the missingness mechanism was chosen for this study. Logistic regression was used to examine whether any of the variables included in the model predicted missingness. They did, and therefore our assumptions were that data was 'missing at random' (missing values can be explained by other observed values in the dataset but not to the variable itself), and multiple imputation could be used to handle missing data. Multivariate imputation by chained equations was the method used to deal with missing data. The number of imputed datasets that were created was 5, with sex and age set as regular variables. Proportional odds assumption means that for each term included in the model, the 'slope' estimate between each pair of outcomes across two response levels are assumed to be the same regardless of which partition was consider. Assumptions made by these methods are often violated, the proportional odd assumption was tested using Brant test (Liu, X. 2009), assumptions hold for all independent variables, the proportional odds assumption have not violated.

Results

Participants

At least one week of data was provided by 69,475 people during the 8 weeks (21/03/2020 to 15/05/2020) included in this study, see table 5. Total number of participants providing data per week, for full details. 16,980 (62%) people started the study and contributed a minimum of 5 weeks of the 8 weeks studied, these participants were the analytic sample for the current study. Full information on missingness per week for these participants are shown in table 6.

6906 (25%) provided complete data for the full 8 weeks of this study and comprised the sample for the complete case analysis.

Table 5. Total number of participants providing data per calendar week

Week commencing	Week	Frequency
21/03/20	1	28,930
28/03/20	2	27,873
04/04/20	3	38,169
11/04/20	4	38,458
18/04/20	5	38,500
25/04/20	6	36,516
02/05/20	7	36,685
09/05/20	8	37,595

Table 6. Missingness per week for participants who provided 5-8 weeks of data (N=16,980)

Week	Complete	Missing	% Missing
1	16,980	0	0
2	16,032	948	5.6
3	15,741	1,239	7.3
4	15,718	1,262	7.4
5	15,325	1,655	9.8
6	14,510	2,470	14.6
7	13,099	3,881	22.9
8	13,389	3,591	21.2

Participant characteristics are presented in table 7. 75% were female, mean age was 51.3 years (SD = 14.3) and 96% were white (British/Irish/other), 70% had degree level or above education, 63% were employed, and 66% reported a higher income (above £30k) threshold. Key workers accounted for 22% of the participants and 16% were carers. 53% reported a chronic long-term health condition, 40% stating a physical health condition and 18% a mental health condition, 24% reported being active prior to lockdown.

Table 7. Baseline characteristics of participants (n=16,980)

Variable	Total Sample (n = 16,980)		Active (n = 2,878)		Intermittent (6,937)		Inactive (n = 7,165)	
	n	%	n	%	N	%	n	%

Sex								
Female	12,653	*74.5*	849	*76.1*	2,075	*75.5*	2,192	*74.7*
Male	4,250	*25.0*	262	*23.9*	659	*24.5*	837	*25.3*
Age category								
18-29	1,238	*7.3*	272	*9.5*	611	*8.8*	355	*5.0*
30-45	4,841	*28.5*	871	*30.3*	2,203	*31.8*	1,767	*24.7*
46-59	5,469	*32.2*	917	*31.9*	2,137	*30.8*	2,415	*33.7*
60+	5,432	*32.0*	818	*28.4*	1,986	*28.6*	2,628	*36.7*
Ethnicity								
White	16,206	*95.5*	2,698	*93.8*	6,590	*95*	6,918	*96.6*
BAME	774	*4.6*	180	*6.2*	347	*5.0*	247	*3.4*
Income								
>£30K/year	11,137	*65.6*	4,187	*58.4*	4,814	*69.4*	2,136	*74.2*
<£30K/year	5,843	*34.4*	2,978	*41.6*	2,123	*30.6*	742	*25.8*
Education								
≥Degree	11,813	*69.6*	2,264	*78.7*	5,098	*73.5*	4,451	*62.1*
≤high school	5,167	*30.4*	614	*21.3*	1,839	*26.5*	2,714	*37.9*
Employed								
Yes	10,721	*63.1*	1,944	*67.6*	4,621	*66.6*	4,156	*58.0*
Key worker								
Yes	3,715	*21.9*	596	*20.7*	1,584	*22.8*	1,535	*21.4*
Carer								
Yes	2,681	*15.8*	431	*15.0*	1,062	*15.3*	1,188	*16.6*
Lives alone								
Yes	3,317	*19.5*	490	*17.0*	1,214	*17.5*	1,613	*22.5*
Urban living								
Yes	13,259	*78.1*	2,329	*80.9*	5,445	*78.5*	5,485	*76.6*
Chronic health condition								
Yes	9,042	*53.3*	1,030	*35.8*	3,062	*44.1*	3,846	*53.7*
Physical health condition								
Yes	6,844	*40.3*	858	*29.8*	2,606	*37.6*	3,380	*47.2*
Mental health condition								
Yes	2,995	*17.6*	344	*12.0*	1,103	*15.9*	1,548	*21.6*
Active prior to lockdown								
Yes	4,105	*24.2*	1,286	*44.7*	1,684	*24.3*	1,135	*15.8*

Physical Activity

Reports of being physical activity in an individual week ranged from 25% (week 1) at the lowest, to 30% (week 4) at the highest. Details of Physical Activity Pattern Index and within

category results are shown in Table 8. This shows that 42% of participants were inactive, 41% were intermittently active and 17% were consistently active across the 8 weeks. Within the intermittently active group, the majority (59%) were active for only 1 or 2 weeks during the 8 weeks of the study. Fewest of the intermittent group (12%) were active for 5 weeks. Within the active group, there was a fairly even split of those active for 6, 7 or 8 weeks.

Table 8. Physical Activity Pattern Index and within category results

Number of active weeks	Number of participants	Total group %	Within category %
Inactive N=7,165 (42%)			
0	7,165	42.2%	100%
Intermittently active N=6,937 (41%)			
1	2,519	14.8%	36%
2	1,510	8.9%	23%
3	1,065	6.3%	14%
4	992	5.8%	15%
5	851	5.0%	12%
Consistently active N=2,878 (17%)			
6	893	5.3%	31%
7	1,006	5.9%	35%
8	979	5.8%	34%
Total	**16,980**	**100**	

In unadjusted regression models, see Table 9. A positive association between sustained physical activity behaviour and social support was found, medium support OR 1.56 (95% CI 1.44 – 1.69) compared to low support, high social support OR 2.05 (95% CI 1.89 – 2.22) compared to low support. All covariates were associated with physical activity in the expected direction. Factors that were adversely associated with physical activity included

loneliness, social isolation, living alone, having a physical or mental health condition, and being aged 30+ years.

Table 9. Ordinal logistic regression with association of individual covariates on sustained physical activity (n=16,980)

Physical Activity	
Variable	Odds ratio (95% CI)
Social support	
Low	Reference
medium	1.56 (1.44 – 1.69)***
high	2.05 (1.89 – 2.22)***
Loneliness	
low	Reference
high	0.80 (0.75 – 0.85)***
Social isolation (>wk 4)	
No	Reference
Yes	0.66 (0.57 – 0.78)***
Sex	
Male	Reference
female	1.11 (1.04 – 1.20)**
Age	
18-29	Reference
30-45	0.74 (0.66 – 0.83)***
46-59	0.58 (0.52 – 0.65)***
60+	0.49 (0.44 – 0.55)***
Ethnicity	
White	Reference
BAME	1.56 (1.36 – 1.78)***
High income (>£30K)	
Low	Reference
High	1.70 (1.60 – 1.80)***
Employed	
No	Reference
Yes	1.41 (1.33 – 1.49)***
University education	
No	Reference
Yes	1.81 (1.70 –1.93)***
Lives alone	
No	Reference
Yes	0.75 (0.69 – 0.80)***
Urban environment	
No	Reference

Yes	1.18 (1.10 – 1.27)***
Physical health condition	
No	Reference
Yes	0.60 (0.57 – 0.64)***
Mental health condition	
No	Reference
Yes	0.62 (0.58 – 0.67)***
Carer	
No	Reference
Yes	0.91 (0.84 – 0.98)
Key worker	
No	Reference
Yes	1.01 (0.94 – 1.08)
Active prior to lockdown	
No	Reference
Yes	2.67 (2.50 – 2.86)***

Social factors

Social support There was an association between physical activity and social support. Of those who were active, 13% had low, 41% had medium and 46% had high social support. Intermittently active, 15% had low, 43% had medium and 42% had high support. The inactive, 23% had low, 43% had medium and 33% had high support. Ordinal logistic regression demonstrated an increase in likelihood of being active amongst individuals with both medium and high support compared to those with low support (Table 9). High and medium social support continued to be positively associated with physical activity even when accounting for all demographic, health-related factors and other covariates. High social support OR 1.64 (95% CI 1.5 – 1.8) p=<0.001. Medium social support OR 1.32 (95% CI 1.2 – 1.44) p=<0.001 (Table 10.).

Loneliness There was a slight increase in in loneliness from week 1 to week 8. Percentage of people reported as lonely, per the UCLA scale, was 32.2% in week 1, increasing to 35.5% in

week 8, chi squared test showed no statistical difference in loneliness between week 1 and week 8.

There was a reduction in likelihood of being active amongst people who were lonely when accounting for sex and age, OR 0.92 (95% CI 0.86 – 0.98) p=0.011, although the association was attenuated after further covariate adjustments (Table 10.).

Social isolation There was a reduction in likelihood in being active amongst those who were living in isolation in unadjusted models, and again when accounting for sex and age, OR 0.77 (95% CI 0.66 – 0.91) P=0.002, this was attenuated in further models (Table 10.).

Table 10. Ordinal logistic regression model of physical activity category (inactive, intermittently, active) with social support, loneliness and social isolation (n=16,980)

Physical Activity Category	
Variable	**Odds ratio (95% CI)**
Model 1 – sex, age	
Social support	
medium	**1.46 (1.34 – 1.59)*** **
high	**1.89 (1.72 – 2.07)*** **
Loneliness	
Yes	**0.92 (0.86 – 0.98)***
Social isolation	
Yes	**0.77 (0.66 – 0.91)** **
Model 2 – sex, age, ethnicity, employment status, income and education	
Social support	
medium	**1.35 (1.24 – 1.47)*** **
high	**1.70 (1.55 – 1.86)*** **
Loneliness	
Yes	0.95 (0.89 – 1.02)
Social isolation	
Yes	0.87 (0.74 – 1.02)
Model 3 – sex, age, ethnicity, employment status, income, education, chronic physical and mental health conditions	
Social support	
medium	**1.32 (1.21 – 1.44)*** **
high	**1.64 (1.50 – 1.80)*** **
Loneliness	

Yes	1.02 (0.96 – 1.10)
Social isolation	
Yes	0.97 (0.82 – 1.14)

***P<0.05; **P<0.01; ***P<0.001**

Full case analysis

Six thousand nine hundred and six participants provided data for all 8 weeks of the study, see table 11. For full details. Analysis was replicated for full case analysis and findings were similar. Demographics were similar; 74% were female, mean age was 52.7 years (SD = 13.4) and 96% were white (British/Irish/other), 70% had degree level or above education, 63% were employed, and 60% reported a higher income (above £30k) threshold. Key workers accounted for 20% of the participants and 15% were carers. 52% reported a chronic long-term health condition, 42% stating a physical health condition and 17% a mental health condition, 25% reported being active prior to lockdown.

Table 11. Baseline characteristics of participants (n=6,906) who completed data collection weeks 1-8

Variable	Total Sample (n = 6,906)		Active (n = 1,115)		Intermittent (2,748)		Inactive (n = 3,043)	
	n	%	n	%	n	%	n	%
Sex								
Female	5,116	74.1	849	76.1	2,075	75.5	2,192	74.7
Male	1,758	25.5	262	23.9	659	24.5	837	25.3
Age category								
18-29	438	6.3	77	6.9	228	8.3	133	4.4
30-45	1,762	25.5	312	28	775	28.2	675	22.2
46-59	2,206	31.9	367	32.9	842	30.6	997	32.8
60+	2,500	36.2	359	32.2	903	32.9	1,238	40.7
Ethnicity								
White	6,652	96.3	1,058	94.9	2,636	95.9	2,958	97.2
BAME	254	3.7	57	5.1	112	4.1	85	2.8
Income								
>£30K/year	3,726	59.9	701	70.6	1,567	62.9	1,458	53.3
<£30K/year	2,493	40.1	292	29.4	925	37.1	1276	46.7
Education								
≥Degree	4,804	69.6	872	78.2	2,023	73.6	1,134	37.3
≤high school	2,102	30.4	243	21.8	725	26.4	1,909	62.7
Employed								
Yes	4,109	59.5	723	64.8	1,735	63.1	1,651	54.3

Key worker								
Yes	1,359	19.7	200	17.9	582	21.2	577	19
Carer								
Yes	1,065	15.4	164	14.7	409	14.9	492	16.2
Lives alone								
Yes	1,546	22.4	219	19.6	561	20.4	766	25.2
Urban living								
Yes	5,333	77.2	894	80.2	2,154	78.4	2,285	75.1
Chronic health condition								
Yes	3,591	52	410	36.8	1,207	43.9	1,698	55.8
Physical health condition								
Yes	2,924	42.3	344	30.9	1,075	39.1	1,505	49.5
Mental health condition								
Yes	1,152	16.7	129	11.6	397	14.5	626	20.6
Active prior to lockdown								
Yes	1,746	25.3	531	47.6	707	25.7	508	16.7

Details from the Physical Activity Index (see table 12.) show the same results with 44% classified as inactive, 40% intermittently and 16% active, along with the number of weeks active and within category breakdown. Within the intermittently active group over half (56.5%) were active for only 1 or 2 weeks of the study. The consistently active group had an even split of those active for 6, 7 or 8 weeks.

Table 12. Baseline characteristics of participants (n=6,906) who completed data collection weeks 1-8

Number of active weeks	Number of participants	Total group %	Within category %
Inactive N=3,043 (44.1%)			
0	3,043	44.1%	100%
Intermittently active N=2,748 (39.8%)			
1	930	13.5%	33.8%
2	624	9.0%	22.7%
3	417	6.0%	15.2%
4	425	6.2%	15.5%
5	352	5.1%	12.8%

Consistently active N=1,115 (16.1%)			
6	348	5.0%	31.2%
7	375	5.4%	33.6%
8	392	5.7%	35.2%
Total	**6,906**	**100**	

Ordinal logistic regression of individual covariates on sustained physical activity, see table 13. Found the same positive associations with; medium and high social support, being female, being BAME, high income, employed, university educated, living in an urban environment and active prior to lockdown.

Table 13. Ordered logistic regression with association of individual covariables on sustained physical activity (n=6,906)

Physical Activity	
Variable	Odds ratio (95% CI)
Social support	
Low	Reference
medium	1.46 (1.29 – 1.65)***
high	1.99 (1.76 – 2.27)***
Loneliness	
low	Reference
high	0.88 (0.80 – 0.97)**
Social isolation (>wk 4)	
No	Reference
Yes	0.70 (0.60 – 0.83)**
Sex	
Male	Reference
female	1.19 (1.08 – 1.32)
Age	
18-29	0.99 (0.75 – 1.3)
30-45	Reference
46-59	0.93 (0.79 – 1.09)
60+	0.77 (0.19 – 0.92)**
Ethnicity	
White	Reference
BAME	1.57 (1.24 – 1.98)**
High income	
No	Reference

Yes	1.66 (1.50 – 1.82)***
Employed	
No	Reference
Yes	1.43 (1.30 – 1.57)***
University education	
No	Reference
Yes	1.76 (1.59 – 1.94)***
Lives alone	
No	Reference
Yes	0.77 (0.69 – 0.86)**
Urban environment	
No	Reference
Yes	1.23 (1.11 – 1.38)**
Physical health condition	
No	Reference
Yes	0.58 (0.53 – 0.64)***
Mental health condition	
No	Reference
Yes	0.61 (0.54 – 0.69)***
Carer	
No	Reference
Yes	0.91 (0.81 – 1.03)
Key worker	
No	Reference
Yes	1.02 (0.92 – 1.14)
Active prior to lockdown	
No	Reference
Yes	2.74 (2.47 – 3.04)***

Ordinal logistic regression showed high and medium social support continued to be positively associated with physical activity when compared with low social support even when accounting for all demographic, health-related factors and other covariates. High social support OR 1.74 (95% CI 1.50 – 2.03) p=<0.001, medium social support OR 1.30 (95% CI 1.13 – 1.49) p=<0.001 see table 14. Both loneliness and social isolation had a negative effect on physical activity, this association was attenuated in minimally adjusted models (table 14). Results for medium social support are the same for both full case analysis and

imputed results. High social support, was slightly higher, at 74% increased odds compared to 64% for imputed results.

Table 14. Ordinal logistic regression model of physical activity category (inactive, intermittently, active) with social support, loneliness and social isolation (n=6,906)

Physical Activity Category	
Variable	**Odds ratio (95% CI)**
Model 1 – sex, age	
Social support	
medium	1.42 (1.25 – 1.62)***
high	1.95 (1.70 – 2.24)***
Loneliness	
Yes	1.03 (0.92 – 1.15)
Social isolation	
Yes	0.79 (0.66 – 0.94)**
Model 2 – sex, age, ethnicity, employment status, income, education	
Social support	
medium	1.34 (1.17 – 1.54)***
high	1.81 (1.56 – 2.11)***
Loneliness	
Yes	1.04 (0.92 – 1.16)
Social isolation	
Yes	0.87 (0.73 – 1.06)
Model 3 – sex, age, ethnicity, employment status, income, education, chronic physical and mental health conditions	
Social support	
medium	1.30 (1.13 – 1.49)***
high	1.74 (1.50 – 2.03)***
Loneliness	
Yes	1.12 (1.00 – 1.26)
Social isolation	
Yes	1.01 (0.83 – 1.22)

***P<0.05; **P<0.01; ***P<0.001**

Discussion

Management of COVID-19 created barriers for how people interact and maintain physical activity. In this large UK-wide study of adults I identified a sub-sample of participants that were able to maintain their physical activity during lockdown despite restrictions. Those

with high social support had a 64% increased odds of maintaining recommended levels of physical activity during lockdown compared to those with low social support. Those with medium social support had 32% increased odds compared to those with low social support of maintaining physical activity. Although associations between loneliness and social isolation had decreased odds of sustaining physical activity during lockdown. This was observed in minimally-adjusted models, and the association was lost after adjusting for wider covariates.

When looking cross-sectionally at the data, levels of self-reported physical activity in our study are similar to those from other UK sources. For example, Sport England (2020) reported that 32% of adults were meeting the guidelines of 150mins/week MVPA in the last week of April 2020 (study week 6), whilst our study reported 27% active for the same week. While both used self-reported physical activity, the Sport England participants are randomly selected households and data is weighted to the Office of National Statistics Populations measures, and therefore not directly comparable. However, our study highlights the difference between cross-sectional results and those who are meeting physical activity guidelines regularly. There is a risk that it could be less than the 32% reported by Sport England which is concerning as they are lower than the estimated 63-66% of adults who met physical activity guidelines prior to COVID-19 (Sport England, 2020). However, this study builds on previously reported cross-sectional data by showing that just 17% of adults analysed maintained recommended levels of physical activity throughout lockdown, 42% were inactive and a further 23% were active for only 1 or 2 weeks of the 8 weeks studied. This demonstrates the difference in those meeting the guidance when looking cross-sectionally compared to longitudinally and suggests that the number of people who were consistently active during the first UK lockdown could have been substantially lower than

the cross-sectional reports. It is well known that not achieving the recommended levels of physical activity is associated with poor physical health, poor mental health, and premature mortality (Füzéki et al., 2020). These finding suggests that more work needs to be done on supporting people during COVID-19 and potential future pandemics to meet physical activity guidelines on a regular basis in order to get maximum benefit from physical activity.

This study explored the social factors that predicted the likelihood of an individual engaging in sustained physical activity across lockdown. Social support was found to be a consistent predictor, but loneliness and isolation were only associated in less-adjusted statistical models. The reasons for this may have been both direct and indirect. Directly, theories that are commonly used in physical activity interventions e.g., Social Cognitive Theory, Theory of Planned Behaviour, Social Ecological Model, and Health Belief Model all contain social support as a key factor in affecting behaviours (Lindsay Smith et al., 2017). The findings reported here suggest that even during social restrictions when such support may be disrupted from usual patterns (e.g., offered virtually rather than face-to-face), social support remains a key influencer of physical activity behaviours. Indirectly, it is also possible that social support may have played a role in buffering against the negative effects of poor mental health on physical activity during the pandemic. There is published literature showing how mental health was adversely affected during the first UK lockdown (Fancourt et al., 2021). Poor mental health is associated with lower physical activity engagement (Shor & Shalev, 2016). But research during the pandemic suggested that social interactions helped to reduce the experience of depressive symptoms, supporting the findings presented here (Sommerlad et al., 2021). While the pandemic may have led to rises in loneliness and social isolation, this was situational due to lockdown. Chronic or prolonged social isolation and loneliness has a known negative impact on health and wellbeing (Groarke et al., 2020), but it

is possible that short-term loneliness and isolation do not have the same effect. Multiple lockdowns or prolonged restrictions increase the potential for increased rates of loneliness to become chronic and impact on physical activity.

Strengths and limitations

The strengths of the study include its longitudinal design that enabled me to identify those participants who maintained their physical activity throughout lockdown. The sample provided information on a range of demographic factors, health conditions and social factors that enabled me to adjust our analyses for potential confounding. Limitations of the study include non-random sampling approach leading to a less representative sample of the UK population. As with many studies, participants were highly educated, white and female which could be due to sampling bias. Although sampling was not random, steps were taken to get as representative a sample as possible. Being white and well educated are well-known predictors of physical activity (Bauman et al., 2012; Smith et al., 2015) therefore it is possible that the sample was skewed to being more active than the general population. Due to this the results are less generalisable than a representative sample and have weaker statistical inference. The higher drop in participants in the later weeks of the study could also have skewed the results. The participants who remained in the study may have been different to those who dropped out, reducing the generalisability and potentially skewing the results. The study used self-reported measure of physical activity leaving it open to recall and reporting bias e.g., imprecise recall. Attempts were made to minimise this by providing examples of common types of exercise with corresponding intensities. Asking participants to self-report on a single day of activity has its limitations, physical activity was one of thirteen measures of time use/activities which were collected. Due to concerns

about focusing on a 'typical' day, which involves aggregating information from multiple days and averaging, a 'time diary' approach was used based on the previous weekday. There is potential that an 'active' person was allocated as 'inactive' if they had not undertaken physical activity on the previous working day. However, to achieve the WHO guidelines of 150min MVPA/week, regular adherence should be ≥5 days/week of ≥30mins MVPA. To the best of our knowledge the Covid Social Study was the only study set up quickly enough to capture weekly data during the first UK lockdown. With more time, validated questions may have been considered in the study providing better quality physical activity data. Another potential limitation is the use of ordinal logit regression. Using this analysis the dependent variable is ranked, but the distances between the categories is unknown and it measures the effect of predictors on the odds of moving into any next-highest-ordered category. The physical activity index suggests that there might be a smaller difference between inactive and partly active, with the majority inactive 0-2weeks, than the difference between partly active and active. This study looks at those who have remained active throughout lockdown, I am not aware of similar data published anywhere else looking at sustained activity.

