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The ongoing effects of the COVID-19 pandemic on perceived physical activity, physical function and mood of older adults in the U.K: A follow-up study (March 2020–June 2021)

Darren L. Richardson [a,*], Jason Tallis [a], Michael J. Duncan [a], Neil D. Clarke [a], Tony D. Myers [b]

[a] *Centre for Applied Biological & Exercise Sciences, School of Life Sciences, Coventry University, Coventry, UK*
[b] *Sport, Physical Activity and Health Research Centre, Newman University, Birmingham, UK*

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ABSTRACT

Coronavirus (COVID-19) and its variants, continue to spread globally more than two years after the discovery of the wild-type virus in Wuhan, China. Following the onset of COVID-19, fluctuating restrictions have likely impacted the daily lives of older adults living in the United Kingdom (UK). Subsequently, the longer term effects of COVID-19 on physical activity levels, perceived physical function and mood of older adults are unclear. Therefore, the present study aimed to follow a group of older adult's living in the UK for one year, to monitor physical activity levels, perceived physical function and mood. A longitudinal, mixed-methods, observational study was conducted using self-administered, online surveys at 3-month intervals between March 2020 and June 2021. A total of 100 participants (46 males [age: 76 ± 5 years] and 54 females [age:74 ± 4 years]) completed all surveys. Bayesian analysis allowed calculation of direct probabilities whilst incorporating our prior knowledge. Throughout this period, older adults maintained or increased their pre-lockdown physical activity levels despite a decrease in intensity of effort of physical activity tasks, whilst sitting time increased at two of the follow-up time-points. Furthermore, perceived physical function decreased (ps = 91.78%;>1.21 AU) and mood undulated in a pattern that reflected the tightening and easing of restrictions. Despite total physical activity being maintained, perceived physical function decreased by a small but clinically meaningful margin.

1. Introduction

The SARS-CoV-2 virus responsible for the disease COVID-19 and its subsequent variants continue to spread globally, two years after the discovery of the original wild-type virus in Wuhan, China. As a consequence, the United Kingdom (UK) has been placed into three national lockdowns alongside a myriad of restrictions including: restricted movement of people, social distancing measures, restricted travel, closed businesses and schools, restricted social gatherings and mandatory face coverings that have fluctuated in response to new variants, number of infections and hospitalisations (Institute For Government, 2021). Such disruptions to daily routines, and restrictions placed on everyday life have the potential to lower physical activity (PA) levels (Roschel et al., 2020) and through both biological and sociological mechanisms, the COVID-19 pandemic has an undeniable link with an increase in various non-communicable disease risk such as diabetes, hypertension and obesity and as such can be termed a "syndemic" as opposed to a pandemic (Musumeci, 2022). These negative health outcomes resulting from factors surrounding COVID-19 are of particular concern to vulnerable populations such as older adults as the relationship between PA and positive health outcomes is strong (Taylor, 2014), and reductions in PA and increased sedentary behaviour are associated with a decrease in physical health, mental health and subjective vitality (Cheval et al., 2021).

Evidence thus far indicates that globally, COVID-19 has had a negative impact on PA (Wilke et al., 2021). In the United States, MA Greenwood-Hickman et al. (2021) observed that older adults spent more time sitting, and completed less steps compared with pre-COVID-19. In the UK, Richardson et al. (2020) observed an increase in sitting time. Indeed, a recent systematic review that included 25 studies (Oliveira et al., 2021) reported a significant reduction in PA in older adults that resulted in declines in physical fitness and an increase in sedentary behaviours.

COVID-19 also has the potential to disrupt elements of mood and

* Corresponding author.
E-mail address: ad1534@coventry.ac.uk (D.L. Richardson).

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individual mental health (Terry et al., 2020). A recent systematic review implicated the indirect effects of COVID-19 in having a negative effect on depressive symptoms and anxiety along with a negative effect on mental health (Vindegaard and Benros, 2020). As older adults are at greater risk of serious complications from contracting COVID-19, this may affect the mental health of older adults to a greater extent than other populations (Shiozawa and Uchida, 2020). Indeed, studies from the UK have presented evidence for the presence of depressive symptoms in response to COVID-19 in both the short term (Richardson et al., 2020) and the longer-term (Zaninotto et al., 2021). However, PA has been shown to be an important moderating factor in ameliorating negative mental health effects, with those individuals who are more physically active, reporting better overall mental health (Jacob et al., 2020). As restrictions have changed periodically throughout 2020 and 2021 in response to infection spikes, understanding mood responses is important as they can be an important indicator of how society is coping mentally with factors surrounding COVID-19 (Terry et al., 2020).

