

TILE PAGE

FULL TITLE. Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed method study.

RUNNING HEAD. Physical activity and mental health during COVID-19.

Leire Ambrosio^{1*}, James Faulkner², Jacqui Morris³, Beth Stuart⁴, Danielle Lambrick⁵, Eric Compton⁶, Mari Carmen Portillo¹

¹ National Institute for Health and Care Research. Applied Research Collaboration Wessex. School of Health Sciences, University of Southampton.

² Department of Sport, Exercise and Health, University of Winchester, UK

³ School of Health Sciences, University of Dundee, UK

⁴ Wolfson Institute of Population Health, Queen Mary University of London, UK

⁵ School of Health Sciences, University of Southampton, UK

⁶ Person with long term conditions. Public and patient Involvement. Southampton, UK

***Corresponding author:** Dr Leire Ambrosio, PhD, MSc, RN, NIHR Applied Research Collaboration Wessex, School of Health Sciences, University of Southampton, Building 67, University Road, SO171BJ Southampton, United Kingdom. E-mail: lag1v19@soton.ac.uk
Tel.: +44-(0)23-8059-7591.

ACKNOWLEDGEMENTS. This study is supported by the National Institute for Health and Care Research ARC Wessex. The views expressed in this publication are those of the author(s) and not necessarily those of the National Institute for Health and Care Research or the Department of Health and Social Care. Besides, the authors would like to acknowledge the collaboration of people living with long term conditions that has participate in this project.

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, *et al.* Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;**14**:e079852. doi: 10.1136/bmjopen-2023-079852

COMPETING INTERESTS. The authors have no conflicts of interest to report. There are not non-financial associations that may be relevant to the submitted manuscript.

DISCLOSURE STATEMENT. The authors report there are no competing interests to declare.

FUNDING STATEMENT. This study is funded by the National Institute for Health and Care Research ARC Wessex. The views expressed in this publication are those of the author(s) and not necessarily those of the National Institute for Health and Care Research or the Department of Health and Social Care. There is not an award/grant number for this study, as the National Institute for Health and Care Research ARC does not allocate grant numbers to the funded projects.

DATA SHARING STATEMENT. Only members of the research team (i.e., corresponding author) have access to the study data. The full anonymised data set was shared between the principal investigator of the study and the research member involved in the data analysis. Direct access will be granted to authorised representatives from the sponsor or host institution for monitoring and/or audit of the study to ensure compliance with regulations.

CONTRIBUTORSHIP STATEMENT. LA: conception and design of the work, data collection, data analysis, drafting the article, critical revision and substantial contribution of the article, approval of the final version for publication. J.F: conception and design of the work, data analysis, critical revision and substantial contribution of the article, approval of the final version for publication. J.M: data analysis, critical revision and substantial contribution of the article, approval of the final version for publication. B.S: data analysis, critical revision and substantial contribution of the article, approval of the final version for publication. D.L: conception and design of the work, data analysis, critical revision and substantial contribution of the article, approval of the final version for publication. E.C: critical revision and substantial contribution of the article, approval of the final version for publication. M.C.P: conception and design of the work, funding acquisition, critical revision and substantial contribution of the article, approval of the final version for publication.

The corresponding author, in representation of the rest of the undersigning individuals, guarantees the precision, transparency, and honesty of the data and information contained in the study. Additionally, that none of the relevant information has been omitted, and that all discrepancies among the authors have been adequately solved and described.

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, *et al.* Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;**14**:e079852. doi: 10.1136/bmjopen-2023-079852

WORD COUNT. 6,947.

ABSTRACT

Objective. To understand the physical activity and mental health of individuals living with long term conditions during the COVID-19 pandemic

Design. A sequential explanatory mixed-methods study with two phases: phase 1) quantitative survey, and phase 2) qualitative follow-up interviews.

Setting: Online. For the quantitative phase, an online survey launched in March 2021, using Microsoft Forms. For the qualitative phase, in depth semi-structured interviews were conducted via online.

Participants: 368 adults over 18 years old living in the UK with at least one long term condition completed the survey. Interviews were conducted in a subsample of participants from previous quantitative phase, with 26 people. Data was analysed using thematic analysis.

Results: Responses from the survey, showed that people with one long term condition were significantly more physically active and spent less time sitting, than those with two or more conditions, presenting with significantly higher well-being ($p<0.0001$), and lower levels of anxiety ($p<0.01$), and depression ($p<0.0001$). Interviews found that that people developed a range of strategies to cope with the impact of changeability and consequences of their long-term condition on their physical activity.

Conclusions. The number of long-term conditions influenced physical activity and how people coped with their condition during COVID-19. Findings will inform policy developments in preparation for future pandemics to support and remain people to remain physically active and mental health.

Key words: Coronavirus, exercise, behaviour change, long term conditions, mental health, mixed methods

ARTICLE SUMMARY

Strengths and limitations of this study

- This is a sequential explanatory mixed-methods study.
- A purposeful sampling strategy was used for the quantitative and qualitative phases.
- Participants were approached using personal and professional networks.
- The sample includes people living with at least one long-term condition in the UK.
- As participants were white and largely living with Parkinson's disease, the generalizability of the findings may be limited.

INTRODUCTION

From the beginning of the coronavirus disease 2019 (COVID-19) pandemic, government-mandated physical distancing/self-isolation/shielding guidelines were implemented to reduce the spread of the virus and the person-to-person transmission [1]. However, it is evident that the government response to the pandemic elicited substantial public health challenges, such as poor lifestyle behaviours (e.g., reduced physical activity (PA) increased sitting time), impaired physical and psychological health, and higher mortality [2]. Such effects of the pandemic may be exacerbated in individuals living with one or more long term conditions (LTCs) [3,4].

LTCs is defined as a chronic condition for which there is currently no cure but could be managed and/or controlled by medication and/or other therapies, such as diabetes, chronic obstructive pulmonary disease, arthritis, and hypertension [5]. Globally, having at least one LTC is associated with 41 million deaths each year, which is equivalent to 71% of all deaths worldwide [6]. In the United Kingdom (UK) over 15 million people have at least one LTC [5] accounting for 70% of the country's health and social care expenditure [7,8]. LTCs can be effectively managed by medication, treatments and/or healthy behaviours [7,9]. For instance, PA is beneficial for managing LTCs symptoms while improving mental health and well-being [10,11].

Studies conducted pre-pandemic [12] involving 22,190 adults demonstrated an inverse association between multimorbidity and levels of PA participation in the youngest and oldest age groups. In addition, both low self-rated health status and functional limitations were related to lower PA in most of the examined population groups [13]. In an English nationally representative cohort of people aged ≥ 50 years ($n = 15,688$) [14], compared to the physically inactive group, the odds ratio for multimorbidity was 0.84 (95% confidence interval (CI) = 0.78–0.91) in the mild, 0.61 (95% CI = 0.56–0.66) in the moderate, and 0.45 (95% CI = 0.41–0.49) in the vigorous physical activity groups.

Large epidemiological studies suggest that PA is associated with better mental health and resilience to psychological distress, such as depression and anxiety symptoms [15,16] as PA has anxiolytic and antidepressant effects [17]. When engaging in PA, the human body increases its release of neurochemicals such as dopamine and serotonin. These have been shown to enhance mood and self-esteem, while also decreasing stress tendencies [18]. People

who exercise regularly also have a better frame of mind and can improve attention, focus, memory, cognition and decision-making [19,20]. During COVID-19, individuals who reported decreases in PA [21,22] experienced poorer mental health compared to individuals who maintain or increase their PA [22,23]. Mental health was an important parameter to monitor during the COVID-19 pandemic as it was a stressful period in people's life [24]. Participation in moderate-to-high volumes of PA was associated with better mental health and wellbeing, both during and following periods of COVID-19 containment, compared to participation in low volumes of PA [25]. When considering people with LTCs, ~18% of these individuals reported a positive change in their exercise behaviour during the early COVID-19 restrictions [22]. Increases in PA may have helped mitigate the effects of COVID-19 on this subgroup of 'higher risk' individuals by boosting immune function, which is essential to control COVID-19 [26] and counteract prevalent LTCs such as obesity, diabetes, hypertension, and vascular conditions [11]. However, a substantial proportion of people living with LTCs (~17.3%) also reported a negative change in their exercise behaviour during the COVID-19 pandemic [22]. Indeed, a negative change may promote the development and/or progression of many LTCs, which may contribute to poorer outcomes for those who contract COVID-19 [22].