Conclusion

Previous research shows the importance of social support for initiating physical activity, this study demonstrates the importance of social support for the long-term maintenance of physical activity behaviour within the context of social restrictions and suggests that it does not need to be delivered face to face. Other social factors, such as loneliness and social isolation, were less consistent with their impact on physical activity. The development of interventions and programs to support physical activity both during and outside of pandemic situations should ensure that social support is built in using theories that have

shown to promote regular physical activity participation. The pandemic has prompted the development of virtual and remote physical activity through online classes and communities, building in social support could be beneficial for regular physical activity both now and in the future.

Chapter 3 – Study 2

Physical activity during the COVID-19 pandemic in the UK: a qualitative analysis of free-text survey data

A version of this chapter is published as

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Background

As described in chapter 1 the COVID-19 pandemic had a profound impact on society globally. Measures taken to control the virus, such as lockdowns, travel restrictions and social distancing fundamentally changed the way we work, socialise and exercise (P. Chen et al., 2020). It is well established that sufficient physical activity is important for physical health and wellbeing (Chekroud et al., 2018; I. M. Lee et al., 2012). This was particularly important during the pandemic as demonstrated by a nationwide cohort study (South Korea) and a retrospective observational study (USA) which found that active adults had reduced risk of severe infection by COVID-19 (S. W. Lee et al., 2021; R. Sallis et al., 2021). Little qualitative work has been undertaken to explore the experience of physical activity during COVID-19 pandemic. A case control study (Sweden) emphasised the importance of maintaining or increasing cardiovascular fitness to strengthen resilience to severe COVID-19

(Ekblom-Bak et al., 2021). Studies also found physical inactivity and weight-related comorbidities were significant risk factors for contracting COVID-19 (Petrakis et al., 2020). In non-pandemic settings, a meta-analysis of 54 studies (seven observational, 42 interventional, five vaccination studies), looked at the effect of regular physical activity on the immune system and risk of community acquired infection. This found regular moderate to vigorous physical activity increases resistance to infectious disease, reducing the risk of community acquired infection, and infectious disease mortality in the general population (Chastin et al., 2021).

Qualitative data are particularly useful in providing insights into peoples lived experiences during health emergencies, providing complimentary data to support epidemiological findings (Johnson & Vindrola-Padros, 2017; Vindrola-Padros et al., 2020). They can help untangle complex and surprising findings, as well as provide specific targets for intervention development. In order to inform intervention design it is useful to map qualitative findings onto a theoretical intervention development framework (Nguyen et al., 2021); one such framework is the Capability, Opportunity, Motivation Model of Behaviour (COM-B) (Michie et al., 2011). As discussed in Chapter 1, the COM-B posits that for a given behaviour such as physical activity to occur, there must be sufficient capability (*physical* or *psychological*), opportunity (*physical* or *social environmental*), and motivation (*reflective* or *automatic*) present. All three components are essential, if any of these components are weak or lacking, the behaviour has lower likelihood of occurrence (Michie et al., 2011). The model also posits that both capability and opportunity influence motivation, making it the central mediator of the model (Howlett et al., 2019a).

During COVID-19 the COM-B model has been used to identify facilitators and barriers to behaviours, such as adherence to COVID-19 social distancing guidelines in the UK (Burton et

al., 2022; Wright et al., 2022). Both studies identified a range of factors that contributed to compliance, good social support and consistent, clear, guidance were found to be drivers for compliance. From the COM-B model, *psychological* capability, *social* opportunity, and *reflective* motivation were important influences on compliance(Burton et al., 2022). The COM-B model has been used less in relation to physical activity in research conducted outside of the pandemic context, Howlett et al. (2019a) found motivation to be strongly associated with physical activity in adults, with capability and opportunity partly mediating the association of physical activity behaviour (Howlett et al., 2019a). Additionally, Willmott et al. (2021) identified associations between behaviour, capability, and opportunity through the mediating effect of motivation in young adults aged 18-35 years (Willmott et al., 2021). In research conducted into the COVID-19 pandemic, an integrative review of 64 studies (both quantitative and qualitative) of which 59 were cross-sectional, and five longitudinal, investigating correlates of physical activity behaviour identified that targeting capability on a psychological level and opportunity on a physical level may facilitate physical activity behaviour (Knight et al., 2021).

Despite the large body of quantitative data on the impact of COVID-19 on physical activity, very few qualitative studies have been conducted. One American study aimed to understand 22 adults attempts to maintain an active lifestyle during the COVID-19 pandemic (Kaur et al., 2020). Participants described how during the initial lockdown they had a lack of motivation for exercise, however, there was a gradual increase in motivation and participation in fitness exercises at home (Kaur et al., 2020). This study recruited only previous regular gym attenders, so findings may not be transferable to groups engaged in less intensive or less formalised physical activity. A qualitative study of 12 adults in Canada with a range of physical activity levels found that physical activity which could not be

undertaken due to COVID-19 restrictions was often replaced by other types of activity such as online workouts, home exercise equipment, walking or biking on local paths. For those who required access to specific sports facilities some did not find an appropriate alternative activity (Petersen et al., 2021). However, due to the small sample size, this study did not allow for comparison across demographic groups. A UK qualitative study looked at barriers and facilitators to physical activity during COVID-19 and mapped to the COM-B model (Roche et al., 2022). This study focused on 116 adults thought most likely affected by restrictions (younger adults aged 18-24, older adults aged 70+, parents with small children and those with physical or mental health conditions) and conducted via in-depth interviews. The study identified 4 themes (with seven subthemes): the importance of outdoor space, impact of COVID-19 restrictions, fear of contracting COVID-19, and level of engagement with home exercise. These were identified as either barriers or facilitators and mapped onto the COM-B model. Opportunity (physical) and motivation (reflective) were found to be factors influencing physical activity, no themes mapped to capability (Roche et al., 2022). Existing qualitative studies were relatively small in size (Kaur et al., 2020), or focus on specific sub-populations (Roche et al., 2022), making them hard to apply to the wider population. There was a lack of research providing broader insight into the general public's attitudes towards physical activity during COVID-19. Such research is important to capture how public opinion and behaviours were affected during a pandemic and to support planning to maintain physical activity, and thus physical health, for future health emergencies.

One method for capturing qualitative data from a large and diverse sample is via open-ended survey questions. Free-text survey options give large numbers of participants the opportunity to explain their experiences in their own words, providing greater insight and detail into their lived experiences. This approach has been successfully used to further

understand pandemic related barriers and concerns regarding catching COVID-19 of people with long-term respiratory conditions and how these concerns were affecting them (Philip et al., 2020), and to identify facilitators and barriers to compliance with COVID-19 guidelines (Wright et al., 2022). Few qualitative studies have been conducted looking at the impact of COVID-19 on physical activity compared with the large body of quantitative data.

Aim

To use large-scale free text survey data to qualitatively gain a more in-depth understanding of the impact of the COVID-19 pandemic on physical activity, and to map barriers and facilitators to the Capability, Opportunity, Motivation Model of Behaviour (COM-B) to aid intervention development for future unforeseen circumstances in which individuals face challenging restrictions on their movement.

Method

Study population

Data were gathered from the COVID-19 Social Study (CSS), as per study 1. Full details of the cohort is provided in study 1. The CSS predominantly involved quantitative surveys designed to explore the impact of the pandemic on mental health and wellbeing. However, a one-off free-text module was introduced between 14th October and 26th November 2020 to gather more in-depth data on participants' experiences during the pandemic. The module consisted of eight free-text question boxes asking participants about the impact of the pandemic on mental health, wellbeing, and coping methods. See Table 15. for free text survey questions.

Table 15. COVID-19 Social Study Free text module questions

Question Number	Question
1	Is there anything you would like to tell us about the changes that have been brought about by the Covid-19 pandemic and the impact these have had on your mental health or wellbeing?
2	What is bothering you the most about the pandemic? What aspects of it have you been finding most difficult?
3	Has the pandemic had any negative impacts on your mental health and wellbeing? If so could you tell us about these?
4	Has the pandemic had any positive impacts on your mental health and wellbeing? If so could you tell us about these?
5	How have your circumstances (e.g. work, housing, local area, finances, social networks, family life, responsibilities etc) contributed to your experiences (positive, negative or both) of the pandemic?
6	How have your personal attributes (e.g. age, gender, ethnicity, sexuality, health conditions etc) contributed to your experiences (positive, negative or both) of the pandemic?
7	What have been your methods for coping during the pandemic so far and which have been the most or least helpful?
8	Since the Covid-19 pandemic began, how have you been feeling about the future? What are you hopeful or concerned about?

Data extraction

A statistician working on the CSS generated a list of 29,303 individual words or numbers (of three or more characters) used in the free-text responses (including spelling mistakes). I identified 304 of the 29,303 extracted words as relating to physical activity and generated a physical activity specific word list, see table 16. This list was used by the statistician to extract all free-text responses that contained one or more physical activity specific words for analysis. 21,260 quotes were extracted and were included in the first order coding. 7,490 quotes from across all eight questions were coded as relating to physical activity. The 13,770 quotes excluded from the analysis used a key word, but not in relation to physical activity

e.g., "*running* the household and working from home has been challenging" or "*juggling* home schooling and working from home was exhausting".

Table 16. Physical activity specific word list

Letter	Physical activity related word
A	activities act4ivity activates active active_ actively actives activiites activites activities activities
B	badminton ball ballet ballets ballroom balls basketball bicycle bicycles bike bikes biking bikr boat boating bodybuilder bodyweight bowling bowls breathlessness brisk briskly
C	canoe canoeing cardiac cardic cardio chi class classes club clubs club's coach coached coaches coaching competing competition competitions competitive competitively competitiveness couch2 courts cricket crossfit crosstrainer curcuit curling cycle cycled cycles cycling cyclist cyclists
D	dance dancefit danceing dancer dancers dances dancesing dancing diving dogwalkers dogwalking
E	ecercise endurance energetic energy excercies excercise excercises excercising excerise excersise excersising excersize excise execise execising execrcise execrise exercis exercise exercise.eating exercised exerciser exercises exercising exericse exerrcise exersice exersise exersize exrecise
F	fatter fit fitbits fitbut fitness fitter fittest football footballer footballers footie footing
G	gardened gardener gardening garmin golf golfer golfers golfing gym gymn gymnastics gyms gym's
H/I	hike hiked hikes hiking horse horsemen horseracing horses inactive inactivity
J	joe joes jog jogged jogger joggers jogging juggle juggled juggling
K/L	kayak kayaking kettlebells kick kickboxing kicked kicking lido
M/O	marathon marathons member members member's membership memberships mileage miles mountain mountaineering mountains outdoorsy
P	padding paddle paddling padel parkrun parkruns parkrun's phyical phyicsal physcial physical physically pilates play players playground playgrounds playing plod plodded plodding plods ponies pony pool pools powerlifting
R	race races race's racing racket racketball ramble rambler ramblers rambling riding rugby runner runners running runs
S	scuba sculling shoot shooting shoots skate skated skating ski skiing skip skipping skips snowboarding soccer sport sportcentre sporting sports sportsmen sporty sprint sprints strava stretch stretched stretches stretching stroll strolls sweat sweating sweats sweaty swim swim2 swimmer swimmers swimmin swimming swimminh swimmng swims

T	train trainer trainers training trampoline trampolining
U/V	ultra ultras vegetate vegetating vegging
W/Y/Z	walker walkers walking walking.exercising walks watersports weight weightlifting weights workout workouts yoga yoga's zumba
Numbers	10,000 10000 _outdoor 10,000s 10000s 10k 10km 11k 12k 1k 1km 20k 20km 21k 2kms 2miles 5km 5ks 5miles

Data analysis

Data was imported into an Excel spreadsheet. Thematic analysis of the quotes was undertaken using an inductive approach following the six-step framework of Braun and Clark (2006) (Braun & Clarke, 2006). An inductive rather than deductive approach was taken at this point as there were no preconceived themes expected to find in the data based on a theory of existing knowledge (Kiger & Varpio, 2020). Once themes were identified they were deductively mapped onto the COM-B model.

I familiarised myself with the data for each comment box and identified and developed potential codes within the responses. A second researcher (my primary supervisor, AF) familiarised themselves with a random selection of the dataset, 120 (0.5%) comments (15 quotes per question), the coding system was discussed and agreed. The approach used was partially adopted from a qualitative study using free-text data from a patient experience survey (cancer) which also had a large dataset and multiple questions (Cunningham & Wells, 2017). Quotes were assigned first order codes, these were based on whether a participant spontaneously mentioned physical activity and whether the comment was positive/negative/mixed/neutral/no physical activity mentioned, see table 17. for full definition. Comments which did not make any reference to physical activity were not included in further analysis.

Table 17. Definition for First order coding

Code name	Numerical coding	Definition
Positive	1	Statement indicated that they had enjoyed physical activity or had increased physical activity
Negative	2	Statement indicated that there had been a reduction in enjoyment in physical activity or had decreased physical activity
Mixed	3	Statement had both positive and negative elements
Neutral	4	Physical activity mentioned but no emotional response indicated or change in volume of physical activity.
Nil	5	Physical activity not mentioned

Second order codes were applied by me to all remaining comments using the following structure:

1. Type of physical activity
2. Change in PA levels (increased/reduced/same/not clear)
3. Barriers to physical activity
4. Facilitators to physical activity
5. Impact: mental health/wellbeing/physical health/none given

Once the coding was complete the responses were grouped according to first order coding (positive/negative/mixed/neutral) and the four groups reviewed individually. For the positive coding group, the facilitators (second order code) were reviewed, grouped and preliminary themes developed. For the negative coding group, the barriers (second order code) were reviewed, grouped and preliminary themes developed. For the mixed and neutral coding groups both facilitators and barriers were reviewed prior to developing preliminary themes. Preliminary themes from all four groups were reviewed together, common concepts and overlapping themes were identified, themes were then refined, reorganised and renamed where appropriated e.g., the weather was identified as both a facilitator and barrier to physical activity, therefore it was reworded to 'impacts' physical

activity. Coding for this study (~21,000 responses) took approximately 10-12 weeks to complete. Themes were identified, defined according to their overall impact on physical activity, discussed with co-authors and a final list agreed. Frequency of each theme was noted to give an indication of the prominence of different themes/subthemes.

Two researchers (AF and I) then used a deductive approach to independently map the themes onto the COM-B model (Michie et al., 2015). Once complete the researchers compared their mapping. There was a high level of agreement between researchers.

Findings

Demographics

The survey was completed by 25,051 individuals during the study period containing the free text module. Participation was optional, 17,082 (68%) provided a response to at least one of the eight questions. 7,490 quotes from 5,396 participants (32%) mentioned physical activity. Participant characteristics are presented in Table 18. The sample were predominantly female (84%), lived in England (79%), white -British/Irish/Other (97%), degree educated (81%) and aged under 60 years old (57%). The subsample who mentioned physical activity differed from the overall sample: there were fewer people aged 46-59 years old, more women, more people with university education and more people with a physical health condition than the overall survey sample. Of the 7,490 included quotes, 6,636 (88.6%) were positive, 804 (10.7%) negative, 31 (0.4%) mixed and 19 (0.3%) neutral regarding physical activity. The most common forms of physical activity mentioned were 'exercise', followed closely by walking, then gardening, yoga and running.

Table 18. Demographic information of those who participated in data collection containing the free-text module (full sample) and those who mentioned physical activity within quotes (subsample)

Variable	Subsample* (total = 5,396)	%	Full free text survey sample (25,051)	%
Gender				
Female	4,525	***83.9***	18,574	*74.4*
Country				
England	4,257	*78.9*	20,056	*80.1*
Wales	764	*14.2*	3,309	*13.2*
Scotland	334	*6.2*	1,447	*5.8*
N Ireland	41	*0.8*	239	*1.0*
Age group				
18-29	235	*4.4*	1,007	*4.0*
30-45	1,160	*21.5*	4,647	*18.6*
46-59	1,698	***21.5***	8,028	*32.1*
60+	2,303	*42.6*	11,369	*45.4*
Ethnicity				
White (British/Irish/Other)	5,214	*96.6*	24,110	*96.6*
Education				
Degree or above	4,383	***81.2***	17,178	*68.6*
Physical health condition				
Yes	2,068	***38.3***	7,078	*28.3*
Mental health condition				
Yes	751	*13.9*	3,749	*15.0*

***Subsample are those who mentioned physical activity within a quote**

Seven themes were identified from the data on the impact of the COVID-19 pandemic and associated restrictions on physical activity. A summary of themes and subthemes are presented in table 19.

Table 19. Themes mapped onto COM-B model

Theme	Facilitator	Barrier
Theme 1: The importance of outdoor space for physical activity		
• Access to garden or green space	Opportunity (*physical*)	Opportunity (*physical*)
• Desire for fresh air outdoors	Motivation (*automatic*) and Opportunity (*physical*)	
• Dog ownership and social contact	Motivation (*physical*) and Opportunity (*social*)	Motivation (*automatic*)
• Weather impacts the decision to participate in physical activity	Motivation (*automatic*)	Motivation (*reflective*)
Theme 2: Changes in daily routine impacted physical activity		
• Changes in commuting habit impacted physical activity	Opportunity (*physical*)	Opportunity (*physical*)
• Increase in caring responsibility decreased physical activity		Opportunity (*physical*)
Theme 3: Covid restriction prevented participation in physical activity		
• Impact of social distancing and travel restrictions		Opportunity (*physical*)
• Closure of gyms and facilities	Opportunity (*physical and social*)	Opportunity (*physical*)
Theme 4: Perceived risks/threats to participation in physical activity		
• Concerns of catching COVID-19 while participating in physical activity		Motivation (*reflective*)
• Feelings of safety		Opportunity (*physical*) and Motivation (*reflective*)
Theme 5: The importance of good physical health during COVID-19	Motivation (*reflective*)	
Theme 6: The use of technology to aid physical activity	Capability (*physical and psychological*) Opportunity (*physical*)	
Theme 7: The importance of physical activity for mental health and wellbeing	Capability (*psychological*) Motivation (*automatic*)	

COM-B model

The seven themes were deductively mapped onto the COM-B model, and categorised as either facilitators, barriers or both, see Table 19. for full details. Theme 4, perceived risks/threats to participation in physical activity, was the only theme identified as solely a barrier. Themes 5, 6 and 7 (importance of good health during COVID-19, use of technology to aid physical activity, importance of physical activity for mental health and wellbeing) were solely facilitators. Capability, opportunity, and motivation were all found to be drivers for behaviour change within these themes. The remaining themes (1, 2 and 3) were identified as both facilitators and barriers, with opportunity and motivation seen within the themes.

Themes

Theme 1: The importance of outdoor space for physical activity

The importance of outdoor space was the most frequently mentioned theme from 3,167 participants. Access to a garden and greenspace was identified as having a positive impact on participation in physical activity. It allowed people to either, maintain regular activity, or engage in different activities during lockdown. Lack of access to greenspace contributed to a reduction in physical activity. The desire to get outside to enjoy nature and outdoor space was identified as supporting many to be active, with walking outdoors reported as a positive and enjoyable experience for many. Those who owned dogs highlighted the positive impact having to exercise their pet had on their own physical activity, with the benefit of social contact with other pet owners. Good weather and change in seasons affected outdoor physical activity, warm dry weather being associated with greater participation.

- Access to garden or green space (1,206 participants, 22%)

  "Lots of gardening has kept me going" (Female, age 60+, England)

- Desire for fresh air outdoors (780 participants, 14%)

  "Exercise- getting out into nature has kept me sane" (Female, age 60+, Wales)

- Dog ownership and social contact (498 participants, 9%)

  "Having a dog is a fantastic outlet for me. From chatting to her and walking every day to meeting other dog walkers whilst out walking and I've been able to have socially distanced chat with them" (Female, age 60+, Wales)

- Weather impacts the decision to participate in PA (111 participants, 2%)

  "Trying to do more exercise but only achieve when weather was good" (Female, age 60+, England)

Theme 2: Changes in daily routine impacted physical activity

One thousand and sixty-four participants had responses related to a change in their routine influencing physical activity. Some experienced a benefit, with increased time and flexibility to undertake physical activity, while others had increased pressures on routines, such as increased caring responsibility, which led to a reduction in activity. Changes in commuting habits had a large impact; positive quotes were identified from 899 participants related predominantly to the release of time normally spent commuting to focus on other activities. Seventy seven participants comments were negative and linked to the loss of physical activity as part of their commute. A reduction in commuting habit was the most frequently mentioned facilitator for protecting mental health and wellbeing. Increases in caring responsibilities and home schooling had an overall negative impact on physical activity.

- Changes in commuting habit impacted physical activity (1,081 participants, 20%)

"Working from home means I don't need to spend time travelling to work. I can use this extra time for other activities such as exercise" (Female, age 46-59, N Ireland)

"Not walking to work every day has had a big impact on my physical health – I have become a couch potato" (Female, age 60+, England)

- Increase in caring responsibilities decreased physical activity (27 participants, 0.5%)

"My exercise is really low as I can't get out to do things with children at home" (Female, age 46-59, England)

Theme 3: Covid restrictions prevented participation in physical activity

Six hundred and eight participants highlighted that COVID-19 restrictions put in place by the Government prevented them from participation in their regular form of physical activity. This included activities such as, going to the gym, swimming, or travelling to participate in outdoor activities. All quotes were negative in relation to the impact of social distancing and travel restrictions with closure of facilities being the most commonly mentioned barrier having a negative effect on physical activity, mental health and wellbeing.