Hastened by physical inactivity, aging is characterised by the progressive loss of muscle mass, muscle strength, and decline of functional performance (Barber et al., 2015) making older adults particularly vulnerable to restrictions that limit PA. Therefore, it is imperative to understand how COVID-19 has impacted PA levels, given that at least some restrictions have been in place in the UK for around 2 years. As physical inactivity negatively impacts strength and muscle mass (Barber et al., 2015), it is also important to consider how any changes may influence physical function and the ability to complete everyday tasks (Miszko et al., 2003). Physical function is essential to the health of older adults and is associated with better perceived quality of life (Fusco et al., 2012) and more years of independent living which can drastically lower healthcare expenditure (Manini and Pahor, 2009). Furthermore, as physical function impairments predict further declines in PA (Metti et al., 2018), understanding changes in activity and function may allow practitioners to pre-empt negative effects in this population. Therefore, understanding the impact on physical function alongside the mental health burden on older adults (Lopes and Jaspal, 2020) will be of particular use to the National Health Service (NHS) in order to strategise measures to avoid healthcare system overwhelm.

As governmental measures introduced in response to COVID-19 have altered the day-to-day lives of people living in the UK, subsequently resulting in decreases in planned PA and increases in sedentary time (Stockwell et al., 2021), longitudinal studies tracking participants over the course of COVID-19 would be useful to monitor patterns of PA and also to observe if and how perceived physical function and mood are affected. This will provide policy makers with a more detailed overview of how COVID-19 is influencing the lives of older adults in the UK so that effective strategies can be developed to aid this population. Therefore, the aim of the present study was to follow up a group of older adults living in the UK during COVID-19 between March 2020 and June 2021 to monitor their PA levels, sedentary time, perceived physical function and mood. We hypothesise that during the yearlong follow-up, when compared to pre-COVID-19 there will be: (1) A decrease in PA (2); An increase in sedentary time (3); Reduced perceived physical function (4); Negative changes to general mood state.

2. Materials and methods

2.1. Study design

This longitudinal, mixed-methods, observational study was conducted using self-administered online surveys completed at 3-month intervals between March 2020 and June 2021 and is a continuation of acute data that has been previously published (Richardson et al., 2020). An initial pre-COVID-19 lockdown survey was completed (retrospectively where necessary as the first lockdown commenced March 23rd 2020) between March 11th – March 28th requiring participants to describe their PA levels, perceived physical function and general mood before the outbreak of COVID-19. Fig. 1 displays key events in the UK relating to COVID-19 restrictions as well as the dates that surveys were distributed and completed.

2.2. Participants

Following institutional ethical approval (P105110), 121 older adults were recruited throughout the UK by self-selection, through online advertisements. As many participants as possible were recruited before the first lockdown in the UK was imposed. Participants met the following inclusion criteria: (1) at least 70 years old, (2) living in the UK, (3) absent of any cognitive disorders e.g., dementia, (4) access to the internet. All participants provided written informed consent before completing the initial survey. Twenty-one participants failed to complete all surveys (17% attrition rate) and were excluded from the final analyses (Table 1). One participant was deceased (Unrelated to COVID-19), two participants requested to formally withdraw and a further 18 failed to return surveys in the allotted time frame.

2.2.1. Survey contents

The initial survey contained five sections (about you; your housing situation; your health; your current PA levels and questions about COVID-19), subsequent quarterly surveys contained four sections (COVID-19 questions, your communications, your activity and your mental health). These questions were designed to provide supplementary qualitative data to help further understand any potential changes observed from the validated self-report measures described in detail below. Clear instructions were provided for all survey questionnaires, with the option to email the lead researcher if necessary. Surveys were generated and collated using JISC online surveys (https://www.onlinesurveys.ac.uk/) with parameters added so all sections were adequately completed before participants could progress. A detailed discussion and justification of the methods used in the present study have been published elsewhere (Richardson et al., 2020).

2.2.2. Physical activity - IPAQ-E

The IPAQ-E (Hurtig-Wennlof et al., 2010) consists of 7 questions about PA completed in the last week, including sedentary time, walking, moderate PA and vigorous PA. Equations are used to convert the frequency (days per week) and amount of time (minutes per day) spent walking, performing moderate PA and/or vigorous PA into MET-minutes of PA per week. Full details of the IPAQ-E and how it is scored can be found at www.ipaq.ki.se.