The applicability of PA guidelines or recommendations for people living with LTCs during the COVID-19 pandemic was typically to stay at home and shield during the COVID-19 pandemic, without providing any specific guidance on how to become or remain physically active [3]. Therefore, given that COVID-19 and future pandemics could affect physical and psychosocial health of people living with LTCs, it is paramount to understand the barriers and enablers to PA, and availability and adequacy of resources to support PA participation during periods of restriction (i.e., shielding) caused by a pandemic. Understanding the what happened to PA and mental health of people living with LTCs during COVID-19 would be beneficial to inform LTC policy development, and to better support people living with LTCs to be physically active during future periods of mobility restriction and/or pandemics.

With improvements in public health and access to good-quality care during non-pandemic periods, people are living longer but frequently with more than one LTC [27]. People with multimorbidity, often defined as the coexistence of two or more conditions [28], have greater difficulty in managing their treatments and have poor health outcomes [29-32]. However, when considering PA data from pre-pandemic studies, contradictory evidence appears apparent. For example, although research has demonstrated that the absence of chronic conditions was associated with more frequent physical activity in late life [33], Hudon et al.

[34] found that regardless of the number of chronic conditions an individual may have (from one to five or more chronic conditions), there was no association between multimorbidity and physical activity levels when long-term limitations on activity, psychological distress, perceived health status, age, sex, education, income, and employment were controlled for [34]. Despite the interesting findings surrounding PA and mental health during COVID-19 with people with LTC [22,25], these previous studies did not allude to what proportion of their sample were actually living with multimorbidity. The effect of multimorbidity on PA and mental health during COVID-19 requires further investigation as the aforementioned associations observed by Faulkner and colleagues may be exacerbated in people who live with more than one LTC.

Thus, the aim of this study was to explore the PA and mental health of individuals living with LTCs during the COVID-19 pandemic, and whether there were any differences between people with one LTC and those people with multimorbidity. It was hypothesised that people living with multimorbidity would experience poorer mental health and lower PA than those individuals living with one LTC. A mixed method approach was chosen to enable broader understanding of peoples' experiences.

METHODS

Design

This was a sequential explanatory mixed-methods study [35], with two phases: phase 1) quantitative survey, and phase 2) qualitative follow-up interviews. Both quantitative and qualitative data was collected and analysed separately during the research process and then integrated. Particularly, findings from the qualitative phase were used to explain and provide a more comprehensive contextualisation of findings and interpretations drawn from the quantitative phase.

Phase 1: Quantitative survey

Design. An online questionnaire was distributed by email using Microsoft Forms. Data was captured anonymously using closed questions whereby participants were asked to respond to questions that assessed the impact of physical distancing on PA behaviour and mental health,

barriers and facilitators to PA participation, and appropriateness of PA resources, in individuals with LTCs.

Participants and sampling. The survey was intended for completion by any adult over 18 years old living in the UK with at least one LTC. There were no geographical restrictions although respondents did indicate their country of residence at the time of survey completion (England, Scotland, Wales, and Northern Ireland). Participants were excluded if they were unable to: read, understand, and answer written questionnaires in English, access a device with internet connection, provide informed consent; and not have a medical-based LTC diagnosis at the time of survey completion.

Participants were approached using personal networks, via online social media engagement (e.g., Twitter and Facebook). Likewise, professional networks, such as National and local LTC charitable and voluntary organizations were also contacted (e.g., British Heart Foundation, Stroke Association, and Parkinson's UK). LTC organisations who supported participant recruitment approached potential participants via social media and from their email/newsletter distribution list on the behalf of the researchers.

A purposeful sampling strategy (non-probability sampling), which included snowball sampling, was launched in March 2021, and continued for 110 days.

Survey development. The survey content was co-designed based on previous research studies in COVID-19 and PA [22,25] and an iterative design process by members of the research team who were experts in LTCs and PA from the UK, until consensus on a final draft was achieved. The survey included sociodemographic questions such as age, gender, ethnicity, and educational level. Data related to LTC including the age of diagnosis, current treatment, and surgery for the LTC was collected. In addition, the following validated and short self-reported outcome measures were used:

- International Physical Activity Questionnaire (IPAQ-SF) measures the previous week PA (days per week, total minutes per day), regards to walking and moderate and vigorous intensity activities [36]. For the IPAQ-SF, results are reported as a continuous variable and in categories (low, moderate, or high PA levels). It is a valid ($r=0.67$) and reliable tool ($\rho = 0.77-1.00$) and is acceptable for assessing PA in large populations across various age groups (e.g., 18-70 y) [37].

- 12-Item Short Form Survey (SF-12) to assess the impact of health on individuals' everyday life [38]. It is often used as a quality of life measure and it provides a mental and physical component score. The SF-12 comprised the following eight domains: 1) Limitations in physical activities because of health problems; 2) Limitations in social activities because of physical or emotional problems; 3) Limitations in usual role activities because of physical health problems; 4) Bodily pain; 5) General mental health (psychological distress and well-being); 6) Limitations in usual role activities because of emotional problems; 7) Vitality (energy and fatigue); and 8) General health perceptions [38]. The SF-12 has been validated against the Medical Outcomes Study 36-item Short-form health survey (SF-36) with r^2 values >0.91 for both the physical and mental component summary scores [38].

- World Health Organisation - Five Well-Being Index (WHO-5) to measure subjective well-being [39]. It includes the following items: 1) 'I have felt cheerful and in good spirits', 2) 'I have felt calm and relaxed', 3) 'I have felt active and vigorous', 4) 'I woke up feeling fresh and rested' and 5) 'My daily life has been filled with things that interest me'. Each of the five items were scored from 0 to 5. The total raw score was translated into a percentage ranging from 0 (absence of well-being) to 100 (maximal well-being). The WHO-5 has been shown to be a valid and meaningful measure of general well-being [39].

- Patient Health Questionnaire-9 (PHQ-9) is a valid and reliable measure of depression severity, with PHQ-9 scores ≥ 10 having a sensitivity and specificity of 88% for major depression [40]. It is a 9-item questionnaire with a dual-purpose that, with the same nine items, can establish provisional depressive disorder diagnoses as well as grade depressive symptom severity. The PHQ-9 score can range from 0 to 27, since each of the 9 items can be scored from 0 (not at all) to 3 (nearly every day). Scores less than 5 usually signifies the absence of a depressive disorder; scores of 5 to 9 predominantly represented patients with either no depression or subthreshold (i.e., other) depression; scores of 10 to 14 represented a spectrum of patients; and scores of 15 or greater usually indicated major depression [41].

- Generalised Anxiety Disorder-7 (GAD-7) is a 7-item anxiety scale, that has good reliability and strong criterion validity for identifying individuals with generalized anxiety diagnoses [42]. The GAD-7 scale inquires about symptoms in the past 2 weeks and score ranges from 0 (low anxiety levels) to 21 (high anxiety levels) [42]. A score of 10 or greater represents a reasonable cut point for identifying cases of GAD. Cut points of 5, 10, and 15

might be interpreted as representing mild, moderate, and severe levels of anxiety. It is commonly used with PHQ-9 as it is well known the high comorbidity of anxiety and depressive disorders and the high correlation between depression and anxiety [42].