- Closure of gyms and facilities (450 participants, 8%)

"Not being able to go to the gym or studio classes, which is what I would usually do to keep myself healthy and happy" (Female, age 18-29, England)

- Impact of social distancing and travel restrictions (129 participants, 2%)

"I have had fewer opportunities to go walking with friends in the mountains which I normally do each week. This has led to reduced fitness and loneliness" (Female, age 60+, Wales)

Theme 4: Perceived risks/threats to participation in physical activity

A smaller but important theme was reported by 28 participants regarding perceived risk and threats to participation in physical activity. 23 respondents reported not feeling comfortable returning to previous indoor activities due to perceived risk of contracting the virus, even though some facilities had reopened. While being active outside was identified as an important factor for many, as the weather deteriorated with the approach of winter this raised a safety issue, five respondents reported a reduction in physical activity due to safety concerns around participating in the dark and a perceived reduction in safe spaces to exercise.

- Concerns of catching COVID-19 while participating in physical activity (23 participants, 0.4%)

  "I have stopped going to my exercise classes and I miss that, but when they did start up again, I didn't want to go back due to the worry of catching the virus" (Female, age 60+, England)

- Feelings of safety (5 participants, 0.1%)

  "I don't like going out on my own for walks and now its darker much earlier I'm not walking on an evening with my husband so rarely leave the house" (Female, age 46-59, England)

Theme 5: The importance of protecting physical health during the pandemic

Three hundred and thirty nine participants (6%) mentioned the need to maintain or start physical activity to ensure they were in good health, with some participants specifically motivated to protect themselves against severe health consequences of contracting COVID-19.

"I have made my health a priority now so that if I did catch Covid I am in better shape to tackle it. I now exercise far more and am losing weight, this has had a positive impact on how I feel about myself" (Female, age 46-59, England)

Theme 6: The use of technology to aid physical activity

Three hundred and five participants (5%) described using technology to support physical activity via apps and online platforms. 287 of the quotes were positive with regards to technology use for physical activity, including the ability to exercise when and where they wanted and the ease of use. 11 participants reported mixed experiences, predominantly because they missed the socialising and social contact during and after the activity.

"Positive impact has been an increase in exercise as zoom has enabled me to practice yoga and Pilates at times that suit me better from my spare room" (Female, age 46-59, England)

"I do yoga online but miss being able to do it in a studio with other people" (Female, age 60+, England)

Theme 7: The importance of physical activity for mental health and wellbeing

Mental health and wellbeing were mentioned by 1,022 (19%) participants in relation to physical activity. Five hundred and eighty five (11%) quotes were related to the benefit the participants experienced on their mental health from physical activity. Sixteen participants specifically noted how important it was to maintain their physical activity throughout the pandemic to support their mental health and wellbeing. Four hundred and twenty one (8%) quotes were negative, commenting that the loss or reduction in physical activity negatively impacted mental health and wellbeing. Eight eight participants specifically stated that the

reduction in opportunities to do physical activity due to COVID-19 restrictions, social distancing restrictions and/or closures, had a negative impact on their mental health and wellbeing.

> "*I started exercising every day during the first lockdown and although I now only do 3-4 days a week, I think it helped my mental health*" *(Female, age 46-59, Wales)*

> *"Not being able to go to the gym during lockdowns had an impact on my mental health" (Female, age 46-59, England)*

Discussion

This study reports on findings from a large UK-wide survey of free-text data from 5,396 adults. It provides insight into the way the pandemic impacted daily lives, specifically the impact on physical activity. It identified a range of barriers and facilitators affecting physical activity, including the importance of outdoor space, changes in daily routine, impact of COVID-19 restrictions, perceived risks or threats to participation, the importance of physical health, the importance of physical activity for mental health and the use of technology during the COVID-19 pandemic. These findings demonstrate the majority had a positive experience of physical activity with 89% of respondents reporting either continuing, increasing activity, or specifying their enjoyment of being active. 18% of respondents mentioned the relationship between physical activity and mental health, with many specifically highlighting the benefits of physical activity to support their mental health. Others described instances where the restrictions meant they were unable to exercise as they would like and their concerns for the negative impact on their mental health.

The importance of greenspace, both access and the desire to be outdoors, was a key theme. This is not unexpected as exercise in a green space may help motivation to undertake physical activity by increasing enjoyment and escapism from everyday life (Gladwell et al., 2013). Although the relationship between greenspace and physical activity is complex, pre-pandemic there was evidence that increased exposure and access may motivate people to be active and people enjoyed being active outdoors (Stewart et al., 2016). An observational study of 101 subjects in Shanghai, China, of urban green space reported that green space is the preferred place for almost all types of outdoor physical activities (M. Wang et al., 2021). Similarly, an observational study of 671 adults in Seattle, USA, demonstrated that participants who visited the park at least once over the week had increased minutes of daily physical activity than non-park users (Stewart et al., 2016). Suggesting that park visitation contributes to a more active lifestyle, although access alone is not responsible for the increase in physical activity (Stewart et al., 2016). Personal factors, such as having a companion, are significantly correlated with undertaking physical activity in green spaces. Additionally, the availability of exercise equipment and picnic areas is also positively associated with frequency of physical activity (H. Wang, Dai, et al., 2019). Our study highlights the importance of being outdoors in a garden, greenspace, or countryside to get 'fresh air' with the majority reporting their enjoyment of exercising. Gardening and walking were the most frequently reported forms of physical activity in this theme, this is in line with a nationally representative study which reported that the odds for walking for leisure and gardening were 11% and 15% higher during the pandemic than pre-pandemic (Strain et al., 2022). This highlights the importance of outdoor space to support physical activity and confirms that walking is an accessible and acceptable form of moderate physical activity for many. To support physical activity now and during future pandemics, current green spaces

and parks need to be well maintained as the quality, safety and accessibility, affects their use for physical activity (Kondo et al., 2018; A. C. K. Lee & Maheswaran, 2011). Developing green walkways in urban settings and maintaining footpaths in rural environments could provide a solution to an affordable and accessible form of physical activity across all ages and abilities.

Dog ownership was as a positive experience, with dog owners reporting they continued to exercise pets as before, thereby maintaining an active routine. Benefits were not reported for just physical activity but also social interactions. These occurred spontaneously outdoors, often with other dog owners or people gardening. Social support has been associated with physical activity participation; being part of this social network potentially provided people with additional support to remain active prior to the pandemic (Golaszewski & Bartholomew, 2019). Being outdoors meant they were able to follow COVID-19 guidelines, maintain social distancing, and interact safely. Weather had both a positive and negative impact, with good weather encouraging people to go outdoors, while a change in season (going into winter) and related poorer weather were reasons for a reduction in activity. Seasonal changes in physical activity levels have been identified in previous research, with a drop seen during the colder, darker, winter months (Tucker & Gilliland, 2007). In order to increase physical activity during winter months and future pandemics, interventions should include activities that can easily be undertaken both outdoors in greenspaces, and indoors e.g., in the home environment to facilitate year-round participation. This corresponds with findings from the qualitative Canadian study (Petersen et al., 2021), mentioned earlier, which found that people continued to be active if they were able to find alternative activities suitable for the lockdown environment such as online workouts or using home exercise equipment. Designing physical activity programs that can

be used in both an indoor and outdoor setting could increase sustainability of use when outdoor access is restricted so that exercise routines are not disrupted by seasonality or during potential future social restrictions.

While changes in daily routine benefited some participants, particularly those who reduced their commute due to working from home, there were others who experienced a negative impact. Those who gained time from the loss of commute reported better mental health and using the time to participate in exercise and other healthy behaviours e.g., cooking. However, while participants expressed the intention to participate in more exercise, due to the this being a qualitative study I was unable to determine whether this translated to an increase in physical activity. The negative impact was described by those who lost an active commute and struggled to find a replacement, and those who experienced challenges of caring for young and older family members. School and care facilities closed during lockdown creating additional time-related barriers to physical activity. Habit formation occurs when an action is consistently undertaken in the same context (time and place) (Gardner et al., 2012). Changes in routine meant that the context which had facilitated the original action may no longer be in place e.g., passing the gym on the way home from work. This may have made it harder to continue with previous habits e.g., attending the gym, whilst also facilitating habits or patterns of inactivity being broken. Given, on average, it takes 66 days to form a new habit (Gardner et al., 2012), the duration of each lockdown was sufficient to disrupt previous habits or to lead to the formation of new ones. Although many participated in the daily allowance of exercise during early lockdowns (i.e. going outdoors for exercise once a day), with the potential that this has formed a new 'habit' that may have persevered beyond lockdowns, the disruption of lockdowns does appear to have damaged previous routines for many individuals. As such, in future pandemic circumstances, targeted

public health campaigns as lockdowns or social restrictions lift could help individuals to re-establish physical activity habits/routines or continue with newly created ones.

This study highlights a small but important theme of perceived risk to participation in physical activity, with participants noting a reduction in physical activity due to safety concerns, and a corresponding risk to mental health and wellbeing during a time of known stress. The potential of catching COVID-19 outweighed the known health benefits of returning to activities for some. The precautions put in place and the actions of other people did not adequately reduce the risk associated with interacting with others. The five participants who raised concerns about personal safety while participating in physical activity outdoors were female. With gyms and facilities closed and exercising outdoors encouraged, ongoing concerns about safety were highlighted. Staying safe during physical activity is just as important for health as the activity. Personal safety on the streets, public transport, and around outdoor sports venues is essential to support ongoing participation. Ensuring high quality lighting and maintenance of streets, footpaths and greenspaces will encourage people's feelings of safety, with long term benefits for future pandemic planning.

The importance of physical activity for mental health and wellbeing was identified across all themes. The positive effect on mental health was particularly evident in those who had access to outdoor space and the release of time spent commuting to participate in other activities. This echoes findings from another quantitative study during the pandemic (Stock et al., 2022). Some participants took the opportunity to get more active during COVID-19, due to the beneficial effect of physical activity on mental health and wellbeing. Loss of access to gyms and social contact had an expected negative impact on physical activity which subsequently impacted mental health. Overall, this highlights that encouraging

physical activity during COVID-19 was not just about maintaining physical health, but also about supporting mental health. Indeed, there were multifaceted adverse effects on depression, anxiety, stress and wellbeing (Santomauro et al., 2021). Given physical activity was evidently an important coping strategy for such psychological effects, this increases its importance as a public health measure for future pandemics.

The COM-B model of behaviour change illustrates potential mechanisms to determine which conditions need to be met to facilitate physical activity behaviour change at individual and population level (Michie et al., 2011). Pre-pandemic, capability and opportunity were identified as influencing factors for physical activity, they also influence motivation, making it the central mediator of the model (Howlett et al., 2019a; Willmott et al., 2021). Motivation is a multidimensional construct and is a key factor that influences both initiation and maintenance of physical activity participation. It is thought that motivations for maintenance could be different from those that promoted individuals to make initial changes (Huffman et al., 2020). Motivation can also be different for different types of activity, age, and gender in adults (Molanorouzi et al., 2015). For example, there is evidence to support that in adults, extrinsic motives (getting fitter, weight loss) dominate during the initiation of physical activity while intrinsic motives (competency and enjoyment) are important for maintenance (Aaltonen et al., 2012; Huffman et al., 2020). An integrated review of 64 articles looking at correlates of physical activity during COVID-19, the articles were assessed for risk-of-bias using the Mixed Methods Assessment Tool, with correlates identified, coded and themed via thematic analysis (Knight., 2021). Having mapped the themes to the COM-B model they identified psychological capability and physical opportunity as crucial for facilitating physical activity (Knight et al., 2021). Theme 6, the use of technology to aid physical activity was the only theme that mapped to both capability

(physical and psychological) and opportunity (physical) as a facilitator, suggesting that using technology as a means of engaging in physical activity was appreciated by participants. This could be of particular importance in future pandemics for those who have restricted access to in-person activities e.g., those living in rural settings, those with mobility issues or those who would prefer to be active in the home setting. Some participants found the technology easy to navigate and enjoyed the flexibility, while others identified the loss of socialising and social contact as a negative; building in social time as part of the class could help resolve this. It will be important to address these issues and concerns and build stronger, more accessible technological solutions to support physical activity ahead of future pandemics. Themes found in this study are reflective of themes identified in an interview based qualitative study that looked specifically at those most likely to be impacted by the restrictions put in place during the pandemic (Roche et al., 2022). Themes that overlapped with this study included, the importance of outdoor space, impact of COVID-19 restrictions, fear of contracting COVID-19, caring responsibilities, and using physical activity to protect mental health. Study authors mapped the themes predominately onto opportunity (physical) and motivation (reflective), while in this study themes were mapped across all three domains. While there are differences, the overlapping themes suggest that barriers were similar for the broader population and those who might have been more affected by COVID-19 restrictions. The overlapping themes should be considered when developing physical activity interventions as we move out of this pandemic and into future pandemic planning.

Strengths and limitations

A strength of this study is the large sample size, and the manual, structured approach to data analysis. Manual coding rather than using software allows for the researcher to gain a deeper understanding of the subject, to refine and interpret the data and gain a more nuanced picture. While this approach allowed the lead author to become familiar with the content, identify and apply the codes and themes, and manual coding is time heavy. The content was at times tough to read, with strong opinions, in depth descriptions of difficulties faced and stories of deteriorating mental health. This was difficult to manage and compartmentalise whilst living through the COVID-19 pandemic.

Content warning. The following statements contain potentially distressing material covering mental health and suicide

> "*I live on my own in a tiny flat and previously managed my depression with daily gym classes. With lockdown, loneliness has been really overwhelming but I could just about cope when the gyms reopened as it got me the exercise endorphins and was an opportunity to leave my flat. Facing another full lockdown in winter, with gyms having to close, I am feeling suicidal on a daily basis*" *(Female, age 30-45, England)*
>
> "*I lost 3xweekly exercise classes. One teacher's husband killed himself, as he was unable to cope during lockdown. The other two teachers were unable to use the hall they used. I relied on these classes to help me prevent depression and now I'm having frequent bouts*" *(Female, age 46-59, England)*

While the benefits of manual coding are noted above the use of software coding or computer learning may have produced different results. The benefits of software coding include, the significant reduction in time needed to process the data, the reduced risk of human error, a more robust and consistent coding process and potentially a greater insight

into to the data. Running the data through software and comparing the results could produce a more robust and rounded output.

Limitations of the study are that although this was a large dataset it was not a randomly selected sample and therefore not representative of the UK population. The sample was predominantly female, white British and educated to degree level, which will limit the perspectives provided in the responses and generalisability. This study captures experiences mid-pandemic, and in the autumn and thus may miss the overall experience of physical activity during the pandemic. The survey questions did not specifically ask about physical activity, rather the survey collected data on the impact of the pandemic on mental health, wellbeing, and coping methods. During the data collection period, Wales entered another lockdown, leading to different restrictions across the home nations. This had the potential to effect responses however, during this period the percentage of participants reporting a change in physical activity across the 4 home nations was very similar, therefore is unlikely to have affected the results. Access and availability of public infrastructure to support physical activity and socioeconomic position would limit the transferability of our results to other settings. Due to this being a qualitative study I was unable to identify associations between reported themes and impact on physical activity. Future work could investigate whether the positive and negative themes identified in this study were associated with quantitative measures of physical activity. Future research should consider seasonality, especially as the weather was identified as a barrier to outdoor activity. Moving forward, our findings support the benefits of physical activity for mental health and wellbeing and can be used as evidence to support local and national public health initiatives that focus on the wider benefits of physical activity and the use of activity outdoors for mental health and wellbeing.

Conclusion

This study provides a large, novel, participant-led, in-depth understanding of the experience of physical activity during a period of restrictions (lockdown and social distancing). It raises the importance of access to, and desire to be outdoors when active, and highlights the need to develop accessible, well maintained, greenspace in urban environments as a public health priority. Changes in daily routine had both positive and negative impacts on physical activity, a flexible approach to working could support long term health benefits to both employers and employees. Concerns about catching COVID-19 and ongoing social distancing restrictions prevented people from returning to activities. For some the concern of becoming seriously ill from COVID-19 encouraged them to become more aware of their health and become more active. Online resources were utilized to help support people to stay or become active. With the growing use of technology to aid participation in physical activity, this is an opportunity to develop a broad range of online/technology resources to promote and support physical activity as an alternative to conventional face to face delivery. Should this be successful it could provide a cost-effective and flexible way to deliver quality content to a large audience. Many people acknowledged and appreciated the positive impact of physical activity on mental health and wellbeing. Finally, while the closure of gyms had a negative impact on both physical activity and mental health, most participants reported enjoying physical activity, specifically walking outdoors. This study makes several recommendations for how to support physical activity during future periods of restrictions. However, given the importance to global health of increasing physical activity levels, such measures also have a relevance to broader public health initiatives outside of health emergencies.

Chapter 4 – Study 3

Association between neighbourhood cohesion and physical activity trajectories during the COVID-19 pandemic

A version of this chapter is published as:

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Background

In Study 2 (Chapter 4) themes were identified from free text data regarding the impact of the pandemic on physical activity. One theme was 'perceived risk/threats to participation in physical activity' with the subtheme of 'feelings of safety'. While there are several physical factors that impact physical activity, the theme was about 'perception' of risk and 'feelings' of safety leading to the decision to look at neighbourhood cohesion.

During the COVID-19 pandemic people spent more time in their immediate neighbourhoods due to lockdowns, travel restrictions and working from home. As the pandemic recedes people continue to work from home, and hybrid working has become more popular. Consequently, the neighbourhoods we live in becomes more important as we spend more time living and working in them. Most health behaviours are socially patterned with both the social and physical environment impacting behaviours (McNeill et al., 2006). Neighbourhood factors are increasingly recognised as determinants of health and of health behaviours (McNeill et al., 2006; Yi et al., 2016). In particular, neighbourhood cohesion – referring to a sense of belonging in one's neighbourhood and social connections shared with

one's neighbours (Buckner et al., 1988) may influence a number of health behaviours, including physical activity (McNeill et al., 2006; Yi et al., 2016).

Regularly meeting physical activity guidelines is important for health, this has been associated with reduced all-cause mortality and contributes to prevention of many chronic illnesses, some cancers (e.g., breast, colon), anxiety and depression and can promote healthy cognitive function and healthy ageing (Nazzari et al., 2016; Reiner et al., 2013). There is evidence that physical activity levels declined substantially as a result of pandemic restrictions (Tison Geoffrey, 2020) , although there are few longitudinal studies that include a true pre-pandemic baseline. A reduction in physical activity has health implications, putting long term health at risk, making it a public health priority.

Previous studies have demonstrated a positive association between social support and physical activity on an individual level both prior to COVID-19 (Lindsay Smith et al., 2017; Scarapicchia et al., 2017) and during COVID-19 (Hailey, Fisher, et al., 2022). There is a small body of literature at group-level prior to the COVID-19 pandemic, for example, on the relationship between social cohesion or neighbourhood cohesion, and physical activity (Echeverría et al., 2008; Murillo et al., 2016; Quinn et al., 2019; Samuel et al., 2015). This is predominantly from the USA and few employed representative population samples. A study of 23,006 respondents of the USA National Health Survey (2017), showed a positive relationship between neighbourhood cohesion and meeting physical activity guidelines. Those with higher social cohesion undertook more physical activity compared to low social cohesion, taking an extra 45 minutes of aerobic activity per week, and had increased odds of meeting both aerobic and strength training guidance (OR = 1.14, $p<0.01$) (Quinn et al., 2019). A retrospective study of changes in physical activity in 449 adults in the USA demonstrated a relationship between physical activity and social cohesion. Following a

move to a ‘walkable’ community there was an increase in physical activity, social interactions and neighbourhood cohesion reported across the sample (Zhu et al., 2014). A cross-sectional study of 2,590 Native Hawaiian and Pacific Islanders from the Native Hawaiian and Pacific Islander National Health Interview Survey (2014) compared physical activity from those in low social cohesion neighbourhoods to participants in high social cohesion neighbourhoods. This study found that high social cohesion was associated with increased odds (1.59, 95% CI: 1.19-2.12; p = 0.003) of achieving sufficient physical activity (M. L. Wang et al., 2022). These studies highlight the importance enhancing social cohesion as a potential strategy to promote physical activity. Whether these finding remain consistent, or indeed the influence of neighbourhood cohesion is even stronger, during the COVID-19 pandemic has not been examined.

The mechanism by which neighbourhood cohesion may influence physical activity is not fully understood. According to social cognitive theory, individuals with high self-efficacy are healthier and more engaged in healthy behaviours (Brand & Cheval, 2019). High self-efficacy can be developed through a strong support network, higher levels of neighbourhood cohesion may provide a strong social network, therefore an individual will be more likely to engage in health behaviours such as physical activity (Bot et al., 2016; Rosenblatt et al., 2021). Another theory is that neighbourhood cohesion increases healthy behaviours such as physical activity, by increasing awareness of chronic disease and dissemination of health-related information (W. L. Chen et al., 2019; Rosenblatt et al., 2021). Personal knowledge and awareness of disease development and prevention may be enhanced by strong social cohesion, leading to increased engagement in healthy behaviours and attendance at community level preventative healthcare initiatives (Rosenblatt et al., 2021). Another pathway is the link between social cohesion and walking through perceived walkability.

Social cohesion has been shown to be positively associated with time spent walking for leisure and transport, mediated by perceived neighbourhood walkability (Koohsara et al., 2023). Perceived neighbourhood walkability has a positive effect on social cohesion via neighbourhood-based social interaction (van den Berg et al., 2022). Social cohesion may enhance perceived walkability via social interaction, positively influencing walking behaviour.

According to socio-ecological theory, several factors at the individual, social and physical environment level impact an individual's physical activity behaviour (Trost et al., 2002). Physical environmental factors, such as crime, traffic, or lack of green space may influence an individual's ability to participate in physical activity (He et al., 2020). The social environment, such as neighbourhood cohesion and social capital, are core social environmental factors that influence health related behaviours (He et al., 2020; McNeill et al., 2006).

Factors that are associated with lower neighbourhood cohesion include poor physical and/or mental health and socio-economic insecurity. Poor health can be associated with social isolation, and economic insecurity can lead to prioritisation of resources to the immediate household rather than the community. Socially and economically disadvantaged communities may also be more vulnerable due to community-level factors, such as lower social resources, cultural norms of trust and engagement, or weaker civic organisation infrastructure. These may be weaker and less resilient to begin with and are important for cohesion (Lim & Laurence, 2015).

The social environment such as neighbourhood cohesion, influence health related behaviours. Whilst there is evidence that neighbourhood cohesion had a positive effect on physical activity prior to COVID-19, this study aimed to understand if high neighbourhood

cohesion continued to have a positive effect on physical activity during the pandemic. Identifying what factors supported people to stay active during the pandemic has implications for health improvement initiatives. To the best of our knowledge this is the first study to explore these associations under pandemic restrictions and with a large sample size drawn from a representative sample of the population.