2.2.3. Perceived function physical – LLFDI

The late-life function and disability instrument (LLFDI) (Jette et al., 2002; Haley et al., 2002) is designed to assess and be responsive to both changes in perception of function and disability in older adults. The three domains: frequency (16 items), limitation (16 items), and function (32 items), consist of questions that are scored based on the answer given. These responses are then scaled (0–100) for easier clinical interpretation. Higher scores indicate greater frequency of activity, less limitation and greater physical function. Full details of how the LLFDI is scored and data presented can be found at: https://www.bu.edu/sph/files/2011/06/LLFDI_Manual_2006_rev.pdf

2.2.4. Mood - BRUMS

The Brunel mood scale (BRUMS) contains 24 mood descriptors, such as angry, energetic, nervous, and unhappy etc. Respondents indicate if they have experienced these feelings on a 5-point scale (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely). The 24 items comprise six subscales: anger, confusion, depression, fatigue, tension and vigour that are each made up of 4 items. In accordance with BRUMS instructions (Terry et al., 2003), during the initial survey, participants indicated the extent they felt each word "normally" (pre-COVID-19 outbreak) and all quarterly surveys were answered "How have you felt

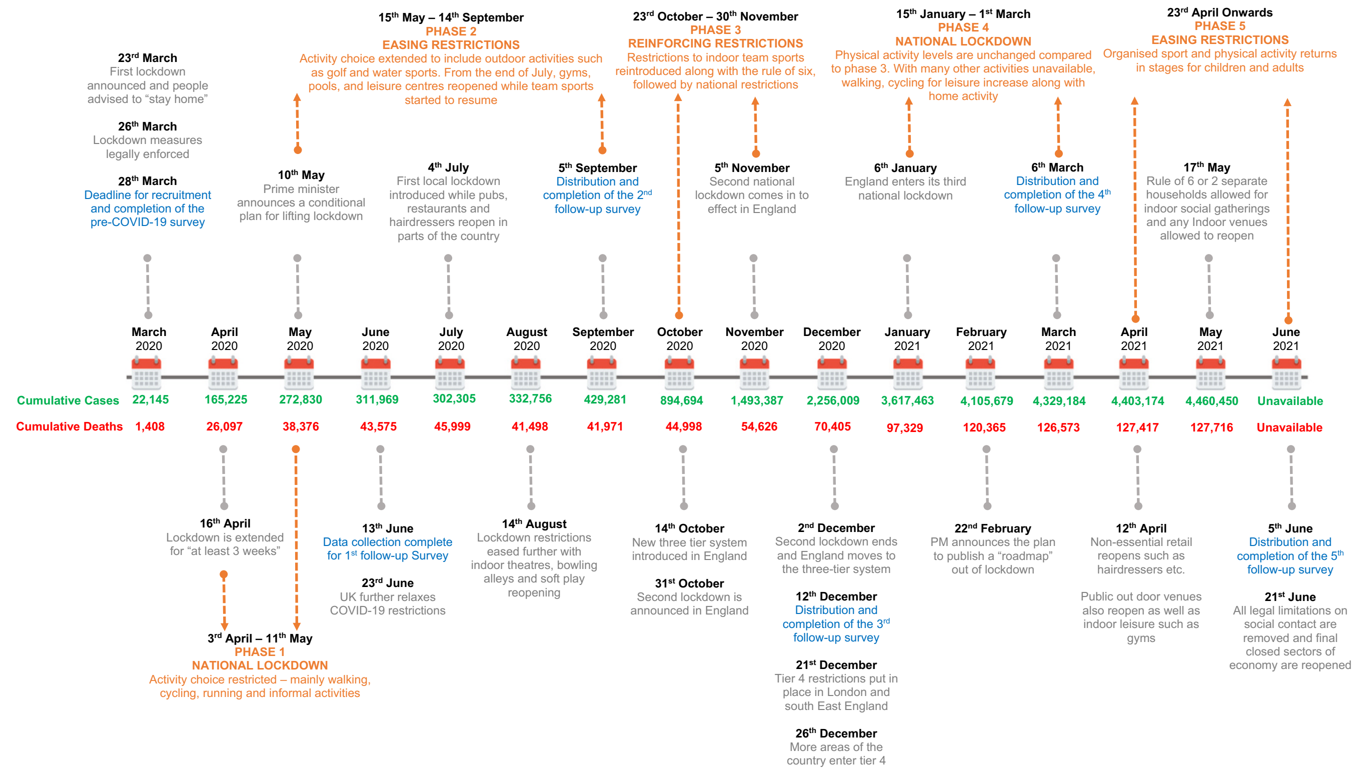

Fig. 1. ***Note***: Cumulative cases and deaths data are derived from the closest update given by the WHO (WHO, 2020) to the last day in each month; Time line updates are provided by the Institute for government (Institute For Government, 2021); PHASE 1-5 updates from Sport England provide an overview of activity trajectories and permissions (Sport England, 2022); WHO = World Health Organisation; COVID-19 = Coronavirus.

during the past week including today". Results are presented after being scored into the aforementioned subscales.