Data collection. Potential participants clicked on the survey link, and they were firstly taken to the participation information sheet. The participation information sheet acted as an invitation to take part in the study. Contact details of the researcher were included so that individuals could ask any question about the study. Those participants interested in participating, gave consent online before moving on. They needed to tick the box for the following statement: “Please tick (check) this box to indicate that you have read and understood information on this form, are aged 18 or over and agree to take part in this survey”. After giving the consent to participate, the online survey was completed. Data was held within Microsoft Forms and extracted as an Excel file for analysis. Those participants not interested in participating, could close the survey and withdraw from the study at any point before submitting the survey (i.e., first page of survey or last question of the survey), if they felt they didn’t want to take part. In those cases, no record of them ever looking at the survey and no information about them was stored. To minimise missing data, all questions in the survey were compulsory. Accordingly, participants who completed all questions and submitted their responses on completion of the survey were included in the sample and proceeding data analysis.

Data analysis. All quantitative analysis was completed in Stata version 16.0 (Stata Corp, College Station, Texas, USA). Prior to analysis, data distributions were checked for inconsistencies and outliers. Participants were classified as having either one (LTC1) or more than one LTCs (LTC2+). LTCs were presented as a percentage of the total study population, along with the age, sex, ethnicity, living situation and employment status. A series of independent sample t-tests were used to compare total PA (Metabolic Equivalent of Task, MET·min⁻¹·week⁻¹) and sitting time, as calculated by the IPAQ-SF, as well as WHO-5, PHQ-9, GAD-7 and SF-12, between those participants classified as having either one or two (or more) LTC’s. A multiple linear regression model, adjusting for age, sex, ethnicity, education and duration of LTC [22]. Adjusted Mean differences, 95% confidence intervals and p values for each comparison were calculated. Correlations and their 95% confidence intervals were used to assess the association between total PA and sitting time (IPAQ-SF) with WHO-5, PHQ-9, GAD-7 and SF-12 for the whole study population, LTC1 and LTC2+.

Phase 2: Qualitative interviews

Design. In depth semi-structured interviews were conducted via online videoconferencing (Teams and ZOOM). In accordance with the sequential explanatory mixed method approach [35] qualitative interviews were used to expand and explain the quantitative findings from Phase 1. In particular, the qualitative data addressed the primary research questions ‘What perceived effects did shielding have on the physical and mental health of adults with LTCs living in the UK?’ What coping strategies were used by adults with LTCs living in the UK to address the effects of self-isolation/shielding for those?

Participants and sampling. A subsample of participants from the previous quantitative phase were selected. A purposeful sampling strategy (non-probability sampling) was selected since it involves identifying and selecting individuals or groups of individuals that are knowledgeable about or experienced within a specific phenomenon, such as the COVID-19 pandemic. A purposeful-maximum variation sampling was used [43], addressing location with areas of deprivation, demographics, and LTCs. Interviews were conducted until no new themes were generated from the narratives (data saturation) [44].

Interview development. An interview guide was developed based on a prior literature review [3] and the findings of the previous quantitative phase. Experiences of PA as a coping strategy for living with a LTC, barriers and facilitators to PA participation and use and perceptions of online/offline resources for PA at different stages of COVID-19 were explored. For further information on the interview guide, see supplementary material 1.

Data collection. Participants expressing an interest in contributing to future COVID-19 and PA studies could provide consent at the end of the quantitative survey and provide their email address so the research team could contact them at a later date. Thereafter, and in relation to the qualitative study, those who consented to be contacted were emailed a participant information sheet regarding the qualitative study. If they decided to take part additional consent was obtained and an interview date was arranged. In depth, audio-recorded, semi-structured interviews were conducted by the researcher (LA) between January 2022 and April 2022. The audio recording of each interview was sent to a professional transcription service of the University of Southampton. Those participants indicating, they did not wish to take part in the qualitative phase of the study by answering ‘no’, were not contacted. That decision did not

affect their clinical care or rights and they did not have to give any reason for declining participation.

Data analysis. Qualitative data was analysed using thematic analysis to explore the content of question responses, identify patterns within data, and describe and interpret their meaning and importance [45] looking for explanations to findings from the quantitative phase of the study. The analysis was undertaken by two researchers (LA and JM). Both researchers read initial transcripts and agreed on a coding strategy. LA coded the remaining transcripts. Both researchers reviewed the codes and grouped them into categories relevant to participant experiences of PA during the COVID-19 pandemic [4]. Both researchers next collated categories into themes, reviewing and defining them to ensure they provided detailed descriptions of participant experiences and perceptions and their interpretation. Early analysis was inductive and guided by the qualitative research questions but also involved a deductive component guided by the findings from the quantitative phase [4]. Data were managed in analytical matrices within Excel field, which also helped integrate qualitative and quantitative findings shown in the discussion section following mixed methods guidelines [35].

Ethical issues

Ethical permission was obtained for both study phases by the University of Southampton research ethics committee (ERGO: 63225 and ERGO: 69471). Participants willing to voluntarily participate in the study gave their signed consent via email after engaging with the participation information sheet and providing the pertinent written and verbal information. All data, including information on the participants' identity, were confidentially treated throughout the research process.

Public and patient involvement and engagement (PPIE)

PPIE was an essential element throughout all the mixed methods study. In our study, we facilitated advisory/consultative involvement which is characterized by involving PPIE representatives at any point of the study to gather a lay perspective on a specific issue or issues, like in this care the study findings. PPIE supported the development of the survey as well as the interview guide. Particularly, four PPIE representatives who were living with more than one LTCs were consulted to gather their feedback in relation to the study findings and future recommendations. This session included the following components: a) presentation of the

research team and the project; b) explanation of the main findings; c) discussion about the findings; d) future steps and dissemination strategy; and e) further collaboration at a later stage in the project. The PPIE event was totally voluntary, online and lasted ~90 minutes. Our four PPIE representatives were consulted on and contributed to with the findings from this study. Our use of a multiplicity of perspectives supported the trustworthiness and rigour of the qualitative data analysis process. We recognized and welcomed the individuality of lived experience through which to refract our data analysis. Our approach endorsed the view that there is not a right or wrong perspective, just different perspectives on lived experience, which enriched the study findings. Based on the PPIE as well as the qualitative findings used to provide a more comprehensive contextualisation of the quantitative findings, a policy brief was developed as shown in supplementary material 2.

RESULTS

Phase 1: Quantitative results

Sample. 368 participants (Female, n=192; 63.1 ± 12.6 y) living with at least one LTC completed the online survey. Participants were generally >50 years of age (85.6% of respondents), retired (59.8%) and of white ethnicity (98.1%). For further sociodemographic characteristic see Table 1. The age, gender and ethnicity of those with LTC1 and those with LTC2+ were similar. Those with LTC2+ were more likely to be living with extended family and more likely to be unable to work due to disability.

A majority of the population identified Parkinson's Disease as their primary LTC (56.3%), with cancer, diabetes mellitus and multiple sclerosis reported as other common LTC's (between 5.1% and 6.8% of participants). Over half (53%) of the participants reported living with more than one LTC, with asthma (5.4%), arthritis (5.2%), hypertension (4.9%) and depression (4.6%) most frequently reported. For further information see Table 2.

PA, mental health, and wellbeing: As demonstrated in Table 3, IPAQ-SF category data demonstrated that during the pandemic, people living with LTC1 engaged in more moderate and high intensity PA compared to those with LTC2+. Particularly, people living with LTC1 were significantly more physically active during this time (mean difference [95% CI]; 945

(MET·min⁻¹·week⁻¹) [434, 1455]; p <0.0001), and per day, spent less time sitting (-64 min [-107, -21]; p <0.01), than those with LTC2+.