The hypothesis was that overall physical activity dropped through the COVID-19 pandemic and that higher neighbourhood cohesion was a protective factor against reduced physical activity during the pandemic. Therefore, the aim of this study was to examine the association between neighbourhood cohesion and physical activity trajectories during the COVID-19 pandemic using longitudinal data of respondents aged 16 years and older from the UK-based *Understanding Society* COVID-19 sub-study.

Method

Data for this chapter was from *Understanding Society* COVID-19 study, a sub-study of *Understanding Society*: the UK Household Longitudinal Study (UKHLS). The UKHLS is a representative longitudinal study of 40,000 British households, followed since 2009, providing data on subjects such as health, work, education, income, family, and social life, to help understand the long-term effects of social and economic change (Buck & Mcfall, 2012). The survey has four sample components, a large General Population Sample (drawn from throughout the UK) plus three additional components: the Ethnic Minority Boost Sample, the former British Household Panel Survey sample and The Innovation Panel. Respondents aged 16 years and over complete the adults survey. Data were collected by trained interviewers every 2 years via face-to-face interviews (Buck & Mcfall, 2012; University of Essex, 2022).

The *Understanding Society* COVID-19 study is a panel study intended to capture individuals' experiences during the COVID-19 pandemic. Those in households who had participated in at least one of the previous two waves of data collection and were aged ≥16 years (as of April 2020) were eligible for participation in the COVID-19 Study. Those who refused, or who were mentally or physically unable to make an informed decision to take part, and those with an unknown or address abroad were excluded (Institute for Social and Economic Research, 2021). During the pandemic participants completed a web-based online survey which included core content designed to track change alongside rotating content modules. COVID-19 study data collection started in April 2020, 9 waves were collected, with the final data collected in September 2021. Ethics approval was granted by the University of Essex Ethics Committee (ETH1920-1271) for the COVID-19 web and telephone surveys. *Understanding Society*: the UK Household Longitudinal Study is a publicly available, anonymised, dataset, and thus exempt from ethical compliance and UCL Ethics Review.

Measures

Dependent variable – *Physical activity*

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) short form, an internationally used instrument of self-report physical activity. IPAQ comprises 4 questions aiming to measure the volume and intensity of physical activity performed over the last 7 days. The questions ask about the duration (days per week and minutes per day), and intensity of physical activity (vigorous, moderate, and walking). Sedentary (sitting) behaviour data was not collected. IPAQ is shown to be reliable and at least as valid as other physical activity measures for adults aged 18-65 (Craig et al., 2003)

and validated for use with older adults (≥ 65 years) (Cleland et al., 2018; Tomioka et al., 2011).

Participant response to IPAQ were used to estimate the total amount of physical activity completed over a seven-day period in metabolic equivalents (MET). For each category the duration (hours and minutes) and frequency (days) were used to calculate the total number of minutes of activity for each category across a 7-day period. This was multiplied by the weighted MET estimate for each category and added together to produce a total physical activity per week (MET-min/wk). See table 20 for the weighted estimate for each category and associated calculation for total MET-min/wk.

Table 20. Calculation of MET-min/wk variables for IPAQ to calculate a continuous score

Category	**Weighted Met level**	**Calculation of MET-min/wk**
Walking	3.3 METs	3.3 x walking mins/wk
Moderate	4.0 METs	4.0 x moderate mins/wk
Vigorous	8.0 METS	8.0 x vigorous mins/wk
TOTAL MET-min/wk		walking MET-min/wk + moderate MET-min/wk + vigorous MET-min/wk

Physical activity data was processed and analysed following the current IPAQ data usage guidelines (Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ)-Short and Long Forms, 2005). If participants reported implausible physical activity levels, the observation was excluded from analysis. This included any participant who reported a total activity time >960minutes (16 hours) per day, assuming an average of 16 hours of waking time. Those who reported <10 minutes of activity per day were recoded to zero. Finally, data were truncated, as in previous studies, so that individuals exceeding 180 minutes in any intensity category were recoded as 180 minutes,

permitting a maximum of 21 hours of activity in a week for each category (Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ)-Short and Long Forms, 2005). Data processing guidelines were followed to maintain the reliability and validity of the questionnaire and allow for comparison with other studies using IPAQ data.

For descriptive purposes physical activity was categorised into three levels of activity. 'Low activity' (1-449 MET-min/week) defined as not meeting any criteria of physical activity. 'Moderate activity' (450-894 MET-min/week) equivalent to 'half an hour of at least moderate-intensity PA on most days', and therefore likely to be meeting current PA guidelines of 150 minutes of moderate intensity physical activity per week (Bull et al., 2020). 'High activity' (895-1794 MET-min/week) describes highly active participants which equates to ≥1 hour per day, of at least moderate-intensity activity (Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ)-Short and Long Forms, 2005). A clinically meaningful shift in MET-min/wk is hard to quantify. Current WHO guidelines recommend replacing sedentary behaviour with any intensity of activity for health benefits, doing some physical activity is better than doing none (Bull et al., 2020). A large systematic review of 196 articles suggested that the greatest population health benefits can be achieved by getting inactive people undertaking small increases in physical activity (Garcia et al., 2023).

Independent variable – social environment

Neighbourhood cohesion

Neighbourhood cohesion was assessed at the baseline of the present study using Buckner's Neighbourhood Cohesion Instrument. This instrument was developed incorporating three key domains; the concepts of psychological sense of community, attraction to the neighbourhood and social interaction within the neighbourhood (Buckner et al., 1988). For *Understanding Society* study the original 18-question instrument was adapted into an eight-question scale (McCulloch, 2003). See table 21. for the eight-questions in Buckner's neighbourhood cohesion instrument. This has been validated for *Understanding Society* study (University of Essex, 2022). The questions are measured on a 5-point Likert scale (1-strongly agree; 5-strongly disagree), computed as the mean reverse coded response to the original variables. Values range from 1"lowest cohesion" to 5"highest cohesion", higher values represent greater cohesion. Example question, 'I can borrow things from neighbours', full details in Table 21.

Table 21. Questions for Buckner's neighbourhood cohesion instrument

#	**Buckner's neighbourhood cohesion index Questions**	**Concept**
1	I plan to stay in the neighbourhood	Attraction to neighbourhood
2	I can borrow things from my neighbours	Measure neighbouring
3	If I needed advice, advice is obtainable locally	Measure neighbouring
4	I talk regularly with neighbours	Measure neighbouring
5	I am similar to others in this neighbourhood	Psychological sense of community
6	I feel like I belong to this neighbourhood	Psychological sense of community
7	Local friendships mean a lot to me	Psychological sense of community
8	I would be willing to improve my neighbourhood	Psychological sense of community

Covariates

Socioeconomic covariates included sex (male or female), age in years, ethnicity (white or non-white), employment status (employed, unemployed, student, retired), higher education (yes or no), and urbanicity (urban or rural). Other covariates included long standing illness or disability (yes or no).

Analysis

I used linear mixed-effect model (LMM) with a random intercept and slope at the individual level and an unstructured correlation matrix to examine the association between neighbourhood cohesion and physical activity during the follow-up period. Data was hierarchical with repeated measures nested in individuals. The fixed effects account for the mean responses of the model at different time points, shared across all participants (physical activity, neighbourhood cohesion). The random effects account for individual-specific correlation (individual participants, time). LMMs can accommodate missing data, allowing me to use all available data over the follow-up allowing for a bigger sample, and account for intra-individual clustering. Mixed-effect models were run regressing physical activity on neighbourhood cohesion, using linear regression models for physical activity. Interactions with age were checked and found not to be statistically significant, models were centred at age 50 and were adjusted for all covariates and their interactions with age at baseline, significant based on the Wald test. There was not a significant time period (39 months) when considering someone's difference such as sex, education status etc. Continuous MET-min/wk of physical activity were used in the main analysis, categorical data were used for descriptive purposes to describe the proportion of people likely not meeting current physical activity guidelines. I checked if neighbourhood cohesion would fit categorically however Buckner's Neighbourhood Cohesion Instrument cannot fit

categorically as it is not an integer scale. Higher order interactions were checked and were found to be non-significant. I ran the model accounting for clustering by including a random intercept on cluster, there were negligible changes in the main results so excluded it from further analysis. Longitudinal weights for Understanding Society COVID-19 sub study are not available therefore I was unable to include this in the model. Analysis was carried out using Stata 17.0 (StataCorp, College Station, TX) statistical software with a two-sided p-value <0.05 considered to be significant.

Results

Complete baseline data was available for 28,268 participants, listwise deletion was utilised to manage missing data prior to analysis. Those with complete baseline data and at least one pandemic PA measure were included in the current study, N = 14,475. Multiple imputation was not required as LMM can accommodate missing data. See appendix 1 Figure 1. for flowchart of study participant selection. Baseline and participant characteristics are shown in table 22. Participants were predominantly female (58%), white (British/other) (88%), mean age was 50 years (SD = 16.3) range 16-95 years, two thirds reporting being employed, with almost half having achieved higher education. Three quarters reported living in an urban setting and a third reported having a long-standing health condition. Baseline and study participants are similar, the study population has a slightly higher number of white, higher educated and working people than baseline.

In wave 9 of the main survey, participants were asked if they planned to move home in 2017-2019 (prior to the next survey), 3.4% of participants reported they were considering moving. Data was not available to identify if participants had moved. The pandemic and lockdown policies significantly reduced the rate of moving (Wang Y. et al,. 2022), even with the UK Government introduced a stamp duty holiday (July 2020 to September 2021) to

stimulate the property market during the pandemic (UK Gov, Stamp Duty. 2020). Due low percentage considering moving, and the reported reduction in movement, it was thought unlikely to impact the outcome of this study.

Table 22. Description of sample characteristics of study and baseline participants

	Study participants		Baseline Wave 9	
Variable	**Number** (N=14,475)	**%**	**Number** (N=28,268)	**%**
Sex				
Male	6,050	41.8	12,558	44.4
Female	8,426	58.2	15,710	55.6
Ethnicity				
White British/ White Other	12,659	**87.5**	23,321	82.5
BAME	1,817	12.5	4,947	17.5
Employment status				
Employed	9,254	**63.9**	16,576	58.6
Unemployed	1,283	8.9	3,254	11.5
Student	733	5.1	1,960	6.9
Retired	3,206	22.1	6,478	22.9
Higher Education				
Yes	6,864	**47.4**	11,947	42.3
Urban living				
Yes	10,853	75.0	21,560	76.3
Long-standing health condition				
Yes	4,854	33.5	9,880	35.0

Neighbourhood cohesion and physical activity

At baseline, the mean neighbourhood cohesion score was 3.5 (SE 0.003) and mean physical activity was 2934 MET-min/wk (moderate physical activity is 450-894 MET-min/week). There was an average reduction of -441 MET-min/wk, (CI 374.51 – 507.65, p<0.001) from baseline (wave 9, 2018/2019) to the end of the follow up period (January 2021). After adjusting for sex, age, ethnicity, employment status, higher education, urban living and long-term health condition, there was an association between neighbourhood cohesion and

physical activity at baseline (p≥0.001), with a one unit increase in neighbourhood cohesion corresponding to an increase in physical activity of 193 MET-min/wk (95% CI 39.88 – 346.80 p=0.014). At baseline, the difference in physical activity between highest and lowest neighbourhood cohesion was 896 MET-min/wk (95% CI 639.9 – 1151.6, p<0.001), and at the end of follow up it was 1269 MET-min/wk (95% CI 989.3 – 1549.1, p<0.000), (figure 1.). The difference in change between lowest and highest neighbourhood cohesion categories was 373 MET-min/wk, p=0.036; see figure 1. This supports the hypothesis that higher neighbourhood cohesion was protective to reduced physical activity during the pandemic.

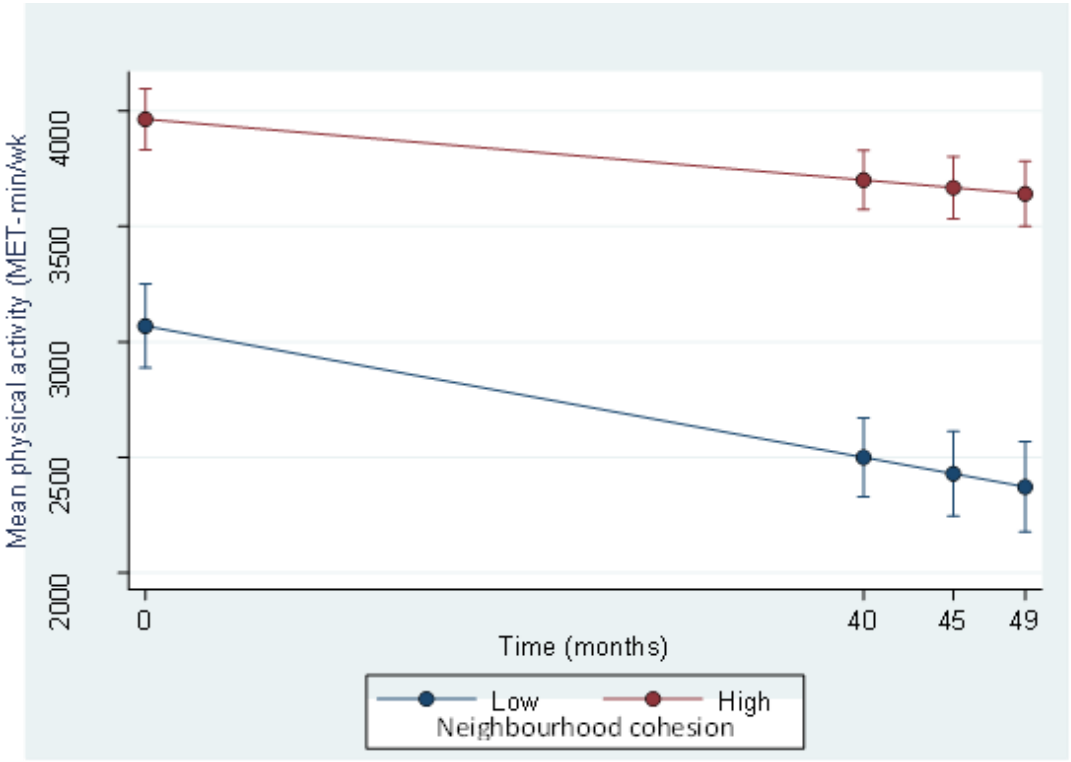
Table 23, shows the percentage of people reporting low physical activity, not meeting any criteria of physical activity (0-449 MET-min/week), increased from 24.1% at baseline to 32.8% at the final time point. Moderate activity (450-894 MET-min/week), the group likely to be meeting current physical activity guidelines, stayed stable with 34.5% at baseline and 35.4% at the final time point. A slight dip was seen in April 2020 (28.4%) which corresponds with the first lockdown. The biggest drop in active participants appears to have come from the highly active group (895-1794 MET-min/week) which was 41.3% at baseline, this group had a slight increase to 42.8% during the first lockdown before dropping to 31.8% at the final time point. See table 23. for full details pf physical activity results.

Table 23. Categorical physical activity at four time points

Wave	Total number of observations	Low 0-449 MET-min/wk	Moderate 450-894 MET-min/wk	High 895-1794 MET-min/wk
2017/2018 (baseline)	14,476	3,492 (24.1%)	4,999 (34.5%)	5,985 (41.3%)
April 2020	13,785	3,979 (28.8%)	3,912 (28.4%)	5,897 (42.8%)

Sept 2020	10,217	2,943 (28.8%)	3,303 (32.3%)	3,971 (38.9%)
Jan 2021	9,557	3,135 (32.8%)	3,387 (35.4%)	3,035 (31.8%)

Figure 1. Mean physical activity (MET-min/wk) over time (months) by baseline neighbourhood cohesion



Discussion

This study aimed to examine associations between neighbourhood cohesion and physical activity trajectories during COVID-19. Our findings support our hypothesis that the COVID-19 pandemic had an overall negative impact on physical activity. I found a significant reduction

in physical activity (-441 MET-min/wk, $p<0.001$) through the COVID-19 pandemic. I found that higher neighbourhood cohesion was related to higher physical activity pre-pandemic, these differences were maintained throughout the pandemic with a slower decline in physical activity over time for participants with higher neighbourhood cohesion, suggesting it has a protective effect on activity.

As hybrid working continues as the new normal, neighbourhood cohesion may become more important to physical activity levels. People spend more time in their neighbourhood due to the increase in hybrid and home working. To support hybrid working an increase in facilities will be needed to provide physical activity opportunities at the office and local neighbourhoods so people can be active in both.

The impact of COVID-19 pandemic saw an overall reduction in physical activity, as the pandemic recedes activity levels were starting to recovery however, they had not returned to pre-pandemic levels. This reduction in physical activity has long term implications for health and wellbeing beyond the pandemic. It requires urgent action to reinvigorate and support public health initiatives to increase physical activity. Supporting efforts to re-engage people to be active through social cohesion by developing group schemes/activities is encouraged. This study highlights the importance of neighbourhood cohesion and suggest it could be a protective factor against reduced physical activity during, and potentially beyond the pandemic, an area for future research.

Studies from previous environmental disasters suggest that higher perceived neighbourhood cohesion creates greater community resilience which aids in faster recovery from natural disaster (Cagney et al., 2016), with individuals living in more cohesive neighbourhoods more likely to be positive about the future (Jung, 2019). A study exploring

the impact of the COVID-19 pandemic on neighbourhood cohesion showed that levels in June 2020 were lower compared to the pre-pandemic period. They also noted that the decline was particularly high in vulnerable groups (deprived communities, some ethnic minority groups and lower-skilled workers) which is concerning (Borkowska & Laurence, 2021). Those in vulnerable groups, such as lower-skilled workers living in deprived communities are likely to work in low-skill jobs, these jobs include supermarket workers, hospitals staff or transport workers, all roles which required staff to work onsite during the pandemic making them potentially the most affected with the loss of structured sport and closure of gyms. Prioritising recovery programs in neighbourhoods with low cohesion rates could aid with improved future outcomes in cohesion and physical activity.

Our study showed that people with lower neighbourhood cohesion undertook less physical activity before and during the pandemic. Individuals from vulnerable groups with lower cohesion are at particular risk of low physical activity with the associated risk to physical and mental health. Including a 'social cohesion assessment' as part of a health and wellbeing review could help identify those at increased risk of low physical activity and help direct people to the most suitable type of physical activity program. Building and promoting social/group interventions could support these already vulnerable groups.

Promoting community cohesion involves addressing fractures, removing barriers and encouraging positive interaction between groups. The most effective interventions will be one developed with local people and partnerships which is rooted in ideas and values which local people have helped developed and support. An effective community cohesion strategy underpinned by a shared vision. Investigate and working with the community to identify

what they want and need underpins the essence of how to target neighbourhood cohesion and subsequently improve physical activity.

The strengths of this study include a true pre- COVID-19 baseline, with data captured from January 2017 to December 2019, making it close to the period of interest but unaffected by the COVID-19 pandemic. Few studies have true baseline physical activity data, most rely on activity levels reported in the weeks prior to the pandemic leading to recall bias and physical activity that may have already been affected by the pandemic. There were multiple waves of physical activity data collected which allowed for longitudinal analysis. Validated scales were used to capture physical activity and neighbourhood cohesion. These scales provide reliable output which can be compared to other studies using the same scale. A large sample size increases the reliability and generalisability of the results. Limitations of the study are that while *Understanding Society* is representative of the UK population, the Covid subsample was not thereby reducing generalisability of the results to the general population. This study sample had a slightly higher proportion of white, employed and higher educated participants than the baseline study population, while sex, urban living and having a health condition stayed the same. My study captures data to mid-way through the pandemic, there could be further long-term effect on physical activity which have not been captured. The last time point was January 2021, there is a known drop in physical activity seen during the winter months (Turrisi et al., 2021), the drop seen here could be related to seasonality. Self-reported physical activity was used in this study, potentially reducing the validity and reliability of the measure due to recall bias, a validated scale was used to help mitigate this. A further limitation is that the neighbourhood cohesion data was collected prior to the pandemic, restrictions put in place such as lockdown and social distancing may

have changed neighbourhood cohesion during this time with subsequent impact on physical activity.

Future studies should evaluate the effectiveness of policies aimed at improving neighbourhood social environment not only on neighbourhood cohesion but also physical activity and long-term health and well-being of residents. These policies require realistic time scales for improvements in the social environment to be occur, and then a realistic time scale for the subsequent impact on physical activity and health for effective evaluation. Identifying if overall neighbourhood cohesion or a one of the sub-domains of neighbourhood cohesion affects physical activity could allow for targeted interventions. Additionally, different levels of activity may have different requirements, looking at components of neighbourhood cohesion with different levels of activity could allow for more strategic interventions.

This study offers a unique opportunity to look at neighbourhood cohesion and physical activity during a period of immense change and stress globally. Understanding why, and how, neighbourhood cohesion was important for supporting physical activity during this period could be important to long term intervention development and sustainability.

Findings support that the COVID-19 pandemic had an overall negative impact on physical activity. Results demonstrated that neighbourhood cohesion was associated with physical activity, and this was continued to be seen throughout the pandemic. As hybrid working continues as the new normal, neighbourhood cohesion may become more important as people spend more time in their neighbourhood both for work and living. An increase in facilities will be required to support physical activity at both the office and home environments. As high neighbourhood cohesion has been shown to have a positive impact

on physical activity, building communities with structures in place to support developing a sense of community, social interaction and attraction to the neighbourhood should be a priority to help build long-term neighbourhood cohesion and subsequently support physical activity. Strong relationships between public health and urban planning/design sectors are needed to develop and support local strategies in response to the health challenges that have been identified during the pandemic.

Chapter 5 –Study 4

The influence of perceived social support on participation in a physical activity digital health intervention

Background

In study 1 (Chapter 2) social support was identified as an important factor for maintaining physical activity during the first COVID-19 lockdown. In Study 2 (Chapter 3) themes from free text data regarding the impact of the pandemic on physical activity were identified. One theme 'the use of technology to aid physical activity' showed that the majority (94%) of people who reported using technology to support physical activity had a positive experience. Reporting they liked the ability to exercise when and where they wanted, and the ease of use. The remainder predominantly missed the socialising and social contact during and after the activity. Understanding why people are active or inactive allows researchers to develop interventions that target the behaviours that support activity. There is little known about the importance of social factors for the maintenance of physical activity within the digital health settings.