2.3. Statistical analysis

All analyses were conducted in R using Bayesian Regression Models using 'Stan' (brms) (Bürkner, 2017) to implement a Hamiltonian Markov Chain Monte Carlo (MCMC) with a No-U-Turn Sampler. To determine the univariate reliability of data from the BRUMS and the LLFDI measures, the posterior mean and 95% credible interval for McDonald's Omega were calculated using the Bayesrel r package. For IPAQ MET-minutes and sitting time an Intraclass Correlation 3 was conducted, with data averaged across time-points.

A series of mixed effect Bayesian regression models were fitted with the intercepts allowed to vary for each participant. Time-point and sex were included as categorical predictors, with interactions specified for each variable. The response distributions compared for each model included: Normal (Gaussian), Skew-Normal and Student-t. Each model had a similar structure but with the different response distributions detailed below.

$$y_i \sim \text{Normal}\left(\mu_i, \sigma_e\right)$$

$$\mu_i = \alpha + \alpha_{\text{participant}[i]} + \beta_{1\text{Time}[i]} . \beta_{2\text{Gender}[i]}$$

$$\alpha_{\text{participant}} \sim \text{Normal}\left(\alpha, \sigma\alpha\right)$$

Measurement informed priors were used to counteract chance highs or lows in the data and help reduce the impact of potential regression towards the mean. For the BRUMS and LLFDI data, the prior for B was a student-t distribution (df = 3, location = 0, scale = 1). The priors for B for IPAQ-E MET-minutes (mean = 0, sd = 200) and for sitting time (mean = 0, sd = 50) were normal priors. The intercept for all models used a student-t distribution and a sigma half student-t (df = 3 with location = Median(y), scale = Median Absolute Deviation(y)). Prior predictive checks were conducted on each prior to confirm that the data simulated was consistent with our prior knowledge.

A Bayesian multivariate regression model was fitted to explore differences in mood states and their relationship with PA levels. All models were then compared using Leave-One-Out (LOO) cross-validation with the results of the best fitting model for a particular measure being reported. A LOO information criterion (LOOIC) difference greater than twice its corresponding standard error was the criterion used for determining the best models. All models were checked for convergence ($\hat{r} = 1$), with graphical posterior predictive checks.

Pairwise differences across time-points were explored using both Probability of Direction and Practical Significance calculations. Probability of Direction (pd) is expressed as a percentage and is the probability of the posterior distribution being strictly positive or negative. The range of directional probability is from 50% to 100% (i.e., 0.5 and 1). Practical Significance (ps) was determined using a unidirectional equivalence test and is the probability an effect is above a given threshold. The threshold for a negligible effect was set at 0.1· the standard deviation of Y. The arbitrary unit (AU) values refer to the threshold that determines practical significance for each variable (e.g., that used a scale with values such as the BRUMS) and are only reported when assessing the probability of the difference going beyond a negligible effect.

3. Results

3.1. Reliability

Our analysis shows the reliability of mood states data was good. McDonald's Omega values suggest very good reliability for LLFDI function and limitation, but reliability for LLFDI frequency data was poor. Intraclass Correlation (ICC_3, k) suggest good reliability for MET-minutes 0.84 (0.80 to 0.88) and sitting time 0.83 (0.77 to 0.86).

Table 1
Participant characteristics.