Participants with LTC1 presented with significantly higher wellbeing (WHO-5) results (12.8 % [8.3, 17.2]; p<0.0001) than those living with LTC2+. The GAD-7 (-1.4 [-2.3, -0.5]; p<0.01) and PHQ-9 (-3.0 [-4.3, -1.8]; p<0.0001) were significantly lower in participants with LTC1 (see Table 3). Significant differences were also identified for the SF-12 ‘physical’ sub-domain (p=0.0001), with people with LTC1 reporting better overall quality of life than people with LTC2+. There were no differences between participants on mental health sub-domains (Table 3). These relationships were not changed in an adjusted model controlling for age, gender, ethnicity, education and duration of LTCs.

As shown in Table 4, WHO-5, PHQ-9, GAD-7, and SF-12 had weak to moderate correlations with PA and sitting time for the total sample (r = -0.11 to 0.39). LTC1 (r = -0.13 to 0.40) had slightly stronger correlations than LTC2+ (r = -0.08 to 0.24) when comparing for all outcome variables with PA and sitting time.

Phase 2: Qualitative results

Sample. A total of 26 people living with LTCs were subsampled from the survey in Phase 1 and interviewed. 12 were female, and ages ranged between 38 and 79 years old. 20 participants were from England, four were from Scotland and two from Wales. Twenty-four participants had White ethnicity and two had Asian or Asian British – Indian ethnicity. Seventeen participants were retired, and nine had studied to postgraduate level. Participants were living with different LTCs such as Parkinson’s disease, diabetes mellitus type 2, asthma, heart failure or arthritis (Table 5).

Identified explanatory themes. The qualitative findings are intended to illustrate the context for the quantitative findings by providing analysis of the consequences pandemic on people living with LTCs and to evaluate the coping strategies used by participants during the pandemic to manage their condition. We describe the findings in an overarching theme, Living with LTCs in the pandemic, which has three sub-themes: Changeability, Consequences of the pandemic; and Coping during the pandemic.

Findings showed that the precise nature and consequences of the LTCs experienced by the study participants were diverse and that they used a wide range of coping strategies to

manage their condition and its consequences through physical activity before and during the pandemic, depending on the perceived severity of their condition and the context they were in.

- *Changeability:*

The impact of the long-term conditions on peoples' lives during the pandemic were, for many, characterised by changeability. For some, changeability meant gradual worsening of the condition or conditions, characterised by increased symptoms, and worsening of functioning, that for some was accelerated through the pandemic. Worsening of the condition for people with early onset, or only one condition, was often characterised by slowing and fatigue.

“In terms of daily life, I don't think it stops me doing much. I still drive. I maybe get a bit tired sometimes and later on in the day, I maybe have got a wee bit slower but other than that, I don't think it really impacts me a great deal” (P17).

For others, loss of function was more severe, characterised for a few participants by the gradual decline in ability to walk during the periods of lockdown, requiring a wheelchair for mobility, or dependence on spouses for support.

“I've lost quite a bit of mobility, it's got worse as we go on, but we try to do things that I can still, it's not what I can't do, it's what I can do. We look at it that way with my mobility and getting out and about. I can walk some distance but usually, I want to hold on to something, either my husband, or I have a walker” (P20).

For some whose disease was characterised by minimal symptoms that they could ignore or minor symptoms that often fluctuated but which they could manage and live with. This meant sometimes having few symptoms and being able to function and engage in social and physical activities and work, and at other times finding these activities more difficult.

“Most of the time, no affect, only when there's certain times of the year when I'm more symptomatic if I'm wheezy that day then I'll still push myself, I'll still do what I normally do, but it's just a bit more difficult. I stay as active as I possibly can because that's very important with any lung condition” (P6).

- *Consequences of the Pandemic Restrictions:*

For many with a less severe disease, the changing nature of their ability to participate in usual PA that required exertion beyond activities of daily living, because of the suspension of usual exercise activities, and in some cases seemed to worsen the effects of the disease.

“Well, yes, that stopped us, they closed the swimming pool. No, other than as I mentioned, because I wasn’t swimming, my arthritic knee got weaker, and I wasn’t walking as much and we had to force ourselves to go out. In fact, I bought a walking stick” (P11).

“Yes, it really affected it, but I did walk because that’s all there was. I did want to start doing open water swimming, but the whole COVID thing I found so frightening that I really didn’t want to go out if I thought there might be other people” (P9).

The value of PA for managing their condition was however expressed by most participants, and most reported engaging in physical activity prior to the pandemic. However, restrictions of the pandemic influenced motivation to be active, leading to a cycle of low motivation and worsening of their general health and condition. For some this was related to the monotony of lockdown and for others it related to the fear of being infected with COVID. For others, fear of catching COVID meant that despite motivation to be active, they were unwilling to risk infection, and describe a decisional balance made in which fear of covid outweighs the impacts of not being active.

“I mean, I’m trying to get back to physical fitness now and lose the weight I put on in COVID...I think if I could have motivated myself, I could have done a lot more activity because we had the time to do it. Every day is the same and, ‘I’ll do it tomorrow. Then, tomorrow never comes” (P23).

“I think the fear of getting COVID is stronger than the fear of the cancer, if that makes sense. I didn’t really want to get out the house, I felt safe in my little bubble...I felt secure and looking back, yes, more walking but I was more concerned about getting COVID than anything” (P20).

- Coping During the pandemic:

Physical Activity and functioning

Despite restrictions, many participants developed coping strategies to enable them to deal with their condition, during the pandemic, depending on how the condition affected their lives and their ability to function at a given time. For many PA was a central strategy to control symptoms, improve their mood and wellbeing, and slow the progression of the condition.

“Actually, now I’m walking faster than my husband because he’s got problems with his hip! I think from what you read, all the research on Parkinson’s, if you are active physically then it does just keep the disease at bay, really. It doesn’t deteriorate as quickly and doesn’t affect the quality of your life so that’s what I want to do, is to make sure that it doesn’t affect the quality of my life” (P3).

Where participants saw PA as essential to managing their condition and maintaining their mental health, the activity needed to match their interests and abilities, with enjoyment as a primary motivating factor.

“I think as long as I’m exercising, I’m helping myself, so I suppose it’s like self-medicating almost. I view exercise as medicine. As long as I’m able to exercise, I’ve got that positivity that I’m helping myself” (P17).

Participants often modified their PA during the pandemic to remain as physically active as possible within the constraints imposed by the condition as it progressed or fluctuated and by the pandemic restrictions. Despite the impact of the restrictions on organised PA, however many participants with less severe disease found ways to be active within the restrictions posed by lockdown and by their own condition.

“It is good to get out of the house, so I don’t want to stop exercising, but to the level I want to live, the level I want to exercise, it doesn’t really affect. I sort of live within my parameters rather than trying to do things and get frustrated because I can’t because of emphysema, or COPD” (P2).

“It’s changed a bit. Instead of going to the gym I would go for a two-and-a-half mile walk, get some cardio workout going to keep the circulation going, etc. That takes time and time is something we don’t always have. The weather’s not always good for walking either! I started doing walking a bit more when I was, during lockdown, on my own” (P22).

Some participants were helped to manage their condition with physiotherapy or pulmonary rehabilitation. Others managed their condition with careful medication regimes that controlled symptoms, creating an interactive strategy between medication and PA. Over time, however, some medications could become less effective, leading to a sequence in which PA became more difficult as the medication became less effective, limiting PA as a coping strategy. When these coping strategies diminished in effects, this could lead to tension and frustration between what participants wanted to do and what they could do.

“I can get very breathless, and I can lose my voice, and so with what's happened, it can make me think that it's an infection or whatever, but anyway, there is no medication for that. It's had to be breathing exercise, respiratory physio from the hospital, that went into online stuff during the pandemic” (P26).

Physical Activity and Mental Health

During the pandemic, being unable to exercise through organised, physical activities involving social participation often negatively influenced participants' mental health, leading to a cycle of inactivity and worsening mental health for some. Some described a cycle in which their mental health deteriorated if they were not physically active, leading to a loss in motivation to be active because they felt tired and lethargic, which further lowered their sense of wellbeing and motivation.