As technology has become more advanced and available, healthcare is using technology to deliver interventions and improve outcomes (Kane, 2014). Digital health interventions (DHIs) refer to health services that are delivered through electronic devices, the internet and related digital devices and is often defined as 'the use of information and communications technology, especially the internet, to improve or enable health and health care' (Van Der Mispel et al., 2017). This covers a wide range of services such as smartphone applications (apps), videogames, wearable health and movement-trackers, websites, messaging services (text message, emails, voicemail), and telehealth.

Technology provides an alternative to conventional face to face delivery and can provide a cost-effective and flexible way to deliver physical activity content to a large audience.

Technology allows for physical activity to be undertaken in a home-based setting, providing an opportunity for the performance of physical activity across a broad spectrum of levels and activities. This can range from simple movements tutorials that require no equipment and little space, through to complex virtual reality systems such as Zwift® or Peleton® that have specific equipment and allow virtual interaction/competition between instructor and other participants. Prior to the pandemic DHIs had been used to deliver a wide variety of lifestyle and health behaviour interventions. This included diet and weight loss programs, smoking cessation, alcohol consumption, and physical activity promotion to both children and adults. DHIs have the potential to have a large reach in both a time-efficient and a cost-effective way compared to in person contact (Van Der Mispel et al., 2017) and have increased in number since the start of the pandemic.

Google trends data was used to explore community interest in physical activity before and during COVID-19 outbreaks in Australia, the UK and the USA, community interest in exercise surged immediately following lockdown and then remained at a higher level than before the lockdown (Ding et al., 2020). While DHIs have the potential to reduce health disparities through their high reach capabilities and cost effectiveness, attrition is acknowledged as a significant problem in this area. Attrition is the main barrier to effective evaluation of DHIs with rates often reaching 60-80% (Geraghty et al., 2013). There are two main types of attrition: (I) attrition from the intervention itself (II) attrition from the follow-up assessment, making it very challenging to effectively evaluate a DHI (Geraghty et al., 2013).

There was an increase in web-based content during the COVID-19 pandemic, with online classes and apps developed and utilized by many, with users reporting the benefits of remote access such as increased flexibility (Hailey, Burton, et al., 2022). The content was

developed to support the new increase in interest for home-based physical activity and help reduce sedentary behaviour, for example P.E. With Joe. This was a live, free, exercise video on YouTube provided by Joe Wicks, British fitness coach, it was aimed at kids and families to support them keep active while schools were closed due to the pandemic. Although interest in physical activity increased, there is no information on participation, therefore the actual change in online engagement with physical activity resources is not known (Ding et al., 2020).

Digital health products, in the same way other health services and products, need to be evaluated. The Office for Health Improvement and Disparities published guidance 'Evaluating digital health products' (Office for Health Improvements and Disparities, 2020). The guidance highlighted the importance to conduct evaluations whether the product is in production or was already launched. There is additional specific guidance on the rapid evaluation of digital health products during the COVID-19 pandemic, when there was rapid implementation of many products. Digital products can be challenging to evaluate as they can change and evolve rapidly, and can also be complex, with many different features and functionality. Evaluation is important, especially during a period of rapid development and implementation of new technology, this can focus on a specific feature or take an overall approach.

Although there is a lack of data on the use and effectiveness of DHIs during the COVID-19 pandemic, there are a number of studies pre-pandemic looked at the impact DHIs had on physical activity. Appendix 2, table 1 has a summary of studies to promote physical activity via digital health interventions. Results for DHIs to promote physical activity is mixed, with effectiveness on physical activity often modest. A 2021 systematic review of 92 reviews (47

with meta-analysis) summarised that digital interventions are more effective than no intervention although the effect sizes were small, and effect was mixed compared to face-to-face interventions (Gold et al., 2021). Most trials reported that attrition rate was high and long follow-up was scarce. There was possible effectiveness in combined diet and physical activity interventions, there was no effectiveness when targeting physical activity alone except when delivered by mobile phone, which had medium size effect (Gold et al., 2021). A further systematic review and meta-analysis of 19 studies (16 random controlled trials (RCT) and three cluster RCTs), of which 11 explicitly targeted physical activity and the remaining eight targeted weight loss, general health or physical activity and diet. The studies used a range of digital technologies, an found that DHIs aimed at increasing physical activity were effective for people of high SEP but were not observed to be beneficial for people of low SEP (Western et al., 2021). A systematic review and meta-analysis of 22 RCTs looking specifically at web-based interventions found a positive and significant effect on increasing physical activity. However, further analysis showed the effect to be influenced by mean age (<45yrs), trial duration (>6weeks) and study quality (Jahangiry et al., 2017). Results from a meta-analysis of 34 studies demonstrated that internet-delivered interventions are effective in producing small but positive changes in physical activity, effect sizes were small, long-term change remains uncertain (Davies et al., 2012).

Primary care is recognised as an important setting for the promotion of physical activity, health care professionals have a role to play in promoting physical activity to patients. National Institute for Clinical Excellence (NICE) public health guidance (PH54) recommends physical activity exercise referral schemes when referred by a primary care practitioner or allied health professionals (NICE, 2014). Social prescribing enables primary care-based Health Care Professionals (HCPs) to refer people to a range of local, non-clinical services

e.g., physical activity classes, to support their health and wellbeing. It aims to address the needs of the patient in a holistic way and to support individuals to take greater control of their own health. It is designed to support people with a range of needs and many schemes are focused on improving physical and mental health and wellbeing. A systematic review of 51 randomised controlled trials of in-person physical activity interventions delivered or promoted by health professionals in primary care found an increased participation in physical activity, patients increased by an average of 14 min MVPA/week (95% CI 4.2-24.6, P=0.006) (Kettle et al., 2022). A further systematic review and meta-analysis of 24 studies looked at the efficacy of physical activity counselling interventions delivered in primary care, the systematic review suggests that health provider-led physical activity counselling interventions in primary care may lead to increased self-report physical activity (Oloo et al., 2020). However, meta-analysis showed that health provider-led physical activity counselling interventions in primary care did not lead to increased aerobic fitness or change in body mass index (Oloo et al., 2020).

The original aim of this study was to understand if social support was important for participation with an online, web based, physical activity program during the COVID-19 pandemic. Specifically, I hypothesised that higher level of baseline social support would be associated with greater participation in the program leading to increased physical activity. However, far lower than anticipated participation numbers (described later) meant that it was not possible to achieve these aims. The subsequent aim was therefore to look at engagement with the program and identify any future modifications.

Methods

The previous data chapters (3-5) used observational data. Benefits of using observational studies include, large samples, and multiple variables (explanatory and outcome).

Drawbacks of observational data include, having to use the variables that were collected, and the use of non-specific data collection tools. In study 1 physical activity was 1 of 12 items measured as part of data captured for 'time in use' rather than as a specific lifestyle action. Additionally, as research and technology advance the way we capture and collect data can change, therefore measures for the same variable across waves may be different. This can mean a loss of longitudinal power until multiple waves have occurred with the new method of measurement. This is of particular importance for physical activity where device measured technology has been available for the past 3 decades during which time technology has advanced. Objectively measured physical activity collected 20 years ago is unlikely to be measured using the same method today, even within the same cohort. With many different measurement and processing options available it is difficult at times to compare within, and between cohort. Due to these challenges the opportunity to work on an experimental study was exciting.

It was not feasible for me to set up and gain ethical approval for a randomised controlled trial within the PhD timeframe. The study in the current chapter was integrated into a MSc project led by Mark Hamer (secondary supervisor). The project was a service evaluation of a social prescribing pilot undertaken by DJ as part of his MSc in sports medicine, exercise and health. DJ was a general practitioner (GP) based at Tynemouth Medical Practice, NHS North Central London Integrated Care Board (ICB). The pilot was the provision of a 12-week, web based, physical activity program, for adults (≥18 years), registered with a GP practice within the UK. Patients had to have an underlying health condition and not be achieving current recommended levels of physical activity (150min/week MVPA). Patients that fitted the inclusion criteria were invited to participate by their GP or primary care practitioner. Recruitment started in August 2022 and finished in January 2023. The aim of the service

evaluation was to examine pre- and post- intervention MVPA to see if the intervention increased participation in physical activity. I embedded quantitative questions on social support and free text questions on the user experience within the questionnaire.

Experimental method

The most commonly used, and gold standard experimental design, is the randomised controlled trial. In clinical practice, quasi-experimental studies are often utilised due to difficulty in randomising subjects, ethical considerations and small available sample size (Harris et al., 2006). The study used a quasi-experimental design to undertake a service evaluation (randomisation is not permitted in a service evaluation) of a physical activity digital intervention in the primary care setting. In line with the Medical Research Framework for developing and evaluating complex interventions, conducting preliminary work was an important step before embarking on a RCT (Skivington et al., 2021). The framework divides intervention research into four phases: development, feasibility, evaluation, and implementation, research can begin at any phase depending on the intervention.

The study was submitted to UCL ethics, project number 22095/001 (April 2022), their decision was the project fell outside of the UCL REC's remit and a NHS Health Research Authority review was required. In May 2022 the NHS Research Ethics Committee decided the study was deemed to be a service evaluation and therefore did not need NHS Research Ethics Committee approval.

Intervention

The intervention was an online exercise program (The Motivation Club) launched in May 2021 in response to the pandemic. 'The Motivation Club' was created by Derrick Evans, aka Mr Motivator, a TV fitness instructor who rose to fame in the 1990 appearing on UK

breakfast shows. He is known for his colourful outfits and enthusiastic delivery and promoting health and fitness as a way of life. The website consisted of various areas supporting exercise and wellbeing. Within the exercise area there were workouts for all levels of fitness, including whole-body workouts, Pilates, yoga, general fitness, warm-up and stretch, strength and toning, chair workouts, weights, and props at home. These were available as pre-recorded videos which could be accessed at any time, and 3 live weekly sessions which users could sign up to attend. Live sessions ran Monday and Wednesday evening and Saturday morning. Users were asked to sign up in advance to the live sessions and participate with their videos on so the instructor could interact with them during the session. 'Find your activity pathway' was a function which calculates the user's current activity level and suggests which level of workout would be suitable for them on the website (colour coded). Another feature on the website was the 'sensible eating club', which aimed to develop balanced and realistic long-term eating habits, this was done via regular updated recipes, articles and cooking tips and pre-recorded demonstrations. Mind matters and wellbeing was the final area, this involved articles and pre-recorded videos discussing various mental health, wellbeing, and mindfulness videos. Members received a weekly email encouraging them to participate in activities.

Study material and resources, intervention poster, privacy notice, and patient information leaflet, were developed and written by both myself and DJ. See appendix 3 for full details.

The program was available for referral across the NHS for patients in primary care who would benefit from a physical activity program. The Motivation Club had agreed reduced price access for all NHS primary care patients of £1.99/month for the first 3 months, then reverting to full price of £5.99/month. This information would have been available through

local ICB communications, with supporting details of how to add the program to the electronic referral system (e-RS) which allowed for a digital referral to be sent to the patients mobile or email account. A patient received the referral link to the Motivator Club website via text or email with a referral code which they needed to input as part of the registration process.

Funding

There were two funding streams. The first started in August 2022, this was the NHS reduced-price scheme (provided by the Website owner to all NHS patients) which allowed access to the program for £1.99/month for 12 weeks, instead of the usual £5.99/month. Due to slow uptake in October 2022 funding was sourced from my secondary supervisor's department at UCL to cover the cost for 200 participants. The funded scheme provided free access for 12 weeks, followed by the reduced-price scheme (£1.99/month).

Study promotion

Study promotion was undertaken via number of different routes. DJ and I utilised professional networks to promote the study. At an individual level, DJ spoke with GPs, and practice managers, and I approached Public Health teams, GP practice pharmacists, making them aware of the program and that they could refer patients. A broader approach was also undertaken with the project discussed at the Royal College of General Practitioners annual conference by DJ, while I spoke with the Medicines Optimisation Lead Pharmacist for North Central London ICB, full study details and resources were provided. Meetings to engage with individual healthcare professional were undertaken virtually and face to face. A significant amount of time was invested in recruiting HCPs as they were essential for patient referral to the study. Initial recruitment started in June 2022, DJ reached out to colleagues and GPs

who had showed interest in the study providing them with full study details including referral methods. Due to slow participant recruitment, the new funding stream was introduced in August 2022, these changes were communicated to all parties who had been contacted previously. There was a further engagement drive of HCPs by DJ and myself in October, November and December 2022 in order to recruit as many health care professionals and subsequently participants as possible.

In December 2022 DJ developed 'champion practices' in the North Central London area to encourage update. This required the practice to have the study poster displayed in the waiting room, the electronic referral template setup in the surgery, and discussed the study in a practice meeting. Four practices in North Central London became champion practices for the study.

All the study information and resources e.g., patient information, patient poster were available on the North Central London weight management and nutrition website. Study information was published in The North Central London GP bulletin (November 2022), a blog about the study was included in the Royal College of General Practitioners Active Practice newsletter, send out on 20/12/2022. Sport London included study information in their monthly 'physical activity for health' newsletter (November 2022). I arranged via my supervisor for UCL, Institute of Sport Exercise and Health, to promote the study across social media (Twitter) and their website (November 2022). I provided relevant twitter accounts to be tagged to raise awareness. These included @BritSocLM @ResilientGP @BJSM_BMJ @NASPTweets @NurseinPractice @HCAssistants @PrimaryCareNHS @DiabetesUKProf @rcgp @gpcentrallondon @nhs_healthedeng @gptraininginfo @nhsenglandldn @enfieldnclicb @camdennclicb @barnetnclicb @nhs_nclicb @haringeynclicb.

If HCPs declined to be involved in the service evaluation they were asked the reason for this decision. Reasons were documented and collated manually by me.

Patient recruitment

Eligible patients were referred to the program by Health Care Practitioner based in primary care. A referral link was sent via email/text, or the patient could scan a QR code via the study poster. Either route took patients to the REDCap (a secure web application for managing online surveys) study page where I had built the week 0 and 12 questionnaires. I also setup REDCap to send out the 12 week link with three reminders. The link page contained further information on the study, patient information leaflet, and patient consent (see Appendix 3 for patient information and consent). Those who declined to take part in the study were taken to a link page directing them to the program website. Those who agreed to take part were taken to week 0 questionnaire, once complete, they were taken to the same link page to the program website. Once at the website they were able to complete the onboarding process.

Behaviour change techniques

Behaviour change interventions aim to change a specific behaviour e.g., physical activity. Interventions include a number of active and interacting components, in research we need to understand the active content of the interventions (successful and unsuccessful). This can be done using behaviour change techniques (BCTs). The BCT taxonomy (v1) is an internationally approved classification system of 93 distinct BCTs providing a rigorous method of characterizing active content of interventions (Michie et al., 2011, 2015). The BCT taxonomy is acknowledged as the standard for identifying and coding interventions for health behaviour change. Interventions with many BCTs can make interventions time-

consuming, less engaging and more confusing, too few they can be ineffective and including only effective techniques may be promising to lower the burden on participants and reduce attrition rates (Schroé et al., 2020), therefore it is important to understand what was incorporated in interventions. The BCT Taxonomy (v1) was used by me to code the BCTs systematically. I had done extensive BCT coding of physical activity interventions as part of my Public Health Masters dissertation, now published (Hailey, Rojas-Garcia, et al., 2022). However, to ensure consistency of coding I undertook online training to refresh understanding and practice coding. The target behaviour of the BCT coding was physical activity, therefore only the exercise areas of the website were coded for BCTs. Initially the website was coded from the perspective of a new starter, moving through the onboarding process and working through the different areas in a systematic manner. The website was subsequently accessed as a return user and BCTs identified via this pathway. The two lists were combined to form a complete list of BCTs for physical activity identified in the intervention. The complete list of BCTs were as follows, instruction on how to perform the behaviour, set graded tasks, credible source, comparative imagining of future outcomes, positive reinforcement, body changes, verbal persuasion about capability.

Measures

Physical activity was measured using the Nordic Physical Activity Short Questionnaire (NPAQ). This is a 2 item self-reported measure of physical activity which covers both time and intensity. It has been found to be reliable and valid to monitor PA levels. Test-retest reliability showed Spearman's rho = 0.82 for MVPA and 0.8 for VPA. When using objective and self-reported measures to monitor WHO's physical activity recommendations, the kappa correlations were 0.42 for open-ended and 0.34 for closed-ended answering modes. (Danquah et al., 2018). The first question asks 'on a typical week, total time spent on

combined moderate and vigorous physical activity?', and the second, 'how much of that time was spent on just vigorous activity?'. A description of the different levels of activity and examples of both were given, with activity that lasted ≥10minutes to be included. Five pre-set time options were provided: <30mins, 30-59mins, 60-<90mins, 90-150, >150mins. Data was coded to reflect Sport England levels of physical activity, inactive (<30mins MVPA/week), fairly active (30-149mins MVPA/week), active (≥150mins MVPA/week).

Perceived social support was measured using Perceived Social Support Questionnaire (F-SozU K-6), the same scale used in study 1. This is a 6-item questionnaire with a 5-point Likert scale ranging from 1=not at all, to, 5=very true, see supplemental Table 1. The scores for each measure are summed to give a total ranging from 6 to 30, where the higher the score, indicates higher levels of social support. The questionnaire was reported in other studies to have excellent construct validity and reliability for perceived social support (Kliem et al., 2015) with an internal consistency of 0.89 (Lin et al., 2018) and a Cronbach's alpha of 0.86, they did not report on other relevant metrics such as face validity (Labrague & De los Santos, 2020).

Self-rated health is a single item question that captures how respondents rate their overall health using is a 5-point scale from poor through to excellent. People who report they are in poor health are likely to have more physical and mental health conditions than those who rate their health as excellent. There is international consensus on the validity of SRH as a good predictor of morbidity and mortality (Cislaghi & Cislaghi, 2019).

Body mass index (BMI) is a calculation based on height and weight to identify potentially underweight /healthy /overweight people. It is not a perfect measure, it can only tell if a person is carrying too much weight, it cannot tell the difference between excess fat, muscle

or bone. Therefore, an athletic adult with a lot of muscle may have a high BMI as well as an adult with high adiposity. In order to calculate BMI self-reported height and weight was collected. Height was collected as either feet/inches or cm, and weight as stone/pound or kilograms. BMI was calculated using the NHS online calculator (NHS, 2022).

Covariates Demographics and medical information were obtained from baseline questionnaire. This included, sex (male/female), age (18-39, 40-49, 50-59, 60+), ethnicity (white/BAME), higher education (yes/no), employed (yes/no) and reason for referred to the program (hypertension, diabetes, risk of diabetes, raised cholesterol, obesity, mental health, osteoarthritis, other and do not know).

At week 12 there were an additional range of 'yes/no' and free text question (see table 24), these captured data on how participants got on with the program and future plans for staying active.

Table 24. Week 12 questions to find out how participants got on with the program

Question	**Response options**
Did you have a suitable device to access participate in the program?	Yes No
Did you need help to access the program?	Yes No
Could you see/hear the sessions clearly?	Yes No
Did you have suitable space in which to participate?	Yes No
Have you been injured during any of the classes?	Yes No
Do you feel confident to continue being active?	Yes No
How would you rate your online experience?	Poor/Average/Great
Moving forward, how do you plan to stay active?	*Free text*
What is the biggest barrier to being active?	*Free text*
If you could change one thing about the program what would it be?	*Free text*

What did you enjoy the most about the program?	*Free text*

See appendix 3 for full details of week 0 and week 12 questionnaire

Analysis

The original analysis plan was to look at baseline characteristics, calculated through percentages, and means with standard deviations (SD) then conduct the following analyses. Chi-squared test to identify differences in those that completed follow-up versus those that did not. Logistic regression to analyse the baseline relationship between physical activity (inactive vs fairly activity) and, social support, BMI and SRH. Further logistic regression to analyse the relationship between week-0 social support, and 12-week outcomes (physical activity, use of the program, enjoyment, participation in live session and pre-recorded session). T-test to identify if there was a change in social support from week-0 and week-12.

Unfortunately, due to lower than anticipated participant numbers it was not feasible to run the original analysis. An adapted plan was developed, this continued to look at baseline and follow-up characteristics calculated through percentages and means with standard deviations and then a review of program usage and feedback.

Results

Forty-nine patients consented to participate in the study and completed baseline questionnaire. Study participant demographics are presented in table 25. At baseline 15 participants were on the discounted payment scheme and 34 were on the funded scheme. The majority were female (77.5%), aged 50+ years (55%), from BAME background (55.1%), higher educated (63.3%), employed (65.3%), and did less than 30 minutes of MVPA/week (51%). Self-rated their health was evenly split between poor/fair (49%) and good/very good

(51%). Mean social support was 22.6 (range 11-30), SD 4.43. And categorised, low social support 14%, medium 57% and high 29%. Mean BMI was 33.5 (range 21.4 to 47.4) SD 7.94. Two participants reported achieving physical activity guidance. Eleven participants preferred not to provide their weight; BMI data is calculated on 36 participants. Nine (18%) proceeded to complete the 12 week follow up questionnaire despite receiving 3 reminder emails.

Table 25. Characteristics of study participants (n = 49) at baseline and follow up

	Week 0 (N = 49)		**Week 12** (N = 9)	
	N	*%*	N	%
Sex				
Male	11	*22.5*	2	*22.3*
Female	38	*77.5*	7	*77.7*
Age				
18-39	9	*18.4*	3	*33.3*
40-49	13	*26.5*	1	*11.1*
50-59	14	*28.6*	4	*44.4*
60+	13	*26.5*	1	*11.1*
Ethnicity				
White (British/Other)	22	*44.9*	4	*44.4*
BAME	27	*55.1*	5	*55.6*
Higher education				
Yes	31	*63.3*	7	*77.8*
No	18	*36.7*	2	*22.2*
Employment				
Yes	32	*65.3*	5	*55.6*
No	17	*34.7*	4	*44.4*
Referral reason				
Hypertension	11	*22.5*	2	
Diabetes	6	*12.2*	0	
Risk of diabetes	8	*16.3*	1	
Raised cholesterol	11	*22.5*	2	
Obesity	22	*44.9*	2	
Mental health	6	*12.2*	2	
Osteoarthritis	6	*12.2*	1	
Other	10	*20.4*	4	
Don't know	5	*10.2*	0	
Physical activity (MVPA)	25	*51.0*	2	*22.2*

Inactive (<30min/wk)	22	*44.9*	3	*33.3*
Fairly (30-150min/wk)	2	*4.0*	4	*44.5*
Active (>150min/wk)				
SRH				
Poor	8	*16.3*	2	*22.2*
Fair	16	*32.7*	2	*22.2*
Good	20	*40.8*	3	*33.3*
V good	5	*10.2*	2	*22.2*
Excellent	0	*0*	0	*0*
Social support				
Low (6-17)	7	*14.3*	1	*11.1*
Normal (18-25)	28	*57.1*	7	*77.8*
High (26-30)	14	*28.6*	1	*11.1*
Social support (continuous)	Mean = 22.6	SD = 4.43	Mean = 21.56	SD = 3.78
BMI	Mean = 33.5 (n=36)	SD = 7.94	Mean = 31.66 (n=7)	SD = 7.12

12-week follow up

Nine (18%) of the 49 participants completed the 12-week follow up questionnaire. Three were from the reduced-price cohort and six were from the funded cohort. There were differences between baseline and the respondents see table 25. There was an increase in respondents in the 50-59 age group in the follow up group. There was an increase in higher educated and unemployed participants. There was a drop in those reporting high social support, this was reflected in an increase in normal support. Two participants preferred not to provide their weight; BMI data is calculated on seven participants.