		Male	Female	Total
Sample Size (*n* =)		46	54	100
Age (years)		76 ± 5 (70–90)	74 ± 4 (70–87)	75 ± 4
Ethnicity (*n* =)		White British: 43 White Other: 3	White British: 47 White Other: 7	White British: 90 White Other: 10
Education Qualification Level (0–8)		5 ± 2 (0–8)	5 ± 2 (0–8)	5 ± 2
Living Situation (*n* =)	Partner/ Spouse	34	35	69
	Alone	9	17	26
	Other Family member(s)	3	1	4
	A friend	0	1	1
Residence type (*n* =)	House	35	40	75
	Flat/Apartment	4	7	11
	Bungalow	7	6	13
	Mobile Home	0	1	1
Have a medical condition that affects physical/ mental health (*n* =)		15	12	27
Consider themselves limited in physical function (*n* =)		6	6	12
Have a carer once or twice weekly (*n* =)		2	2	4
Cigarette smokers (*n* =)	Current Smokers	2	0	2
	Ex-smokers	27	24	51
	Never Smoked	17	30	47
Self-reported meeting the current PA guidelines (*n* =)	All guidelines	21	21	42
	Parts of guidelines	24	32	56
	No guidelines	1	1	2
Parts of the guidelines being met (*n* =)	Active everyday	24	32	56
	Strength/ balance at least 2 days per week	14	20	34
	150 mins moderate (75 mins vigorous) PA	12	14	26
PA levels at baseline (MET-min/ week) using IPAQ-E data median (interquartile range)		2964 (4318)	2670 (3348)	2750 (3578)

Note: Values are presented as Mean ± SD and (Range) other values indicate how many participants (*n* =) fell into each category; MET-mins data is presented as median and (interquartile range); Qualification level is graded on the Regulated Qualifications Framework (RQF) for England and Northern Ireland; M = Male; F = Female; IPAQ-E = International Physical Activity Questionnaire- Elderly; PA = Physical Activity.

3.2. IPAQ weekly MET-minutes

There is strong evidence for self-reported PA increasing from the pre-COVID-19 survey to follow-up two, before reducing at follow-up three, and then increasing again at follow-up four and five (Table 2). This pattern was observed irrespective of sex. There was no evidence of a practically significant change across follow-ups (ps = 2.11%) with PA very unlikely to have increased by more than 343 MET-minutes across measurement points. Lastly, while on average, males had greater levels of PA than females, these differences were uncertain across all time points (Table 3).

3.3. IPAQ sitting

There is strong evidence that sitting time peaked at follow-up one and four but then returned to pre-COVID-19 levels by follow-up five. This pattern was observed irrespective of sex (Table 3). The results provide no evidence (ps ≤44.00%) that sitting time increased by more than 15.8 min per day.

3.4. BRUMS

The multivariate analysis of BRUMS subscales and PA (MET-minutes) suggests a very weak relationship between mood and PA, as the coefficient for the relationship across moods = 0.00.

3.5. Tension

Tension remained constant across the follow-up period with no evidence (ps ≤1.00%) that any differences were greater than negligible (>0.27 AU). While females are predicted to have higher tension levels for each follow-up, differences between sexes are generally uncertain, with only differences at follow-up five suggesting a highly probable difference (Table 3) but a difference greater than a negligible level (>0.27 AU) was more uncertain (ps = 88.52%).

3.6. Depression

Depression slowly increased from the onset of lockdowns until follow-up three, before returning to pre-COVID-19 levels by follow-up five (Table 3). However, evidence that any differences were beyond negligible (0.29 AU) is low (ps range < 1.00%–51.19%). While females are predicted to have higher levels of depression compared to males (Table 2), these differences are uncertain (ps = 77.00%–88.00%; AU >0.29; Table 3).

3.7. Anger

Anger levels initially reduced, from the pre-COVID-19 survey to the first follow-up, only to rise again, peaking at follow-up three, then reducing to their lowest average by follow-up five. There is strong evidence for a decrease in anger over the follow-up period (Table 3) but no evidence this decrease goes beyond a negligible effect (ps = 10.03%; >0.22 AU). Males had greater levels of anger across the measurement period compared to females (Table 2) but there is little evidence of these differences being greater than negligible (ps = 45.00%–53.00%; >0.22 AU).

3.8. Vigour

There is strong evidence (ps = 95.94%; >0.36 AU) that vigour decreased from the pre-COVID-19 survey to follow-up three (Table 2) before starting to gradually increase, albeit evidence of this is far more uncertain (Table 3). There is a high probability that females had higher levels of vigour at the pre-COVID-19 survey, but the probability that this difference was greater than negligible (ps = 74.00%; >0.36 AU) is relatively low.

3.9. Fatigue

There were undulating patterns in fatigue across the study. The highest probability of fluctuations in fatigue being greater than negligible (>0.28 AU) is for the initial reduction (ps = 92.24%) with other probabilities being lower (ps range = 9.00%–92.00%). While, on average, male's recorded higher fatigue levels than females, patterns for fatigue were similar between sexes (Table 2).