“I certainly suffered depression throughout the COVID 19 period. There's plenty of things I should have done differently: I should have kept up the exercise, I should have forced myself and my wife to maintain exercise - that's what I should have done - but that was a personal failure. I do regret that, but I just lost hope in the whole exercise” (P25).

Others however found that being physically active improved their mental health in parallel with their physical health, using PA as a coping mechanism to improve their mood or prevent deterioration in their wellbeing. Some described a cycle in which their mental health deteriorated if they were not physically active, leading to a loss in motivation to be active because they felt tired and lethargic, which further lowered their sense of wellbeing and motivation. Being aware of and proactive in using PA to overcome low motivation was very important for most participants during the pandemic.

“Yes. I find, if I don’t exercise or do something, I get very grumpy, bad tempered - because I’m used to exercising, all my life. So, when I couldn’t, it was difficult. If you’re not happy, you can go for a very long walk, until you felt better” (P4).

“I think I didn't have any real problems with my mental health throughout the period. I because I still kept going mainly doing the activities that I was normally doing. If it had completely stopped then probably, yes. I actually found during that period; I was probably a lot happier” (P18).

In summary, living with LTCs was characterised by changeability stemming from fluctuations in the condition, sometimes deterioration. Coping strategies involved managing interactions between the condition’s status, medication management, PA, and motivation.

DISCUSSION

This mixed methods study has investigated PA and mental health of individuals living with LTCs during the COVID-19 pandemic. The findings of this mixed method study, showed that people living with LTC1 were significantly more physically active, spent less time sitting, presented significantly higher wellbeing and lower depression and anxiety levels than those with LTC2+ during COVID-19 lockdowns. Qualitative and quantitative data showed that PA is beneficial for mental health and that COVID-19 pandemic was a period during which many people developed coping strategies to be physically active. In particular, the changeability of the LTC was the main contributing influence on PA.

Changeability of LTCs contributing influence on PA

Changeability, as described in our study, is a gradual worsening of the condition, characterised by increases in symptoms, and worsening of functioning. In the present study, for many participants, the changeability of the LTC was the main reason to decrease or change their PA routine, and the qualitative findings illustrated how participants used physical activity to maintain and improve their condition and their mental health. Furthermore, our findings also showed that those with one LTC, instead of multiple LTCs, engaged with more PA and less sitting time. Indeed, people living with multiple LTCs are an important group to consider when designing guidelines or delivering recommendations to encourage PA during period of physical distancing and self-isolating (see supplementary material 2). Therefore, PA guidelines are not flexible enough for people living with similar LTCs as they have to account for the range of

symptoms and signs as well as their changeability [4]. In this sense, more personalised information on how to remain physically active while shielding at home according to diverse categories of LTCs. For instance, PA guidelines and recommendations posted during COVID-19 pandemic, should be developed based on conditions with similar symptoms and signs and stage of the condition, such as respiratory LTCs. Also, simple strategies like breaking up sitting time could be promoted as a safe and accessible option to reduce the negative change in PA routines during the COVID-19 pandemic [46]. In this sense, different health promotion strategies may be required from government and policymakers to draw a more individualized and person-centred plans and refine PA strategies during COVID-19 and future pandemics (see supplementary material 2). Therefore, supporting people to tailor their PA according to how they manage and cope with their LTC and its changeability is recommended.

Physical activity is associated with better mental health

It is already known that mental health was an important parameter to evaluate during COVID-19 pandemic [24]. This study, including the PPIE input, reinforced the findings of previous work [10, 21-25], noting that overall, PA is correlated with higher wellbeing and quality of life as well as lower depression and anxiety. This finding is consistent with those of other authors, showing that physical and social distancing during COVID-19 pandemic was linked with a decrease in PA, resulting in poorer mental health and wellbeing of general population including those living with LTCs [22,25,47]. During the COVID-19 pandemic, individuals with LTCs were encouraged to stay at home self-isolating and/or shielding [3]. In accordance with earlier COVID-19 research, higher sitting times were correlated with lower wellbeing and quality of life, and higher levels of depression and anxiety [10,21,25]. In this sense, future policy should examine how adults living with LTCs could maintain or increase PA during periods of shielding. More concretely, policy recommendations for individuals living with LTCs should be individualized according to the circumstances and needs of each person (see supplementary material 2). For instance, our findings showed that during COVID-19 pandemic people living with one LTC present lower levels of depression and anxiety than those with LTC2+. Despite these differences it must be noted that the present study is unable to determine whether such differences were also evident between living with one LTC and LTC2+ before the start of the pandemic, and whether these findings are actually pandemic related or not. Our findings complement previous research from before [48] and during [49,50] the pandemic that has shown that people living with LTCs are more likely to experience mental

health issues (e.g., anxiety, depression) than the general population. The qualitative and quantitative data show that most participants from our study showed that being physically active improved their mental health in parallel with their physical health. In this sense, most participants developed coping strategies, like PA to deal with their LTC in addition to their mental health. This finding could be explained by the fact that people with one LTC (e.g., hypertension), were able to function and engage in physical and social activities with less difficulties and with more enjoyment as a motivating factor than those with LTC2+ (e.g., Parkinson's disease or cancer). Therefore, changeability and severity of the LTC could be a barrier for PA as pointed before. There is evidence that shows that engaging in PA that is enjoyable, improves health and wellbeing, and provides continual novel stimulus, will improve engagement and adherence over time [51-53]. In this sense, our findings have clearly showed that PA is essential to manage LTCs and maintaining the mental health in an enjoyable way. Therefore, once again our findings demonstrated that 'one size fits all' is not working and more individualized PA guidelines according to the person and each LTC is needed.

Integration of Healthcare and physical activity

According to our findings, the reduction of PA due to COVID-19 pandemic, led to the worsening of many LTCs. To face this situation, some participants reported medication and physiotherapy to be important in helping to manage the LTCs during the COVID-19 pandemic. Some participants created a strategy between medication, physiotherapy, and PA to better manage their condition during the lockdown. These findings are aligned with previous works in the LTCs field [54,55] where the inclusion of physiotherapist and occupational therapist to support the person with LTCs has been proposed. Role collaborations between primary healthcare services and non-medical health professionals has been proposed as a way to answer the needs of people living with one or more than one LTCs [54,55]. Currently, this is a challenge that National Health Service as well as other healthcare systems all over the world are facing to address the complex needs of LTCs population. Therefore, the inclusion of medical and non-medical healthcare professionals when developing PA guidelines or recommendations for those living with LTCs is paramount, as is drawing on the successful coping experiences of people with lived experience (see supplementary material 2). Stakeholder co-production will be needed to address the challenge of how to incorporate these into the personalised management of LTCs, weaken the social norms associated with the elderly, and strengthen the idea that PA and independent self-care go hand in hand. This

approach will, in turn strengthen responses to imposed restrictions, should there be another pandemic.

Strengths and limitations

There are limitations and strengths to this work that should be considered. One limitation is associated with the high proportion of respondents who had Parkinson's disease (PD) (> 50%). The underlying reason for this is lies on the key role of Parkinson's UK disseminating the survey. Therefore, the survey results and interpretation are skewed by PD participants and consequently, results are not generalizable to people living with other LTCs like diabetes mellitus, epilepsy, or heart failure for example. Similarly, another limitation is that a large majority of respondents in this study were white living in England. Therefore, the findings are not as representative of people living with LTCs in the other home nations (e.g., Scotland, Wales, or Northern Ireland) and/or other ethnic minority groups, such as black or Asian. Finally, a further limitation is that our findings may not be attributed exclusively to the COVID-19 pandemic because we did not have pre-pandemic data as a comparator. Future studies are recommended to compare pre- and post-pandemic results and identify which of the findings are attributed to COVID-19 pandemic. Accordingly, there needs to be some caution when interpreting some of the findings as differences between LTC and LTC2+ may have been observed between groups prior to the pandemic. The main strengths to the study include the sample size when considering the challenge of recruiting people with LTCs during COVID-19 lockdown, the mixed method design, as well as the speed with which the survey was disseminated through social media, ensuring a population response that was captured during the pandemic.