Three respondents were from the reduced-price cohort therefore there was no data on their access and usage, two reported using the program in the questionnaire. The six funded respondents, one did not activate their account on the platform. Five participants accessed

the platform, four accessed it for ≤2 min and the final participant accessed it three times for a total of 37 minutes across the 12-week study period.

Usage

Usage data was available for the 34 funded participants. 16 participants did not proceed to set up an account and therefore did not interact with the platform. Of the 18 participants who activated their account, six did not log onto the platform for the duration of the study and eight participants logged on for ≤2 min. The remaining four participants accessed the platform for an average of 45.5 minutes (range 26-83) over the 12-week study duration. Note: one of the participants who accessed and used the platform reported achieving physical activity guidelines prior to the study and did not report an underlying health condition therefore did not meet the referral requirements for this study.

Exploratory analysis was run to see if there was a difference in social support between those that did or did not activate their account. A two-sample t test was used for this analysis, mean social support for the 18 participants who did activate their account was 22.7 (SD 2.74) and 21.2 (SD 5.39) for the 16 participants who did not, no statistical difference found ($p=0.32$) suggesting that social support did not affect if people activated their account or not.

Patient feedback

Feedback on using the platform was collected in the 12-week follow up questionnaire (n=9). Six (66%) reported they had an appropriate device and did not need help to access the program and four (44%) reported not having a suitable space in which to participate. Seven (77%) felt confident to continue being active, five (55%) had a plan on how to take this

forward. Activities mentioned to stay active included walking, running, the gym, swimming, Mr Motivator exercises and YouTube videos. The main barriers for being active were pain, time, cost and the program only working on certain devices. Lack of communication, and problems accessing the program were raised as issues. Others reported liking the idea and enjoyed the program, finding it motivating and encouraging and enjoyed feeling like part of a team in the work out sessions.

HCP feedback

Feedback was collected informally, predominantly verbally at point of recruiting HCPs. Feedback was mixed, some commented they were pleased to have something available for inactive patients, especially if there was nothing available locally. Others reported, online physical activity interventions had been tried before and found to be unsuccessful, they felt there was nothing new or unique about the program, so declined to participate. A proportion of HCPs were uncomfortable with the commercial aspect (patients required to pay after 12 weeks) and did not want to be involved because of this. A small number reported they did not like the intervention, aesthetically or content wise and would prefer not to refer patients to the platform.

Discussion

The aim of the study was to understand if social support was important for engagement with a DHI leading to an increase in physical activity. Due to low uptake there was insufficient data to run this analysis. Low patient participation was observed in this study, patients that received a referral, did not interact or use the platform. Attrition is a known problem to the evaluation of DHIs often reaching 60-80% (Geraghty et al., 2013). 11.8% (four) of the 34 (with usage data) used the intervention and 18.4% (nine) of 49 total

participant provided feedback which is higher attrition from the intervention and feedback than I expected.

Recruitment was slower and lower than anticipated. This is likely to be multifaceted, as discussed in more depth later in the discussion this could due to lack of engagement with health care professionals and the end users. Additionally health care providers were still under a great deal of pressure. They were dealing with COVID-19 positive patients, providing urgent medical care and manging patients with long term conditions for the duration of the study. We were still in a pandemic, patients were being seen remotely, appointments were limited, and managing the presenting complaint was a priority. With limited capacity, identifying appropriate patients, discussing, and then referring patients to a physical activity intervention may not have been possible. Additionally, patients who were already dealing with long term conditions, which potentially put them at greater risk of a serious COVID-19 infection may not have been in the right place emotionally to engage with a physical activity intervention.

Attrition was particularly high for this study with only 9 participants providing 12-week data.

While the original analysis plan could not be run there were some strengths and learning from the work. As discussed in the introduction physical activity interventions promoted and delivered by health professionals in primary care can increase participation in physical activity. Planning for this study started in November 2021 when the COVID-19 pandemic was still an ongoing health emergency and restrictions were changing at pace. Should COVID-19 restriction, such as lockdown or gym closures have been reintroduced this would not have disrupted or stopped the study.

There are a number or weaknesses, some of which have already been alluded to in the results section. The key weakness was poor engagement from patients leading to low participation and minimal results. This could perhaps have been minimised by working with the end users via patient and public involvement groups. This could have included a range of HCPs and patients to get their input during the study set up. For HCPs, this could have identified the concerns regarding the use of a commercial product and long-term funding earlier in the process, giving more time to find a suitable long-term solution. The issue was only raised when I started recruiting HCPs, by which point I was unable to change the study. This concern was not just at individual level, it had been hoped that the Royal College of General Practitioners would support and promote the study however, when approached they were unwilling to do this due to the commercial nature of the intervention. The introduction of the UCL funded stream was thought to be a solution for the purpose of this study. However, HCPs had ongoing concerns regarding low-income patients who might find benefit from the intervention and wish to continue accessing the program once the study finished. Patient and public involvement may also have highlighted the concern around the lack of new insight the study would achieve. Engaging stakeholders and economic consideration are core elements of the MRC evaluation complex interventions framework and elements that should be considered early and revisited throughout the research process. The study was promoted as a service evaluation potentially shifting the focus of the study promotion to the role of social support in engagement in physical activity (via a DHI) would have allowed me to communicate more effectively what was unique about the study and may have generated more interest from HCPs.

Due to the network approach and ethics approval as a service evaluation, I was unable to track which HCPs referred patients to the study. Therefore we have no information on

which HCPs actively participated in referring patients to calculate HCP engagement or if referral by one kind of HCP was more effective than another. I also do not know the total number of patients referred to the program to calculate patient engagement. Access to this data would have given greater insight into patient engagement, and at what point they disengaged.

Due to the lack of feedback (nine patients) and low patient engagement (18 patients, activated account and only four used it) it is difficult to identify why patients did not engage with the intervention. In future studies it would be helpful to undertake some qualitative work, speaking with patients/ HCPs via patient and public involvement groups or interviews, to find out what they liked or disliked about the study intervention. If done during initial stages (study set up period), it would have allowed me to identify and mitigate any issues with the study to maximise engagement and participation. Repeating the process at the end of the study would allow me to find out what had, or had not worked, and provided a space for suggestions to improve the intervention. The lack of feedback gave little guidance as to why the intervention was not successful.

Within the intervention there was a lack of BCTs linked to behaviour change which could have contributed to the lack of engagement and use. There were no BCTs from goals and planning, feedback and monitoring, social support, or reward and threat, which are commonly seen in behaviour change interventions. A study of obese patients identified BCTs found to be significantly associated with positive changes in positive changes in physical activity. The largest effects were found where interventions contained 'teach to use prompts/cues', 'prompt practice' or 'prompt rewards contingent on effort or progress towards behaviour' (Olander et al., 2013). Additionally, goal setting and monitoring activity

were consistently found effective in increasing physical activity, instructions on how to perform the task and self-monitoring were also effective (Abdin et al., 2019). An evaluation of 20 physical activity websites identified the majority provided little assessment, feedback, or individually tailored assistance for users (Doshi et al., 2003) suggesting that building BCTs into websites for behaviour change may be under-utilized across this delivery system. Interventions need to target and support change involving the psychosocial and behaviour-shift for long-term behaviour change to be successful (Rabin et al., 2006). The intervention website was set up by a team qualified in the fitness industry and nutrition but appears to lack behavioural specialist input. The lack of experience in behaviour change and apparent insufficient knowledge of BCTs commonly seen in behaviour change interventions may have contributed to the surprising absence of content supporting behaviour change.

A limitation of my study was working in collaboration with another investigator. I initially wanted to include a loneliness measure (UCLA scale) in the questionnaire as I had looked at both social support and loneliness in study 1 and I was interested in if the results were consistent. However my collaborator was not comfortable with the inclusion of this measure and it was removed. Working with an external provider was also a limitation, the collaboration changed over the study period (initially they were providing free access to NHS patients and then changed to reduced cost) which forced the project to change and created problems which had to be resolved quickly to keep the project running on time.

Conclusion

Referral to this web-based physical activity intervention demonstrated poor patient uptake. Research suggests that there was an increased interest in online physical activity during the pandemic (Tison Geoffrey, 2020), the results from this study suggests that it did not translate into engagement and participation. Alternatively, as we move out of the COVID-19

pandemic people may be shifting back to face-to-face as society reopens having used online resources during the pandemic. Behaviour change is a complex, previous research suggest that while some internet-based interventions have had a positive effect on physical activity (Jahangiry et al., 2017), interventions targeting physical activity alone were more effective when delivered by mobile phone (Gold et al., 2021). Contact via SMS/text message can help boost website utilisation and potentially increase physical activity (Joseph et al., 2014). Referring inactive patients to the present intervention may have had greater uptake if more support, engagement, and goal setting was incorporated.

Chapter 6 – Discussion

The overarching aim of this thesis was to look at the role social factors played in supporting physical activity during the COVID-19 pandemic. Data suggests that the COVID-19 pandemic had an overall negative impact on physical activity levels (Ammar et al., 2020; Tison Geoffrey, 2020). There was evidence from before the pandemic that social support was positively associated with physical activity (Scarapicchia et al., 2017). This thesis explored whether social factors contributed to people staying active during periods of lockdown and social disruption. The studies looked at social factors and physical activity to identify what factors had a positive association, what helped people to be active during the pandemic. This information can be used for future pandemic planning and public health initiatives.

Overview of findings

My first study looked at perceived social support and physical activity during the pandemic. The analysis identified that compared to low social support, high social support was associated with a 64% (95% CI, 50-80%) increased odds of sustaining physical activity, and medium social support was associated with 32% (95% CI, 20-44%) increased odds. Although initial associations between loneliness and social isolation had decreased odds of sustaining physical activity during lockdown the association was lost in minimally adjusted models. From the Physical Activity Pattern Index generated to identify those who had remained active during lockdown 1, 42% of participants were consistently inactive, 41% were intermittently active (of which the majority (59%) were active for only 1 or 2 weeks), and only 17% were consistently active.

My second study was a qualitative analysis of free-text survey data, this aimed to gain a greater understanding of the overall impact of the pandemic on physical activity. The data suggested the majority of respondents had a positive experience of physical activity, with

89% reporting either continuing, increasing activity, or specifying their enjoyment of being active. Seven key themes were identified: the importance of outdoor space, changes in daily routine impacted physical activity, COVID-19 restrictions prevented participation, perceived risks or threats to participation, the importance of physical health, the importance of physical activity for mental health and the use of technology to aid physical activity. Themes were mapped to the COM-B framework. The use of technology to aid physical activity was the only theme that mapped to both capability (*physical* and *psychological)* and opportunity (*physical)* as a facilitator, suggesting that using technology as a means of engaging in physical activity could be effective. This theme was a driver for the fourth study.

My third study was developed from the theme 'perceived risks or threats to participation' with the subtheme of 'feelings of safety outdoors'. Although not a direct measure of area safety, neighbourhood cohesion is an indicator of the social environment. I found an association between neighbourhood cohesion and physical activity at pre-pandemic baseline ($p \geq 0.001$), with a one unit increase in neighbourhood cohesion corresponding to an increase in physical activity of 193 MET-min/wk (95% CI 39.88 – 346.80 p=0.014). Across the pandemic I found a significant reduction in overall physical activity of -441 MET-min/wk, (CI 374.51 – 507.65, $p<0.001$). The difference in physical activity change between lowest and highest neighbourhood cohesion categories at follow up was 373 MET-min/wk, p=0.036. This demonstrated a slower decline in physical activity over time for participants with higher neighbourhood cohesion, suggesting that neighbourhood cohesion had a protective effect on activity.

My final study was developed from the theme 'use of technology' as a motivator for physical activity. This was a quasi-experimental service evaluation of a physical activity

website, analysis was to identify if social support was a predictor of engagement and increase in physical activity. Forty-nine patients complete baseline data collection, nine completed the follow-up questionnaire, unfortunately due to the low numbers, original analysis was not possible.

Interpret of results/ Implication

The COVID-19 pandemic created a range of barriers and facilitators affecting how people interact and undertook physical activity. Social factors, such as social support and neighbourhood cohesion, which prior to the pandemic had been positively associated with physical activity, had not been studied during a pandemic setting. The results from this thesis suggests that even with the social upheaval and societal changes that occurred during the pandemic (lockdown, social distancing, working from home) the constructs important for physical activity held during this period of social restriction. Some changes that occurred during the pandemic, such as social distancing, have reverted to pre-pandemic arrangements. While others have remained leading to long-term change, such as hybrid and/or remote working. Even with these short- and long-term societal changes, social support and neighbourhood cohesion continue to be important positive factors for physical activity.

In study 1 I explored the social factors that predicted the likelihood of an individual engaging in sustained physical activity through lockdown. Prior to the COVID-19 pandemic, social support had been associated with positive physical activity participation (Scarapicchia et al., 2017) and levels of physical activity (Lindsay Smith et al., 2017; Kocalevent et al., 2018; Stapleton et al., 2015).

During the pandemic, social support was found to be a consistent predictor of sustained activity. This suggests that even during social restrictions, when support may be disrupted from usual patterns (e.g., offered virtually rather than face-to-face), social support remains a key influencer of physical activity behaviours. This is in line with the theory that strong social relationships with good perceived social support is important should be encouraged to support physical activity (Kang et al., 2018) and that good social relationships support better health during stressful life events and in daily life (Buchwald, 2016).

In study 2 I aimed to understand the impact of the pandemic on physical activity. Undertaking thematic analysis to identified barriers and/or facilitators affecting physical activity. Overall, the majority of participants reported having a positive experience of physical activity during the pandemic, reporting they continued, increased, or specified they enjoyed being active, walking outdoors, and gardening were the most often reported activity. As discussed in the introduction, the majority of studies have shown a drop in overall physical activity which differs from these results. This could be due to a number of reasons, these studies predominantly used self-reported physical activity data which is often inaccurate and requires a respondent to recognise an activity as physical activity. Walking and working in the garden, which were the most mentioned activity, are classified as moderate level. People may not associate this as physical activity and therefore were under reporting the amount of physical activity.

The importance of greenspace, both the desire to be outdoors, and access was the main theme. Walking outdoors was found to be an accessible and acceptable form of moderate physical activity for many, adding to the evidence supporting the importance of outdoor space for physical activity (Gladwell et al., 2013; Stock et al., 2022). Prior to the pandemic, exercise in a green space was found to increase enjoyment and provided escapism from

everyday life (Gladwell et al., 2013). The implication from my study was that this became more relevant during lockdown with the increased challenges faced by many, enjoyment and escapism became more pertinent. Having a companion to be active with was also associated with undertaking physical activity in green spaces (H. Wang, Dai, et al., 2019). The results from study 1, the importance of social support, and the enjoyment of exercise outdoors from study 2 replicates these findings in a pandemic setting. This thesis provides evidence that group, outdoor, walking interventions as public health initiatives should be supported. However, for interventions to be effective, green spaces and parks need to be maintained as the quality, safety and accessibility, affects their use for physical activity (Kondo et al., 2018; A. C. K. Lee & Maheswaran, 2011). Changes in routine were predominantly about the positive impact of a reduction in commuting time. Reduction in commuting allowed more time to participate in physical activity, and a subsequent benefit seen on mental health and stress reduction. This information provides insight into the benefits of access to working from home or hybrid working for both employers and employees. Replicating this with validated mental health scales would provide further evidence of the benefits of flexible working on mental wellbeing.

As COVID-19 management developed through the pandemic, some of the themes which created barriers to physical activity were acute and have resolved as restrictions have been removed. Increase in caring responsibilities, an acute barrier, reduced as facilities e.g., schools, daycare reopened, reducing the burden on families and individuals as carers for children and older adults. Concerns about the risks of participation in physical activity in an indoor or group setting during the pandemic was another acute barrier. With the WHO announcing the end of the pandemic, COVID-19 infections dropping, and restrictions lifted, this should be resolved. While these barriers have resolved as the pandemic recedes, they

provide insight into the lived experience and should be addressed in future pandemic planning to ensure physical activity remains available to all.

The importance of physical activity for health, both physical and mentally, were identified as facilitators for physical activity. COVID-19 provided a tangible reason to be active as studies showed being active prevented severe COVID-19 outcomes (R. Sallis et al., 2021), suggesting that providing real-life health benefits could help support people to be more active rather than trying to be active for generic 'better health'. Knowledge and confusion about physical activity is a known barrier to participation (Amireault et al., 2013), during the pandemic due to the closure of many facilities, walking became the simplest and easily accessible form of activity, providing an opportunity for people to participate without being overwhelmed while achieving the health benefits.

The use of technology to aid physical activity was identified as a facilitator. Some people who had physical activity affected by restrictions, or safety concerns, could replace their activity with technology-based product e.g., apps or online workouts, to support them being active during the pandemic. Participants reported that technology allowed them to participate in a place and setting which they felt safe/comfortable and at a time which suited them. This corresponded with findings from a qualitative Canadian study which found that people continued to be active if they were able to find alternative activities suitable for the lockdown environment such as online workouts or using home exercise equipment (Petersen et al., 2021).

Study 3 looked at community level rather than individual support for physical activity. The results showed that higher neighbourhood cohesion pre-pandemic was associated with higher physical activity which continued during the pandemic. This supports studies, predominantly from the USA and from specific sub-populations e.g., Hispanic, walkable

community, that showed greater neighbourhood cohesion was associated with greater physical activity pre-pandemic (Echeverría et al., 2008; Murillo et al., 2016; Quinn et al., 2019; Samuel et al., 2015; Zhu et al., 2014). The fact that neighbourhood cohesion continued to be positively associated with physical activity, even during periods of lockdown, perhaps links to studies from previous disasters which have suggested that higher perceived neighbourhood cohesion creates greater community resilience which aids in faster recovery from natural disaster (Cagney et al., 2016). Building neighbourhood cohesion does not just benefit physical activity, it also creates community resilience which benefits all aspects of public health. This may also become more important as hybrid working continues and people spend more time living and working in their local neighbourhoods.

It is unlikely that there is a single intervention would result in improvements in social cohesion with community-specific solutions the most likely to be effective. Fostering social trust and strong relationships with long-term strategic approaches are necessary for improving social cohesion and individual well-being. Social cohesion is centred on how space is used and how communities are brought together in them, creating places which provide these opportunities for bridging and bonding is key. Encouraging people to come together around food, games, sport and celebrations can help build bridges between groups, create a sense of unity in the local area and help overcome prejudice and tension in the community.

The final study in this thesis aimed to look at social support and engagement with online physical activity. As mentioned above people reported using technology to support activity during the pandemic, this did not translate into engagement for inactive people as we moved out of pandemic restrictions. Pre-pandemic studies showed that interventions targeting physical activity alone were less effective, combined with diet and support via phone has greater effective (Gold et al., 2021). Study 2 suggests that while people were

aware that physical activity and good health reduced the risk of severe COVID-19 infection and they liked online delivery, the final study shows they did not engage with our online intervention. If study 2 participants were already regularly active, replacing an activity with an online alternative may have supported engagement. Study 4, the target group was inactive people referred to help them increase activity, this may have contributed to the low engagement.

The lack of results from the online physical activity service evaluation highlights the need for robust evaluation of digital physical activity interventions which are currently unregulated. While the website was set up by professionals qualified in the fitness industry, the lack of behaviour change knowledge led to content that was unlikely to lead to a change in physical activity (Michie et al., 2011, 2015). Research suggests that internet-based interventions can be effective if combined with a secondary method of delivery e.g., text message, secondary contact helps boost website usage and subsequently physical activity (Joseph et al., 2014). Adding content to the intervention website to support behaviour change and including secondary support via text/SMS could lead to greater engagement and better results. Repeating the study after these changes could show improved engagement.

Methodological appraisal

There is still much discussion about how best to measure physical activity, with questions raised on the validity of self-report tools and device-based measurements. Across this thesis three different types of self-reported physical activity measures were used. This included a non-validated, self-reported questionnaire using a '*stylised questions*' and '*time diaries*' approach in study 1. The International Physical Activity Questionnaire (IPAQ) short form used in study 3, an internationally recognised and a validated scale that allows for MET/mins week to be calculated. Finally, the Nordic Physical Activity Short Questionnaire (NPAQ) used

in study 4, a 2 item self-reported measure of physical activity which covers both time and intensity, data can be coded to reflect Sport England levels of physical activity (inactive/fairly active/active). It is known that self-reported physical activity measures are all at risk of potential bias, particularly recall and social desirability bias (Olds et al., 2019). Physical activity is seen as a socially desirable behaviour and may lead to overreporting because of this. Recall bias occurs when participants do not accurately remember past events, bias increases as the period of recall extends further back in the past can lead to inaccurate reporting. Both can be a serious threat to the internal validity of self-report. High intensity or planned, structured, physical activity tend to be easier to remember than light activity/incidental movement such as walking. Planned physical activity usually occurs in blocks of time e.g., played tennis for 1 hour, however, high intensity physical activity does not occur for the entire duration, it occurs in short bouts however, this will likely be reported as 1 hour of MVPA (Troiano et al., 2014). There are two possibilities regarding reporting physical activity during the pandemic, as structured sports stopped due to restrictions, potentially making physical activity harder to remember and quantify, leading to inaccurate reporting. Alternatively, going outside to participate in physical activity was one of the few things allowed during pandemic lockdowns making it stand out as an activity and therefore reported more accurately.

Double labelled water method is the gold standard for measuring energy expenditure although this is not an easily utilised method (Westerterp, 2017). While this is the most accurate of measure of energy expenditure (Westerterp, 2017) it is not a technique for use on a large scale or pandemic setting.