CONCLUSIONS

During COVID-19 pandemic, individuals with LTC2+ reported less PA and poorer mental health and wellbeing, than those with one LTC. Nevertheless, the qualitative research showed the range of coping strategies deployed by people with LTCs to remain physically active whilst living with their conditions. These findings have important implications for policy and guidelines development, particularly for those living with multiple LTCs. Therefore, the findings of this study support the development of person-centred policy recommendations to support and sustain individuals living with LTCs during and after COVID-19 or other pandemics.

REFERENCES

1. How to stop the spread of coronavirus (COVID-19). 2021. Available from: <https://www.gov.uk/government/publications/how-to-stop-the-spread-of-coronavirus-covid-19/how-to-stop-the-spread-of-coronavirus-covid-19>
2. Wilson JJ, Smith L, Yakkundi A, Jacob L, Martin S. Changes in Health-Related Behaviours and Mental Health in a UK Public Sample during the First Set of COVID-19 Public Health Restrictions. *Int J Environ Res Public Health*. 2022; 19(7): 3959. <http://doi.org/10.3390/ijerph19073959>
3. Ambrosio L, Lambrick D, Faulkner J, Portillo MC. Accessibility and applicability of physical activity guidelines and recommendations for adults living with long term conditions during COVID-19. *Int J Environ Res Public Health*. 2021; 24: 1-17. <https://doi.org/10.1080/09603123.2022.2066071>
4. Ambrosio L, Morris J, Lambrick D, Faulkner J, Compton E, Portillo MC. Physical activity and mental health experiences of people living with long term conditions during COVID-19 pandemic: a qualitative study. *Plos One*. 2023; 18(7): e0285785.
5. Department of Health. (2012). Report: long term conditions compendium of information (3rd ed). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216528/dh_134486.pdf
6. World Health Organization (WHO) (2020). Noncommunicable Diseases. Available from: <https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases>
7. House of Commons Health Committee. Managing the care of people with long-term conditions. (2014). Available from: <https://publications.parliament.uk/pa/cm201415/cmselect/cmhealth/401/401.pdf>
8. The Academy of Medical Sciences. Multimorbidity: a priority for global health research. 2018 <https://acmedsci.ac.uk/file-download/99630838>
9. Kabudula CW, Houle B, Collinson MA. Socioeconomic differences in mortality in the antiretroviral therapy era in Agincourt, rural South Africa, 2001-13: a population surveillance

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, *et al.* Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;14:e079852. doi: 10.1136/bmjopen-2023-079852

analysis. *Lancet Glob Health*. 2017; 5(9): e924-e935, [https://doi.org/10.1016/S2214-109X\(17\)30297-8](https://doi.org/10.1016/S2214-109X(17)30297-8)

10. Sallis JF, Adlakhav D, Oyeyemi A, Salvo D. An international physical activity and public health research agenda to inform coronavirus disease-19 policies and practices. *J Sport Health Sci*. 2020; 9(4): 328-334. <https://doi.org/10.1016/j.jshs.2020.05.005>

11. Woods J, Hutchinson NT, Powers SK. The COVID-19 Pandemic and physical activity. *Sports Med Health Sci*. 2020; 2(2): 55-64, <https://doi.org/10.1016/j.smhs.2020.05.006>

12. Cimarras-Otal C, Calderón-Larrañaga A, Poblador-Plou B, González-Rubio F, Gimeno-Feliu LA, Arjol-Serrano JL, et al. Association between physical activity, multimorbidity, self-rated health and functional limitation in the Spanish population. *BMC Publ Health*. 2014; 14:1. <http://doi.org/10.1186/1471-2458-14-1170>

13. Vancampfort D, Koyanagi A, Ward PB, Rosenbaum S, Schuch FB, Mugisha J, et al. Chronic physical conditions, multimorbidity and physical activity across 46 low- and middle-income countries. *Int J Behav Nutr Phys Act*. 2017; 18,14(1):6. <http://doi.org/10.1186/s12966-017-0463-5>

14. Dhalwani NN, O'Donovan G, Zaccardi F, Hamer M, Yates T, Davies M, Khunti K. Long terms trends of multimorbidity and association with physical activity in older English population. *Int J Behav Nutr Phys Act*. 2016; 13:8. <http://doi.org/10.1186/s12966-016-0330-9>

15. Da Silva MA, Singh-Manoux A, Brunner EJ, Kaffashian S, Shipley MJ, Kivimäki M, Nabi H. Bidirectional association between physical activity and symptoms of anxiety and depression: the Whitehall II study. *Eur J Epidemiol*. 2012; 27(7):537–546. <http://doi.org/10.1007/s10654-012-9692-8>

16. Hamer M, Stamatakis E, Steptoe A. Dose-response relationship between physical activity and mental health: the Scottish health survey. *Br J Sports Med*. 2009; 43(14):1111–1114. <http://doi.org/10.1136/bjism.2008.046243>

17. Mura G, Carta MG. Physical activity in depressed elderly. A systematic review. *Clin Pract Epidemiol Ment Health*. 2013; 9 (1):125–135. <http://doi.org/10.2174/1745017901309010125>

18. Biddle S. Physical activity and mental health: evidence is growing. *World Psychiatry*. 2016; 15(2): 176-7. <http://doi.org/10.1002/wps.20331>
19. Mahindru A, Patil P, Agrawal V. Role of Physical Activity on mental health and well-being: A review. *Cureus*. 2023; 15(1), e33475. <http://doi.org/10.7759/cureus.33475>
20. Hallam KT, Bilsborough S, de Courten M. Happy feet: evaluating the benefits of a 100-day 10,000 steps challenge on mental health and wellbeing. *BMC Psychiatry*. 2018; 18(19): 1-7. <http://doi.org/10.1186/s12888-018-1609-y>
21. Roche C, Fisher A, Fancourt D, Burton A. Exploring Barriers and Facilitators to Physical Activity during the COVID-19 Pandemic: A Qualitative Study. *Int J Environ Res Public Health*. 2022; 19(15); 9169. <http://doi.org/10.3390/ijerph19159169>
22. Faulkner J, O'Brien WJ, McGrane B, Wadsworth D, Batten J, Askew CD. Physical activity, mental health and well-being of adults during initial COVID-19 containment strategies: A multi-country cross-sectional analysis. *J Sci Med Sport*. 2021; 24(4): 320-326, <http://doi.org/10.1016/j.jsams.2020.11.016>
23. Talic S, Shah S, Wild H, Gasevic D, Maharaj A, Ademi Z. Effectiveness of public health measures in reducing the incidence of covid-19, SARS-CoV-2 transmission, and covid-19 mortality: systematic review and meta-analysis. *BMJ*. 2021; 375: E068302. <https://doi.org/10.1136/bmj-2021-068302>
24. World Health Organization. Mental health. 2021 <http://www.paho.org/en/topics/mental-health>
25. Faulkner J, O'Brein W, Stuart B, Stoner L, Batten J, Wadsworth D. Physical Activity, Mental Health and Wellbeing of Adults within and during the Easing of COVID-19 Restrictions, in the United Kingdom and New Zealand. *Int J Environ Res Public Health*. 2022; 19(3): 1792. <http://doi.org/10.3390/ijerph19031792>
26. Stockwell S, Trott M, Tully M, Shin J, Barnett Y, Butler L, McDermott D, Schuch F, Smith L. Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. *BMJ Open Sport Exerc Med*. 2021; 7(1): e000960. <http://doi.org/10.1136/bmjsem-2020-000960>

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, et al. Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;14:e079852. doi: 10.1136/bmjopen-2023-079852

27. Soley-Bori M, Ashworth M, Bisquera A, Dodhia H, Lynch R, Wang Y, Fox-Rushby J. Impact of multimorbidity on healthcare costs and utilisation: a systematic review of the UK literature. *Br J Gen Pract.* 2020; 28;71(702): e39-e46. <http://doi.org/10.3399/bjgp20X713897>
28. Wang L, Si L, Cocker F, Palmer AJ, Sanderson K. A systematic review of cost-of-illness studies of multimorbidity. *Appl Health Econ Health Policy.* 2018; 16(1): 15–29. <http://doi.org/10.1007/s40258-017-0346-6>
29. Cassell A, Edwards D, Harshfield A, Rhodes K, Brimicombe J, Payne R, Griffin S. The epidemiology of multimorbidity in primary care: a retrospective cohort study. *Br J Gen Pract.* 2018; 68(669): e245-e251. <http://doi.org/10.3399/bjgp18X695465>
30. World Health Organization. Multimorbidity. Geneva: WHO, 2016. <https://apps.who.int/iris/handle/10665/252275> (accessed 4 Jan 2024).
31. National Institute for Health and Care Excellence. Multimorbidity: clinical assessment and management. NG56. London: NICE, 2016. <https://www.nice.org.uk/guidance/ng56> (accessed 4 Jan 2024).
32. Zulman DM, Asch SM, Martins SB, et al. Quality of care for patients with multiple chronic conditions: the role of comorbidity interrelatedness. *J Gen Intern Med.* 2014; 29(3): 529–537. <http://doi.org/10.1007/s11606-013-2616-9>
33. Kaplan MS, Newsom JT, McFarland BH, Lu L. Demographic and psychosocial correlates of physical activity in late life. *Am J Prev Med.* 2001, 21: 306-312. [http://doi.org/10.1016/s0749-3797\(01\)00364-6](http://doi.org/10.1016/s0749-3797(01)00364-6)
34. Hudon C, Soubhi H, Fortin M. Relationship between multimorbidity and physical activity: Secondary analysis from the Quebec health survey. *BMC Public Health.* 2008; 8, 304. <http://doi.org/10.1186/1471-2458-8-304>
35. Cresswell J, Clark V. Designing and Conducting Mixed Methods Research. 3rd ed. 2017. SAGE Publications, Inc, p. 520.
36. The International Physical Activity Questionnaire. Guidelines for Data Processing and Analysis of the International Physical Activity (IPAQ) [Internet]. 2005. Available from: <http://www.ipaq.ki.se>

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, et al. Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;14:e079852. doi: 10.1136/bmjopen-2023-079852

37. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc.* 2011; 35:1381–1395. <https://doi.org/10.1249/01.MSS.0000078924.61453.FB>
38. Ware J, Kosinski M, Keller SD. A 12-Item short-form health survey: Construction of scales and preliminary tests of reliability and validity. *Med Care.* 1996; 34(3): 220–233 <https://doi.org/10.1097/00005650-199603000-00003>
39. Topp CW, Østergaard SD, Søndergaard S, Bech P. The WHO-5 Well-Being Index: A Systematic Review of the Literature. *Psychother Psychosom.* 2015; 84: 167-176. <https://doi.org/10.1159/000376585>
40. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med.* 2001; 16(9): 606-613. <http://doi.org/10.1046/j.1525-1497.2001.016009606.x>
41. Kroenke K, Spitzer RL. The PHQ-9: A new depression diagnostic and severity measure. *Psychiatr Ann.* 2022; 32(9): 509-515. <https://doi.org/10.3928/0048-5713-20020901-06>
42. Spitzer RL, Kroenke K, Williams JB. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med.* 2006; 166(10): 1092-1097, <https://doi.org/10.1001/archinte.166.10.1092>
43. Miles MB, Huberman AM, Saldaña J. Qualitative data analysis. A methods sourcebook, 3rd ed. Sage Publications, 2014.
44. Saunders B, Sim J, Kingstone T. Saturation in qualitative research: exploring its conceptualization and operationalization. *Qual Quant.* 2018; 52(4): 1893-1907. <https://doi.org/10.1007/s11135-017-0574-8>
45. Braun V, Clarke V (2006). Using thematic analysis in psychology, *Qual Res Psychol.* 2006; 3(2): 77-101. <https://doi.org/10.1191/1478088706qp063oa>
46. Pinto AJ, Dunstan DW, Bonfá E, Gualano B. Combating physical inactivity during the COVID-19 pandemic. *Nat Rev Rheumatol.* 2020; 16(7): 347–348, <https://doi.org/10.1038/s41584-020-0427-z>

47. Meyer J, McDowell C, Lansing J. Changes in physical activity and sedentary behaviour due to the COVID-19 outbreak and associations with mental health in 3,052 US adults. Cambridge Open Engage. *Int J Environ Res Public Health*. 2020; 17(18); 6469, <https://doi.org/10.3390/ijerph17186469>
48. The Richmond Group of Charities (2018). Multimorbidity. Understanding the challenge. A report for the Richmond Group of Charities. Available at: https://richmondgroupofcharities.org.uk/sites/default/files/multimorbidity_-_understanding_the_challenge.pdf
49. World Health Organization. COVID-19 pandemic triggers 25% increase in prevalence of anxiety and depression worldwide. 2024. Available at: <https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide>
50. Wu T, Jia X, Shi H, Niu J, Yin X, Xie J, et al. Prevalence of mental health problems during the COVID-19 pandemic: A systematic review and meta-analysis. *J Affect Disord*. 2021; 281; 91-98. <https://doi.org/10.1016/j.jad.2020.11.117>
51. Ekkekakis P, Biddle SJH. Extraordinary claims in the literature on high-intensity interval training (HIIT): IV. Is HIIT associated with higher long-term exercise adherence?. *Psychol Sport Exerc*. 2022; 64: 102295, <https://doi.org/10.1016/j.psychsport.2022.102295>
52. Lakicevic N, Gentile A, Mehrabi S, Cassar S, Parker K, Roklicer R. Make Fitness Fun: Could Novelty Be the Key Determinant for Physical Activity Adherence?. *Front Psychol*. 2020; 11: 577522. <https://doi.org/10.3389/fpsyg.2020.577522>
53. Waaso P, Gofton N, Zuhl M. The Effect of Self-Selected Exercise Workloads on Perceived Enjoyment and Self-Efficacy in Sedentary Adults. *Behav sci*. 2022; 12(7): 224, <https://doi.org/10.3390/bs12070224>
54. Mark D, Comans T, Bisset L, Scuffham PA. Substitution of doctors with physiotherapists in the management of common musculoskeletal disorders: a systematic review. *Physiotherapy*. 2017; 103(4): 341–351. <https://doi.org/10.1016/j.physio.2016.11.006>
55. National Institute for Health and Care Excellence. Multimorbidity: clinical assessment and management. 2016.

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, et al. Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;14:e079852. doi: 10.1136/bmjopen-2023-079852

TABLES

Table 1. Sociodemographic characteristics and LTC data of the quantitative sample

	Total sample (n=368) n (%) or X(SD)	LTC1 (n=173)	LTC2+ (n=195)	p-value (LTC1 vs. LTC2+)
Age (y)	63.1 (12.60)	62.5 (12.43)	63.6 (12.8)	0.400
Age Groups				0.874
18-29 y	4 (1.1%)	2 (1.2%)	2 (1.0%)	
30-39 y	21 (5.7%)	10 (5.8%)	11 (5.6%)	
40-49 y	28 (7.6%)	15 (8.7%)	13 (6.7%)	
50-59 y	70 (19.0%)	37 (21.4%)	33 (16.9%)	
60-69 y	114 (31.0%)	53 (30.6%)	61 (31.3%)	
70-79 y	113 (30.7%)	48 (27.8%)	65 (33.3%)	
80+ y	18 (4.9%)	8 (4.6%)	10 (5.1%)	
Ethnicity				0.329
White	361 (98.1%)	168 (97.1%)	193 (99.0%)	
Asian	5 (1.4%)	4 (2.3%)	1 (0.5%)	
Black	0 (0.0%)			
Mixed groups	2 (0.5%)	1 (0.6%)	1 (0.5%)	
Living situation				0.100
Live alone	65 (17.7%)	32 (18.5%)	33 (16.9%)	
Couple	219 (59.5%)	106 (61.3%)	113 (58.0%)	
Single parent family	4 (1.1%)	0 (0.0%)	4 (2.1%)	
Two parent family	41 (11.1%)	23 (12.3%)	18 (9.2%)	
Extended family - live with other family members	20 (5.4%)	4 (2.3%)	16 (8.2%)	
Flatting or group - live with (mainly unrelated) others in a shared household	2 (0.5%)	1 (0.6%)	1 (0.5%)	
Residential care	1 (0.3%)	0 (0.0%)	1 (0.5%)	
Other	16 (4.4%)	7 (4.1%)	9 (4.6%)	
Employment				0.006
Full time	61 (16.6%)	35 (20.2%)	26 (13.3%)	
Part time	35 (9.5%)	15 (8.7%)	20 (10.3%)	