Wearable technology devices (accelerometers) have been accessible since the 1990s and are thought to be the most objective technique available for measuring physical activity on

a large and small scale (Troiano et al., 2014). Device-measured physical activity helps reduce reporting bias compared with self-reported physical activity questionnaires (Madigan et al., 2021). The most frequently used research grade device is the ActiGraph® motion tracking device, it combines validated motion tracing with an integrated inertial measurement unit which can be worn on a number of body areas (Migueles et al., 2017). Location of the sensor affects accuracy and comparability, a waist mounted sensor is preferred for lying/standing data, while the thigh mounted sensor is preferred for walk/jog/run movements. Compliance with tracking devices is often poor due to discomfort while wearing them, wrist mounted sensors are less accurate at capturing physical activity e.g., step count, but improve wear compliance (Migueles et al., 2017), there are concerns about accuracy and comparability of data captured from different body locations (Troiano et al., 2014).

Evidence has shown discrepancies between validated self-reported and accelerometery measured physical activity with low to moderate correlation (Madigan et al., 2021; Troiano et al., 2014). While these methods are both recording physical activity, these assessment methods are not capturing the same data and are therefore not equivalent (Troiano et al., 2014). Accelerometer data quantifies acceleration from body motion at a fixed point of the body e.g., joint, the raw data is processed, and physical activity is expressed as standard metrics, self-report data provides a proxy measure of body movement of perceived time-use and intensity of movement (Troiano et al., 2014). Both can be expressed in the same metrics e.g., MVPA, however, they are not assessing the same thing. Current WHO guidelines are developed from self-reported physical activity and therefore caution should be applied with device-based measurements due to the difference described above.
While wearable technology devices are commonly used to measure physical activity behaviour in research and there are many benefits to be found using this technology. Due to

the fast onset of the pandemic restrictions, the number of participants involved in both the COVID-19 Social Study and *Understanding Society* COVID-19 sub study, using device-based measurement was not feasible. The only realistic option for physical activity data collection during this period was to use self-reported questionnaires with awareness of the potential biases.

Defining and measuring abstract social constructs, such as social support, is not always straightforward. Studies use different concepts and operationalisations of social constructs to capture social indicators and transform them into a measurable metric. Capturing subjective constructs, such as social support and neighbourhood cohesion, in a meaningful and consistent manner allows researchers to quantify change over time and provides a better understanding of the impact of these constructs on other outcomes such as physical activity. Using an appropriate, reliable, and validated questionnaires can reduce the risk of measurement error, allows for greater certainty that we have measured the construct that we are trying to capture, comparison between studies and conclusions to be drawn with greater confidence.

During the pandemic, established longitudinal studies collected COVID-19 waves from within their samples and COVID-19 specific studies were setup. These studies collected data over multiple time points allowing for both longitudinal and cross-sectional analysis.

Many of the published studies reporting physical activity were cross-sectional, providing a snapshot of what was going on at that specific time point in line with many physical activity studies. When working on study 1 I could only find one study which used a sustained physical activity index (Janssen et al., 2014). Subsequently, studies looking at COVID-19 have looked at sustained physical activity prior to the pandemic, demonstrating the benefits of sustained activity on severe COVID-19 outcomes (S. W. Lee et al., 2021; R. Sallis et al., 2021).

Of 61 studies included in a rapid review of the impact of COVID-19 on physical activity, 52 (85%) were cross sectional and 9 (15%) longitudinal, this study concluded that COVID-19 was linked with significant negative impact on physical activity and increase in sedentary (Park et al., 2022). Where pre-pandemic physical activity was reported, they often reported a baseline which was retrospectively self-reported with potential bias. The baseline data would be at particular risk of recall bias due to the time elapsed from unaffected physical activity and time to data collection. Most questionnaires have been validated with a 1 or 2 week recall period, beyond which accuracy drops (Juniper, 2009).

The Covid Social Study was a pandemic specific study, this was set up swiftly, capturing data from the first week of lockdown. The study captured data weekly allowing me to track behaviours in a large cohort of people through lockdown 1. While there was no pre-pandemic baseline the repeated measures allowed me to identify those who had remained active throughout the first lockdown versus those who were inactive or intermittently active. Looking longitudinally at those who remained active showed that only 16% were classified as consistently active while cross-sectional results gave a higher number (27-32%), which are similar to levels reported by Sport England (32%) (Sport England, 2021a). Cross sectional data showed the percentage of the population reporting being active each individual week, however, longitudinal data allowed me to see that far fewer were consistently meeting the guidelines suggesting more work needs to be done not just to get people active, but to keep people consistently active. This study highlights the need to look at longitudinal physical activity behaviour rather than cross-sectional to get a better understanding of who is maintaining activity. This is important because people need to participate in regular and consistent physical activity as to achieve the greatest benefits (Aaltonen et al., 2012; Moholdt et al., 2018).

Understanding Society is an ongoing longitudinal panel study which established a COVID-19 sub-study at the start of the pandemic. Longitudinal studies utilise more vigorous sampling methods than most cross-sectional studies and often use a consistent measure of physical activity, which can increase the generalisability and reduce the survey recall bias (Park et al., 2022). Physical activity is a revolving module with data collected in alternative waves in the main study and periodically in the COVID-19 sub study. Fortunately, physical activity data was collected in the wave prior to the pandemic, thus data was recent, providing me with a true baseline measure of physical activity to compare subsequent COVID-19 impacted activity levels. Additionally, the self-report questionnaire was validated, and the same one was used pre- and during the pandemic, thus participants would be familiar and experienced completing the questionnaire, potentially strengthening reporting, reducing bias, and allowing for comparison.

The choice of a quasi-experimental model for a service evaluation in clinical practice was the most appropriate. Due to the challenges of blinding and potential cross contamination when undertaking physical activity interventions, using a 'before and after' model was the best fit (Harris et al., 2006). Recruitment and retention are a common problem with clinical interventions and a particular problem with digital health interventions (Geraghty et al., 2013), this study demonstrates this with low recruitment and response rates. The lack of behavioural specialist input to the program was a methodological limitation, this was perhaps due to the pressure of producing something during the pandemic which also contributed to the lack of review and assessment of the intervention prior to launch. An area which the intervention development team need to work on for improved engagement.

Pharmacy and physical activity

As part of study 4 HCP recruitment, I reached out to my pharmacy network to see if they would participate in the study. I knew from my pharmacy background that health is socially patterned, many people do not take enough physical activity, pharmacy is accessible for many people. Pharmacists are embedded throughout primary and secondary care undertaking a variety of roles and counselling patients on a regular basis therefore they were in a position to refer patients to the online intervention. The following discusses whether pharmacy staff are best placed to advice on physical activity as an additional part of their role.

Pharmacists and their teams play an important role in health promotion with public health practice embedded in their everyday role. In the community setting, pharmacies deliver a wide range of public health interventions such as smoking cessation, sexual health services, alcohol interventions, substance misuse, and immunisation, alongside their role supplying and optimising the use of medication. Hospital teams act as antibiotic guardians, optimise medication, provide advice for management of long-term conditions, prescribe in specialist clinics e.g., anticoagulation clinics, and can refer patients to community pharmacies to provide longer term support once discharged from hospital e.g., Smoking Cessation Service. There is also the Discharge Medication Service (NHS, 2021a) which supports patients discharged on new medication who need additional input and support from their community pharmacy.

Community pharmacies play a pivotal role in protecting and improving the health of the population and are one of the most frequented health care settings, averaging 1.2million health-related visits every day (June 2019). This presents an opportunity to support behaviour change, not just for those patients picking up prescribed medicines but also for

individuals seeking ad hoc health advice or purchasing over the counter health related products. Pharmacies are one of the most accessible healthcare facilities with 90% of the population living within a 20-minute walk of a community pharmacy, increasing to almost 100% in areas of highest deprivation (T. J. Brown et al., 2016) compared with 84.8% of a GP surgery (Todd A et al., 2015). As part of the community pharmacy contract pharmacies are required to participate in six NHS England public health campaigns per year. These are predominantly promotion of healthy lifestyles and involves the display and distribution of information and leaflets provided by NHS England. During the COVID-19 pandemic community pharmacists played a vital role providing ongoing face-to-face health services and were a pivotal in the fast and efficient administration of the vaccine quickly.

In December 2022 NHS England and Pharmaceutical Services Negotiating Committee announced a key national health campaign for 2023 focusing on weight management. The campaign aimed to promote adult nutrition and physical activity, this ran from January 3rd to 29th 2023. The use of pharmacies to deliver this key public health campaign suggests that there is confidence that pharmacy teams are capable of such services. Unfortunately, there is no ongoing funding for nationally commissioned pharmacy services to tackle the obesity epidemic, and local authorities are responsible for the commissioning of public health services in the community as part of the integrated care pathway.

The Five Year Forward View (NHS, 2014), published in October 2014, set out that improvements in prevention was needed to improve people's lives and recognised the key role pharmacy could have in delivering this. It highlighted that there should be far greater use of pharmacists in prevention of ill health. Providing support to people to aid self-care for minor ailments, and support long-term condition management as part of a more local

integrated care model. In response to this NHS England developed a program to embed pharmacists in general practice surgeries. Leading to pharmacists being in more patient facing roles within surgeries where historically they were involved in providing support to clinicians for prescription and medication queries, thereby giving opportunities for pharmacists to further embed public health interventions in their practice.

Practice pharmacists work with the multi-disciplinary team to deliver structured medication reviews, assist with medicines management, long term condition consultations, and provide information on medication related queries. This mirrors well established services already provided by pharmacist in hospital as consultant pharmacist and pharmacist in outpatient clinics e.g., anticoagulation, rheumatology, multiple sclerosis, HIV. These services aim to maintain and improve health by providing advice and information that is medication and disease specific for the patient. Delivering patient-centred care utilises clinical knowledge to review and identify the needs of the patient and then advising, signposting, and prescribing appropriate care. Social prescribing enables HCPs, such as pharmacists, to refer people to a range of local, non-clinical services to support their health and wellbeing including physical activity. Lack of NHS approved physical activity interventions or locally commissioned services limits practice pharmacist from prescribing services to help support a more active population.

A systematic review of 19 studies looking at community pharmacy interventions for public health priorities (5 weight management, 2 alcohol reduction, 12 smoking cessation) concluded that pharmacy is a feasible option for weight management interventions. Pharmacy-based interventions produced similar weight loss compared with active interventions in other primary care settings (T. J. Brown et al., 2016).

A single study was identified, looking at feasibility and acceptability of a community pharmacy intervention to improve physical activity (Lemanska et al., 2019). The study was undertaken in the UK and limited to men living with and beyond prostate cancer (n=403). Delivery by community pharmacy was found to be acceptable, and at 3 months there was an average increase of 34mins MVPA/week (95% CI 6 to 62, p=0.018), however, in line with many other physical activity interventions this was not sustained over 6 months (Lemanska et al., 2019).

While pharmacist are capable and well placed to advise physical activity to patient there are issues which require to be addressed. With the increase in advanced services provided by pharmacies e.g., flu vaccines – 600K administered the year it launched 2015/2016, 2.7million in 2020/2021, and 4.85million in 2021/2022 (Community Pharmacy England, 2023), the commitment to provide a seven-day hospital clinical pharmacy service (Department of Health and Social Care, July 2015) and the development and commitment to introduce pharmacist in general practice by NHS England (NHS England, 2015), there are significant capacity issues within the pharmacy profession. Without building and developing capacity and capability in the pharmacy workforce, increasing healthy lifestyle promotion is unachievable. In the past 3 year many community pharmacies have closed, the 5-year contract, signed in 2019, does not meet the rising costs, subsequently the number of community pharmacies in England at the end of March 2020 dropped to its lowest level in five years. In January 2023 Lloyds Pharmacy, the second largest pharmacy chain in the UK, announced the withdrawal of pharmacy services from all Sainsbury's stores leading to the closure of 237 pharmacies (approximately 20% of their premises) in June 2023.

There is already a high demand in health services for pharmacist. To support the professional to be confident and capable to deliver the changing needs of patients and the

healthcare sector across a variety of healthcare settings, from August 2025 students who have completed a 4-year Master of Pharmacy and the foundation pre-registration year (5 years total) will have independent prescribing embedded in their training and will be registered as independent prescribing pharmacists with the General Pharmaceutical Council. The move to train all pharmacist to prescribe highlights the important role they can contribute to patent care and better equips the professional to use their expertise in medicines to its full potential.

Pharmacists are ideally placed to be advocates for public health initiatives. Pharmacist's knowledge and accessibility to the patients enables them to deliver key health messages to hard to reach communities and those who lack access to conventional services. Pharmacy teams already providing numerous public health services, there is the potential for pharmacy to advise physical activity as a public health message to patients. While pharmacy teams are capable of promoting physical activity, there are barriers to the implementation of these services. These include, workforce capacity, funding, time (training and delivery of service), promotion of the service, and access to a suitable, effective, physical activity intervention (local or national) approved by the NHS. Pharmacists are experts in medication, plans to expand community pharmacy services, published in May 2023, via the Pharmacy First service enables pharmacists in England to supply 'prescription only medication' without the need to visit a GP. Medication in this scheme include antibiotics and antivirals to treat seven common health conditions (sinusitis, sore throat, earache, infected insect bite, impetigo, shingles, and uncomplicated urinary tract infections in women), putting pharmacist in a key position as antimicrobial guardians and support the work being done to prevent antimicrobial resistance. From April 2023 community pharmacist are able to manage ongoing oral contraception supporting another key public health objective.

Pharmacists' skills make them invaluable to patients and the public, but too often those skills are not utilised effectively. While pharmacy teams may be capable of referring patients to physical activity services, allowing pharmacist to use their expert knowledge to provide more clinical services, supplying medication without the need to see a GP, may be better use of resource.

Strengths and Limitations

The research methods used in this thesis have several strengths and limitations. A mixed methods approach was taken as information generated by differing approaches has the potential to provide a greater depth and breadth of information than using a singular approach (Molina Azorín & Cameron, 2010). Validated measures and scales were used wherever possible to measure social factors and physical activity behaviours. Using validated scales captures the measure as accurately as possible and allow comparison to other studies using the same measures. The cohort study data allowed large sample sizes, providing statistical power in studies 1 and 3.

Limitations were varied. The data worked on was from early and mid-pandemic, the results may not reflect the behaviour at the end of the pandemic. Changes across society occurred quickly during the pandemic, some of these changes may remain long term, however, some things have reverted to pre-pandemic ways. Further work is needed to identify if there are long term changes in physical activity, the potential causes and those most affected. As discussed in depth earlier in the chapter, self-reported physical activity has various limitations. A particular limitation of study 1 was the use of an unvalidated physical activity questionnaire. While physical activity data were included in the questionnaire, capturing this data was not a priority and physical activity was included as part of a wider 'use of time'

variable. Lack of expert involvement and knowledge of questionnaires meant that a standardised questionnaire was not used. Having a validated questionnaire such as the International Physical Activity Questionnaire or the Nordic Physical Activity Short Questionnaire, would have been helpful to increase validity and comparability. The International Physical Activity Questionnaire is considered to generate good quality data but is long. The Nordic Physical Activity Short Questionnaire is only 2 questions, this is viewed a better length for large survey but generates lower quality data. The open-ended question mode is better, and recommended, however, this is less easy to implement on a digital survey (Danquah et al., 2018).

Sample size was large for both the Covid Social Study and *Understanding Society* Covid Sub study, unfortunately neither sample were representative of the UK population. While the sample size gives power to the studies, they lack generalisability at population level. The large sample size and early data collection during the pandemic meant that self-reported physical activity measures were used rather than device-based measurements. The logistics of trying to capture device measured data from the number of participants in each study was unrealistic in term of timeframe, device numbers, data management, and cost. The use of self-reported physical activity during COVID-19 data collection is in line with other large UK based cohort studies and many studies undertaken during the pandemic.

The Covid Social Study allowed for new participants to join the study throughout the first lockdown. This allowed for large-scale data to be collected, large numbers joined the study initially, however, there was a significant dropout of participants. There may have been a differential dropout rate with those who left quickly, loss of data from these participants is a limitation.

A limitation of the qualitative data from the Covid Social Study was the reliance on free-text data rather than interviews. While free-text responses allows for a large sample size, it does lack the ability of the researcher to ask further questions and probe deeper into responses or clarify information.

There were several limitations in the digital health service evaluation. This study highlights the need for end user, and community engagement. This should be carried out during project planning, during, and at the end of a study. Some issues which negatively affected the study would hopefully have been picked up through engagement at the planning stage and would have given me an opportunity to address the problem prior to the study starting e.g., commercial partnership. The MSc service evaluation study had a large target for recruitment (495 participants) and the initial plan was to recruit health care professionals via national bodies (Royal College of General Practitioners) to achieve these patient numbers. Unfortunately recruitment of health care professionals at national level was not successful. Keeping the study area targeted (within one ICB), DJ was able to contact GP surgeries individually and develop 'champion practices' which helped with HCP engagement and subsequent patient recruitment. I was not able to capture the number of HCPs who received the study information and then did/did not refer patients, or the total number of patients who received a referral. This data would have allowed me to properly investigate engagement and potentially identify solutions.

Recommendations and future research

The WHO announced the official end of the COVID-19 pandemic on 5th May 2023 (WHO news, May 2023). While the pandemic is over and the world moves forward there are ongoing, potentially permanent changes to society that impact how we live our lives. As

discussed in the introduction, measures undertaken to reduce the spread of COVID-19 (social restrictions and closures) negatively impacted physical activity, we need further research to understand if changes in physical activity behaviour continue, what that behaviour looks like, and who has been affected. Established longitudinal studies, such as *Understanding Society,* need to undertake data waves using the same data collection techniques as pre-pandemic to allow for comparison between pre and post pandemic physical activity. Looking at population trajectories of physical activity will help provide us with a greater understanding of the change in activity pre/during/post COVID-19. As noted in the introduction, physical inactivity was a global problem pre pandemic, understanding if this problem has escalated is essential to guide how we support people to be more active. While cross sectional data is useful for providing an insight to activity levels at the point of data collection, it would be helpful if Sport England collected and analysed data longitudinally. This would provide a better understanding of how many people were consistently achieving physical activity targets. Understanding the proportion of the population who remained physically active, and learning from this group is important as we know the greatest benefits of physical activity are seen when people participate in regular and consistent physical activity (Aaltonen et al., 2012; Moholdt et al., 2018).

In study 3 neighbourhood cohesion was shown to have a protective effect on physical activity, further research into the impact of the pandemic on neighbourhood cohesion is needed. There are unsubstantiated reports that communities pulled together and supported each other more during the pandemic, this suggests that neighbourhood cohesion may have increased. Although there is a study that reported an overall reduction in neighbourhood cohesion during the first part of the pandemic, this decline was particularly seen in the most deprived communities, some ethnic minorities, and lower-

skilled workers (Borkowska & Laurence, 2021). Identifying if the pandemic has a long-term effect on neighbourhood cohesion, and if some communities were more affected than others is needed. Should neighbourhood cohesion be more negatively impacted in some communities than others, those most effected should be the priority for rebuilding the foundation for neighbourhood cohesion. Ongoing work needs to be undertaken to ensure that good infrastructure is in place in areas identified 'at risk' so they are protected in future pandemics and times of social disruption.

While digital health interventions are thought to be a time efficient, and cost effective way to reach lots of people compared to in person contact, the literature suggests that results are mixed for physical activity digital health interventions (Gold et al., 2021). More work needs to be done to identify the most effective digital medium, or combination, to deliver physical activity interventions. We also need to understand if physical activity interventions are more effective when promoted alone, or in combination with other lifestyle and health behaviours e.g., nutrition and exercise. Until effective interventions have been developed it is hard for health care professionals to refer patients to programs which have shown limited efficacy for long term physical activity change. There is a need for more research to allow for an effective NHS/WHO approved physical activity toolkit to be developed to support the delivery of high quality interventions in primary care. Delivery of such a toolkit would support the implementation of effective interventions across the spectrum of healthcare settings.

The pandemic shone a light on social factors associated with physical activity, highlighting that they continued to positively affect activity even during a period of societal upheaval. Community is important for physical activity participation, both at the individual and group

level. Social support and neighbourhood cohesion were important factors for supporting physical activity prior to the pandemic and continued to be during the pandemic. People enjoyed physical activity, walking being a commonly reported form of activity. Having access and being able to get outdoors to be active was identified as a strong theme, along with the positive effect physical activity had on mental health. Developing green walkways in urban settings and ensuring high quality lighting and maintenance of streets, footpaths, and greenspaces could provide a solution to an affordable and accessible form of physical activity across ages and abilities. Public health interventions to promote physical activity should not be conducted in isolation, working with town planning teams, and engaging with target users, should be undertaken to ensure we build an environment suitable to support individuals and groups to undertake physical activity.

Conclusion

Previous research had shown the importance of social support and neighbourhood cohesion for physical activity. This thesis demonstrates the importance of social support and neighbourhood cohesion for the maintenance of physical activity during a period of social restriction, suggesting they have a protective effect. Many people reported enjoying walking outdoors during the pandemic highlighting the importance, and need for, accessible, well-maintained, greenspaces for walking and exercise. Interventions designed to increase physical activity should ensure social support is built in using theories shown to promote physical activity participation. The urban planning and property development sectors need to work with public health to ensure we build and renovate communities with healthy environments. Structures need to be in place to support the development of good neighbourhood cohesion and facilities for physical activity should be a priority.

While technology has the potential to provide a flexible way to deliver physical activity content to a wide audience, results from the web-based intervention had poor patient uptake and engagement. More work needs to be done to identify the most effective in person and technology-based interventions for long term physical activity behaviour change. Developing effective interventions incorporating the knowledge acquired through this research is needed in order to deliver successful public health programs and increase population level physical activity.

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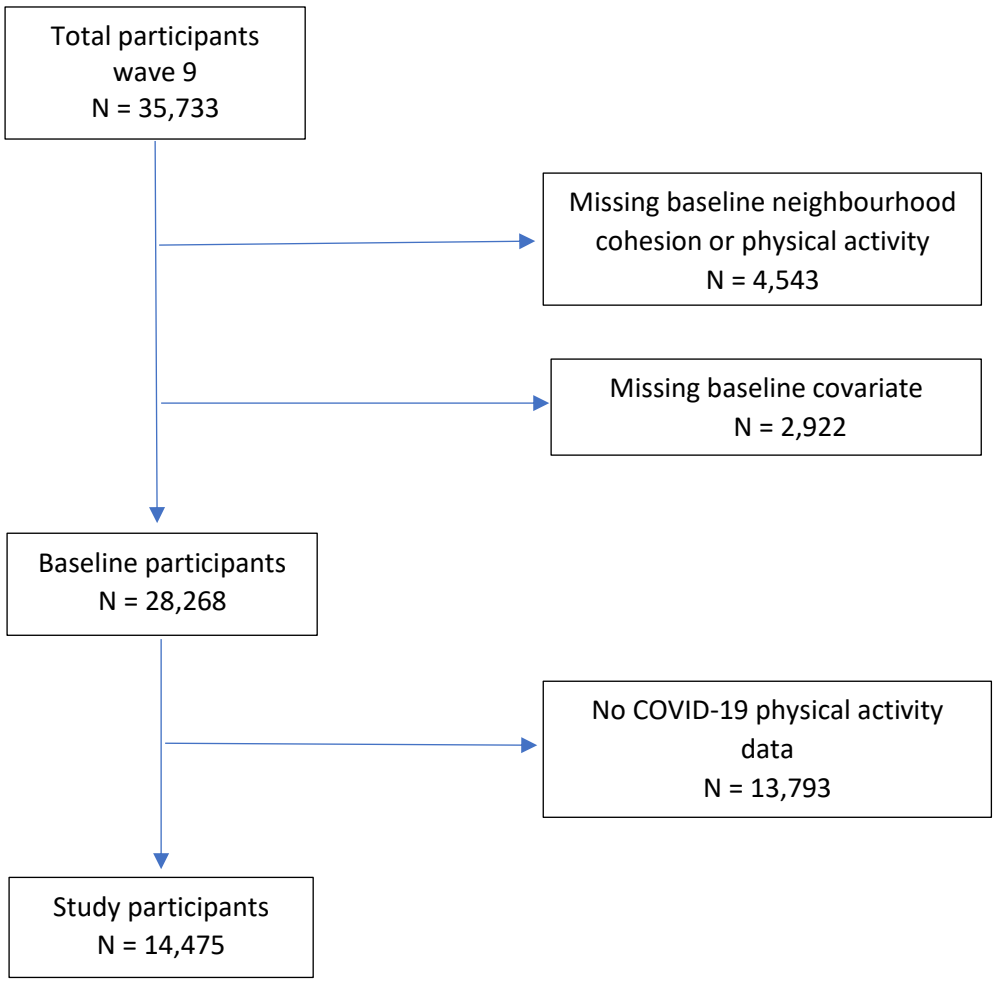
Appendix 1 - Supplemental Material for Study 3

Figure 1 Flowchart of study participant selection



Appendix 2 - Supplemental Material for Study 4

Table 1. Summary of studies to promote physical activity via digital health interventions

First author (year) country	Study type	Population	Health outcome	Digital health intervention	Summary
Gold (2021) UK (Gold et al., 2021)	Systematic review of reviews	Adults	PA, diet, smoking, alcohol		92 reviews Digital intervention was better than no intervention, but the effect sizes were small. Small positive effect seen in intervention that target a combination of diet and PA. No effectiveness seen for interventions targeting PA alone, except for when interventions were delivered by mobile phone
Nunex (2021) Spain (Núñez de Arenas-Arroyo et al., 2021)	Systematic review and meta-analysis	Healthy adults >55 years	PA	Digital health interventions	18 studies eHealth interventions are effective in increasing PA levels among adults >55years, resulting in increased steps/day, MVPA min/day, PA min/wk and MVPA min/wk
Taylor (2021) UK (Taylor et al., 2021)	Randomised controlled trial	Inactive adults with LTC	PA, self-report and pedometer	Web-based support for Exercise referral scheme	Augmenting exercise referrals with web-based behavioural support had only a weak, non-significant effect on MVPA
Western (2021) UK (Western et al., 2021)	Systematic review and meta-analysis	Age 0-100 with SES information	PA 10x self-report 9x device-based	Digital interventions (website, wearables, apps, text/email prompts)	19 studies. Digital behaviour change interventions aimed at increasing PA are effective for people of high SES but were not observed to be beneficial for people of low SES. People of low SES may, in general, tend to use the internet less for health information and have a lower eHealth literacy. In the context of digital PA interventions, eHealth literacy might translate as the users' ability to navigate the technological devices themselves, understand the information received from the educational components,

					and appropriately apply the self-regulatory BCTs that are advocated
Ballin (2020) Sweden (Ballin et al., 2020)	Systematic review	Obese adults	Obesity	Digital exercise interventions	There is no evidence for the effects of digital exercise on visceral adipose tissue, although digital exercise may decrease waist circumference
Kwan (2020) Hong Kong (Kwan et al., 2020)	Systematic review and meta-analysis	Older adults	PA	Digital health interventions	38 studies (25 in meta-analysis) Interventions are effective at increasing the time spent on PA, energy expenditure and the number of walking steps. Further studies should be conducted to determine the most effective e-health strategies
Tang (2020) Australia (Tang et al., 2020)	Systematic review and meta-analysis	Adults	PA	Wearable trackers	12 studies Use of wearable trackers in healthy adults may be associated with modest, short term, increases in physical activity. In overweight adults (n=5), no significant increase in PA occurred. In healthy adults (n=7), a significant increase in PA was observed compared to control groups
Yang (2020) USA (Yang & Koenigstorfer, 2020)	Longitudinal	Healthy adults	Self-report PA	Smart phone apps	PA app use was positively related to overall change in PA, PA decreased less with increasing app use frequency. When app features were added to the model, gamification features had a buffering effect
Cotie (2018) Canada (Cotie et al., 2018)	Systematic review and meta-analysis	Adult women (age 18-65)	PA, obesity	Digital health interventions	60 studies (20 meta-analysis) eHealth interventions are effective at increasing min/week of moderate-to-vigorous physical activity among working-age women from high income countries.
Muellmann (2018) Germany	Systematic review	Older adults >55years	PA	Digital health interventions	25 studies

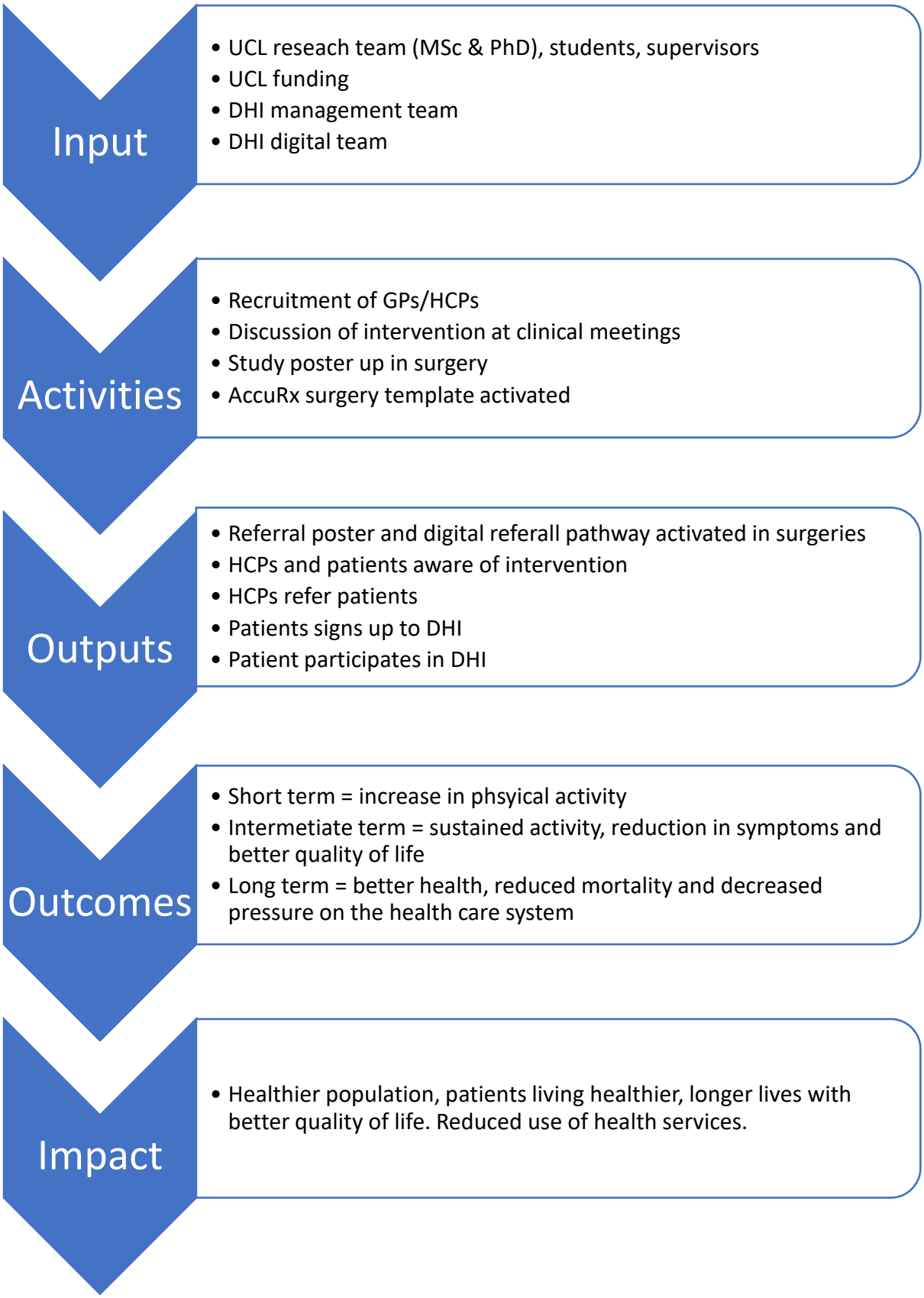
(Muellmann et al., 2018)					eHealth can promote PA in older adults in the short-term, long-term effects and the benefit of eHealth compared to non-eHealth intervention is lacking.
Jahangiry (2017) Iran (Jahangiry et al., 2017)	Systematic review and meta-analysis	General population	PA	Web-based interventions	22 studies Web-based interventions had positive and significant effect on increasing PA. The effect of web-based interventions seems to be influenced by mean age (<45yrs) and trail duration (>6weeks) and study quality One reason is that the users of internet are different from the general population. The most ardent internet users are the young people and the well-educated middle-aged people, who take most interest in online health resources and services
McIntosh (2017) UK (McIntosh et al., 2017)	Systematic review	Young people	PA	Web based and e-communications	10 studies e-Health can be effective in increasing PA in young people. More research is required to look at the length of intervention required for optimal results and the theoretical framework that best underpin interventions
Joseph (2014) USA (Joseph et al., 2014)	Narrative review	Adults	PA	Internet and web-based PA interventions	72 interventions. Website based approach, n=48. Email only, n=6. Website and email, n=20 Overall, the literature suggests that internet-based PA studies are effective in promoting PA. Attrition is a point of concern with high drop out rates. Smartphone contact (SMS/text message) can help boost website utilisation and potentially increase PA, this should be incorporated into future interventions

Davies (2012) Australia (Davies et al., 2012)	Meta-analysis	Adults	PA	Internet-delivered intervention	34 articles Internet delivered interventions produce positive change, however effect size was small. Moderating variables larger sample size, baseline PA levels and inclusion of educational component significantly increased intervention effectiveness. The ability to produce meaningful long-term change in PA remains unclear
Morrison (2012) UK (Morrison et al., 2012)	Critical Interpretive Synthesis	Diverse sample	PA, smoking cessation, weight, nutrition, chronic pain	Internet-based	52 articles Four core interactive design features were identified that may mediate intervention outcomes: Social context and support, contacts with intervention, tailoring, and self-management. More work is needed to understand how and why these design features may affect intervention outcomes
Wolff Hansen (2012) Denmark (Hansen et al., 2012)	Intervention	Inactive adults	PA, BMI, waist circum, body fat %, BP, strength and aerobic fitness	Website with individually tailored feedback	71% did not log onto the website, 22% of the intervention group logged on to the website once, and only 7% logged on more than once. No significant differences in PA and health measurements were found between the active and control group

Anderson-Bill (2011) (Smith Anderson-Bill et al., 2011)	Randomised controlled trial	Adults	PA, nutrition, weight management	Web-based interventions	Users with increased social support, self-efficacy and self-regulation exhibited improved PA levels High initial levels of self-efficacy may be characteristic of Web-health users interested in online interventions Online health interventions participants are likely be middle-aged, well-educated, upper middle-class women whose detrimental health behaviours put them at risk of NCD
Marcus (2009) USA (Marcus et al., 2009)	Narrative review		PA	Web based interventions	The results of internet-based physical activity studies are encouraging, with many studies finding significant differences in physical activity over time, but no indication of a maintenance effect
Neville (2009) Australia (Neville et al., 2009)(Neville et al., 2009)(Neville et al., 2009)	Narrative systematic review	Healthy adults	PA or weight reduction	Websites, email, CD-rom, mobile and remote devices	17 studies The evidence of effectiveness for computer-tailored physical activity interventions is inconclusive. They have potential to reach large groups of people however there is uncertainty whether reported effects are generalizable and sustained

Vandelanotte (2007) Australia (Vandelanotte et al., 2007)(Vandelanotte et al., 2007)(Vandelanotte et al., 2007)	Systematic review	Adults	PA	Website programs	15 studies. 14 were RCTs, 1 study was a cluster nonrandomized controlled trial. 8/15 reported positive change. 5/8 allowed for effect size of 0.44. Studies reported low exposure to intervention materials, due to a decline in website use as the intervention progressed. The RV found modest evidence for the efficacy of website-delivered PA interventions, with just over half reporting a significant positive behaviour change. The effect size for studies were small and the effect was short lived. Studies that had longer follow-ups being associated with less positive outcomes

Figure 1 Logic model for intervention evaluation



Appendix 3 - Study Material for Study 4

Be part of a UCL study and get active with Mr Motivator

Do you have a health condition? Would you like to be more active?

University College London are providing 3 months free access to Mr Motivators website for the first 200 patients who sign up. We are looking at activity levels before and after joining the club to see the effect it has on activity levels.

Mr Motivators Club gives you access to live zoom sessions Mondays, Wednesdays, Fridays and Saturdays, with standing and chair-based options.

Scan the QR code below, or ask reception to text or email the link to join. If you aren't one of the 200 patients, you can still access the club at a discounted price of £1.99 per month!

Privacy Notice for The Motivation Club in Primary Care

Your data: We will use your data to understand the effect referrals to the Mr Motivator Club have on physical activity levels.

The type of personal information we collect: your email address is required for the follow up questionnaire, no further patient identified data will be collected.

Who has access to your data: Personal data will not be shared with any third party. Data will be anonymous in the final report and when published.

How we store your personal information

Your information is securely stored. Data will be stored on the University of College London's (UCL) Research Data Collection Service, and held in the secure UCL Data Safe Haven. Personal information will be kept for five years before it is safely deleted.

Security of your personal data: We respect the security of your data and treat it in accordance with the law. Under the UK General Data Protection Regulation (UK GDPR), the lawful bases we rely on for processing this information are:

a) Your consent. You are able to remove you consent at any time.

b) We have a legitimate interest in this area to improve patient outcomes.

Thank you for taking the time to read this Privacy Notice

UNIVERSITY COLLEGE LONDON
Division of Surgery and Interventional Science

The Motivation Club in Primary Care

This is a service evaluation looking at physical activity levels in patients referred to the Motivation Club from their GP surgery.

We invite you participate in this evaluation project. Before you decide it is important to read the following information carefully. Contact us if there is anything that is not clear or if you would like more information.

Why are we doing this evaluation?

Physical activity is beneficial for health but population levels are very low. This is a service evaluation looking at the impact the Motivator Club has on improving physical activity levels.

Do I have to take part?

It is your decision to take part. If you take part, you are free to stop at any time without giving a reason.

What do I have to do?

If you take part, you will be asked to complete an online questionnaire at the beginning of the study, at 3 months and 6 months. Each questionnaire will take 2-3 minutes to complete and will be emailed to the address you provide at the appropriate time. This will include questions on demographics, activity levels, social support and your experience using the Motivation Club.

What are the possible risks of taking part?

There is a small chance of injury during the classes. If you are struggling with an injury, see your GP.

What will happen if I start and then decide I do not want to carry on with this study?

If you take part in the evaluation, you are free to withdraw at any time and without giving a reason. We will use the information that we have collected up to the time that you leave the study.

What do I have to do now?

If you DO want to take part in the evaluation, please read the following privacy notice and click 'Agree' and this will take you to the first questionnaire. If you DO NOT want to take part, please click 'Disagree' and this will re-direct you to the Mr Motivator Club.

Who can I contact for further information or if I have concerns?

If you have concerns about any aspect of this evaluation, you can contact the evaluation team by email.

All data will be collected and stored in accordance with the Data Protection Act 1998.

Thank you for taking the time to read this information sheet

Week 0 questionnaire

Demographic data

Question	Response options
What is your sex?	Male Female Transgender Prefer not to say
What is your age	18-29 30-39 40-49 50-59 60-69 70+
What is your ethnicity	White (British/Irish/Other) Mixed race (any mixed or multiple backgrounds) Asian, Asian British – Indian, Pakistani, Bangladeshi, other Black, Black British, Caribbean or African, other Not listed
Highest level of educational attainment	No qualifications Completed GCSE/O-level or equivalent (at school until age 16) Completed post-16 vocational course A-Level or equivalent (at school until age 18) Undergraduate or professional qualification Postgraduate degree
Current employment status	Full time employed Part time employed Unemployed – looking for work Unemployed – not looking for work Student Retired Unable to work due to disability
Reason for referral to the program	High blood pressure Diabetes At risk of diabetes Raised cholesterol Obesity Mental health Osteoarthritis Other Don't know
Height	Feet/inches cm
Weight	Stones/pounds Kg Prefer not to say

Physical activity data (Nordic Physical Activity Short Questionnaire)

Question	Response options
On a typical week, how much time do you spend in total, on moderate and vigorous activities, where your heartbeat increases and you breath faster (e.g. brisk walking, cycling, heavy gardening, running or recreational sports). Only include activities that lasted at least 10 minutes at a time.	Less than 30minutes (less than half an hour) 30mins to less than 60mins (half an hour – 1 hour) 60mins to less than 90 mins (1 – 1.5 hours) 90 – 150 mins (1.5 – 2.5 hours) More than 150 mins (more than 2.5 hours)
Of the total time spent on physical activity in a typical week (which you indicated above), how much do you spend on vigorous physical activity? This includes activities that get your heart racing, make you sweat and leave you short of breath that speaking becomes difficult (e.g. swimming, running, cycling at high speeds, cardio training, weight lifting or team sports such as football). Only include activities that lasted at least 10 minutes at a time.	Less than 30minutes (less than half an hour) 30mins to less than 60mins (half an hour – 1 hour) 60mins to less than 90 mins (1 – 1.5 hours) 90 – 150 mins (1.5 – 2.5 hours) More than 150 mins (more than 2.5 hours)

Self-rated health

In general, would you say your health is	Excellent Very good Good Fair Poor

Perceived social support. This question is about social support. We are especially interested in understanding how social environments relate to how people engage with physical activity programs.

Question	Response options
I experience a lot of understanding and security from others	Strongly disagree Disagree Undecided Agree Strongly agree
I know a very close person whose help I can always rely on	
If necessary, I can borrow something I might need from a neighbour or friend	
I know several people whom I like to do things	
When I am sick, I can without hesitation ask friends or family to take care of important matter for me	
If I am down, I know who I can go to without hesitation	

Week 12 questionnaire

Usage

Question	Response option
Have you used any online physical activity programs before?	In the past, not anymore Yes No
Did you use this program?	Yes No
How often did you attend live sessions?	Not at all Less than once a week Once a week Twice a week
How often did you participate in pre-recorded sessions?	Not at all Less than once a week Once a week Twice a week Three times a week More than three times a week
How much did you enjoy the program?	Very much Somewhat Neutral Not much Not at all
To what extent did the program help you become more active	Very much Somewhat Neutral Not much Not at all

Physical activity data (Nordic Physical Activity Short Questionnaire)

Question	Response options
On a typical week, how much time do you spend in total, on moderate and vigorous activities, where your heartbeat increases and you breath faster (e.g. brisk walking, cycling, heavy gardening, running or recreational sports). Only include activities that lasted at least 10 minutes at a time.	Less than 30minutes (less than half an hour) 30mins to less than 60mins (half an hour – 1 hour) 60mins to less than 90 mins (1 – 1.5 hours) 90 – 150 mins (1.5 – 2.5 hours) More than 150 mins (more than 2.5 hours)
Of the total time spent on physical activity in a typical week (which you indicated above), how much do you spend on vigorous physical activity? This includes activities that get your heart racing, make you sweat and leave you short of breath that speaking becomes difficult (e.g. swimming, running, cycling at high speeds,	Less than 30minutes (less than half an hour) 30mins to less than 60mins (half an hour – 1 hour) 60mins to less than 90 mins (1 – 1.5 hours) 90 – 150 mins (1.5 – 2.5 hours) More than 150 mins (more than 2.5 hours)

cardio training, weight lifting or team sports such as football). Only include activities that lasted at least 10 minutes at a time.	

Demographic data

Height	Feet/inches cm
Weight	Stones/pounds Kg Prefer not to say

Self-rated health

In general, would you say your health is	Excellent Very good Good Fair Poor

Perceived social support. This question is about social support. We are especially interested in understanding how social environments relate to how people engage with physical activity programs.

Question	**Response options**
I experience a lot of understanding and security from others	Strongly disagree Disagree Undecided Agree Strongly agree
I know a very close person whose help I can always rely on	
If necessary, I can borrow something I might need from a neighbour or friend	
I know several people whom I like to do things	
When I am sick, I can without hesitation ask friends or family to take care of important matter for me	
If I am down, I know who I can go to without hesitation	

The following questions are about how you got on with the program.

Question	**Response options**
Did you have a suitable device to access participate in the program?	Yes No
Did you need help to access the program?	Yes No
Could you see/hear the sessions clearly?	Yes No

Did you have suitable space in which to participate?	Yes No
Have you been injured during any of the classes?	Yes No
Do you feel confident to continue being active?	Yes No
How would you rate your online experience?	Poor/Average/Great
Moving forward, how do you plan to stay active?	*Free text*
What is the biggest barrier to being active?	*Free text*
If you could change one thing about the program what would it be?	*Free text*
What did you enjoy the most about the program?	*Free text*