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, *et al.* Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;**14**:e079852. doi: 10.1136/bmjopen-2023-079852

Unemployed	9 (2.5%)	7 (4.1%)	2 (1.0%)	
Cannot work due to disability	28 (7.6%)	6 (3.5%)	22 (11.3%)	
Retired	220 (59.8%)	106 (61.3%)	114 (58.5%)	
Other	15 (4.1%)	4 (2.3%)	11 (5.6%)	
Currently undergoing treatment	282 (76.6%)	128 (74.0%)	154 (79.0%)	0.259
Sex				0.995
Male	174 (47.3%)	90 (52.0%)	102 (52.3%)	
Female	192 (52.2%)	82 (47.4%)	92 (47.2%)	
Non-binary	2 (0.5%)	1 (0.6%)	1 (0.5%)	

LTC: Long term condition; n: number; % percentage. SD: standard deviation.

Table 2. Long term conditions of the quantitative sample

	First condition (n)	%	Second condition (n)	%
Total sample	368	100	368	100
Asthma	14	3.8	20	5.43
Atrial fibrillation	6	1.63	11	2.99
Cancer	21	5.71	9	2.45
Chronic Kidney disease	3	0.82	3	0.82
COPD	4	1.09	4	1.09
Depression	5	1.36	17	4.62
Diabetes mellitus	25	6.79	13	3.53
Epilepsy	5	1.36	2	0.54
Heart failure	9	2.45	6	1.63
Hypertension	6	1.63	18	4.89
Mental Health	1	0.27	10	2.72
Obesity	3	0.82	1	0.27
Osteoporosis	2	0.54	9	2.45
Parkinson's disease	207	56.25	5	1.36
Rheumatoid arthritis	10	2.72	19	5.16
Stroke	4	1.09	4	1.09
Other	11	2.99	24	6.52
Vascular	4	1.09	5	1.36
Colon	4	1.09	2	0.54
Skin	1	0.27	1	0.27
MS	19	5.16	0	0
Angina	2	0.54	7	1.9
Thyroid	0	0	5	1.36

N: number; % percentage; COPD: Chronic Obstructive Pulmonary Disease; MS: Multiple Sclerosis.

Table 3. Measurement results in people with one or more than one LTC

	Total sample	Individuals LTC1	Individuals with LTC2+	p value	Adjusted mean difference (95% CI; p-value)
IPAQ-SF (x/SD)					
Total PA (MET·min⁻¹week⁻¹)	2132.7 (2519.82)	2633.4 (2918.00)	1688.8 (2010.59)	p=0.0003	-705.23 (-1220.07, -190.40; p=0.007)
Sitting time (min)	437.3 (210.12)	403.5 (187.67)	467.7 (224.12)	p=0.004	59.68 (17.02, 102.35; P=006)
IPAQ-SF Classifications (n/%)					
Low	111 (30.2%)	38 (22.0%)	73 (37.4%)		
Moderate	172 (46.7%)	87 (50.3%)	85 (43.6%)		
High	85 (23.1%)	48 (27.8%)	37 (19.0%)		
WHO-5 score (x/SD)					
WHO-5 score (x/SD)	51.3 (22.46)	58.1 (20.65)	45.3 (22.34)	p<0.0001	-11.15 (-15.37, -6.94' p<0.001)
PHQ-9					
PHQ-9	8.0 (6.25)	6.4 (5.44)	9.43 (6.59)	p<0.0001	2.68 (1.51, 3.86; p<0.001)
GAD-7					
GAD-7	4.6 (4.64)	3.9 (4.07)	5.3 (5.01)	p=0.004	1.16 (0.27, 2.05; p=0.011)
SF-12					
SF-12	0.6 (0.10)	0.7 (0.09)	0.6 (0.10)	p=0.0204	-0.03 (-0.06, 0.001; p=0.055)
Physical	1.8 (0.80)	1.6 (0.72)	1.9 (0.84)	p=0.0001	0.27 (0.11, 0.43; p=0.001)
Mental	3.5 (2.97)	3.6 (3.21)	3.3 (2.73)	p=0.3404	-0.36 (-0.98, 0.26; p=0.259)

GAD-7: Generalised Anxiety Disorder Assessment; IPAQ-SF: International Physical Activity Questionnaire – Short Form; LTC: long term condition; LTC1: Living with one Long Term Condition; LTC2+: Living with two or more long term conditions; MET: Metabolic Equivalent of Task; n: number; PA: physical activity; PHQ-9: Patient Health Questionnaire – Depression test questionnaire; SD: standard deviation; SF-12: The 12-Item Short Form Health Survey; WHO-5: The World Health Organisation- Five Well-Being Index; % percentage;

This is an accepted manuscript of the following published work:

Ambrosio L, Faulkner J, Morris JH, *et al.* Physical activity and mental health in individuals with multimorbidity during COVID-19: an explanatory sequential mixed-method study. *BMJ Open* 2024;14:e079852. doi: 10.1136/bmjopen-2023-079852

Table 4. Correlations between measurements

	IPAQ-SF					
	Total sample		LTC1		LTC2+	
	Total PA (MET·min· ⁻¹ · week ⁻¹)	Sitting time (min)	Total PA (MET·min· ⁻¹ · week ⁻¹)	Sitting time (min)	Total PA (MET·min· ⁻¹ · week ⁻¹)	Sitting time (min)
WHO-5	0.39	-0.28	0.40	-0.14	0.24	0.02
PHQ-9	-0.34	0.34	-0.35	0.19	-0.13	0.19
GAD-7	-0.30	0.25	-0.23	0.15	-0.18	0.17
SF-12	0.22	-0.11	0.25	-0.13	0.15	-0.08

GAD-7: Generalised Anxiety Disorder Assessment; IPAQ-SF: International Physical Activity Questionnaire – Short Form; LTC: long term condition; LTC1: Living with one Long Term Condition; LTC2+: Living with two or more long term conditions; PA: physical activity; SF-12: The 12-Item Short Form Health Survey; PHQ-9: Patient Health Questionnaire – Depression test questionnaire; WHO-5: The World Health Organisation- Five Well-Being Index;

Table 5. Sociodemographic characteristics and LTC data of the qualitative sample

		Sample (n = 26)
Country	England	20
	Wales	2
	Scotland	4
Local area	Rural area (<2,500 habitants)	1
	Semi-rural area (between 2,501-10,000 habitants)	11
	Urban (>10,000 habitants)	13
	Other (specify)	1
Gender	Male	14
	Female	12
Ethnicity	White – English, Welsh, Scottish, Northern Irish or British	24
	Asian or Asian British – Indian	2
Highest Educational level	College	6
	Secondary School	2
	Undergraduate studies	8
	Apprenticeship	1
	Post graduate studies	9
Employment status	Full time	3
	Part time	5
	Unable to work due to disability	1
	Retired	17
Number of LTCs	Individuals with one LTC	14
	Individuals with more than one LTC	12

LTC: Long term condition