3.10. Confusion

Confusion peaked at follow-up four with a high probability of a difference from the pre-COVID-19 survey (Table 3). However, the evidence for confusion increasing beyond a negligible level (>0.19 AU) between these points is not strong (ps = 75.00%). Males are predicted to have had higher levels of confusion pre-COVID-19 but had lower levels of confusion by follow-up five (Table 2).

Table 2
Estimated marginal means and 95% credible intervals of the best fitting models for each measure across the follow up period with interactions for sex.

Time	IPAQ-E (95% CI)	IPAQ-E sitting (95% CI)	Tension (95% CI)	Depression (95% CI)	Anger (95% CI)	Vigour (95% CI)	Fatigue (95% CI)	Confusion (95% CI)	LLFDI limitation (95% CI)	LLFDI frequency (95% CI)	LLFDI function (95% CI)
Pre-COVID-19	4094 (3651: 4581)	405 (382: 429)	1.9 (1.47: 2.34)	1.75 (1.25: 2.21)	1.79 (1.43: 2.17)	9.62 (8.92: 10.33)	3.35 (2.83: 3.87)	1.29 (0.92: 1.67)	75.7 (72.7:78.8)	55.2 (54.2: 56.4)	70.4 (68.1: 72.7)
Follow-up 1 (	4261 (3784: 4762)	420 (396: 445)	1.84 (1.42: 2.29)	1.76 (1.26: 2.24)	1.53 (1.18: 1.86)	8.96 (8.25: 9.66)	2.8 (2.29: 3.32)	1.28 (0.91: 1.65)	55.9 (54.4: 57.5)	44.2 (43.3: 45.2)	70.2 (67.9: 72.5)
Follow up 2	4279 (3814: 4785)	409 (384: 433)	1.89 (1.46: 2.33)	1.85 (1.36: 2.33)	1.59 (1.26: 1.92)	8.70 (8.02: 9.43)	3.19 (2.68: 3.73)	1.44 (1.05: 1.81)	60.0 (58.4: 61.6)	47.2(46.3: 48.2)	69.5 (67.2: 71.7)
Follow-up 3	3921 (3449: 4414)	410 (386: 435)	1.91 (1.49: 2.35)	2.05 (1.54: 2.53)	1.69 (1.35: 2.04)	8.48 (7.81: 9.18)	2.83 (2.32: 3.33)	1.38 (1.01: 1.76)	56.3 (54.9: 57.9)	45.3 (44.4: 46.3)	69.2 (66.9:71.5)
Follow-up 4	4027 (3521: 4495)	417 (391: 441)	1.86 (1.43: 2.30)	1.96 (1.46: 2.46)	1.51 (1.18: 1.85)	8.58 (7.89: 9.26)	3.1 (2.59: 3.62)	1.59 (1.22: 1.97)	55.6 (54.1: 57.2)	45.1 (44.1: 46.0)	68.9 (66.6: 71.1)
Follow-up 5	4204 (3734: 4710)	405 (380: 430)	1.85 (1.41: 2.28)	1.75 (1.23: 2.21)	1.46 (1.13: 1.79)	8.80 (8.11: 9.51)	3.24 (2.72: 3.75)	1.25 (0.88: 1.62)	63.3 (61.6: 65.1)	48.8 (47.8: 49.8)	68.7 (66.4: 70.9)
Female											
Pre-COVID-19	4087 (3620: 4563)	407 (384: 432)	2.25 (1.63: 2.83)	2.05 (1.36: 2.75)	1.71 (1.23: 2.20)	10.01 (9.07: 10.94)	2.98 (2.25: 3.67)	1.10 (0.59: 1.61)	74.5 (69.7: 79.5)	56.8 (55.5: 58.2)	68.9 (65.5: 72.0)
Follow-up 1	4220 (3752: 4740)	421 (394: 446)	2.09 (1.49: 2.68)	2.13 (1.45: 2.85)	1.45 (0.98: 1.91)	9.40 (8.43: 10.34)	2.26 (1.55: 3.01)	1.46 (0.96: 1.97)	54.5 (52.5: 56.5)	45.4 (44.1: 46.7)	69.2 (65.9: 72.5)
Follow up 2	4251 (3765: 4746)	412 (387: 438)	2.29 (1.67: 2.86)	2.20 (1.53: 2.90)	1.51 (1.05: 1.95)	8.39 (7.45: 9.34)	2.92 (2.21: 3.67)	1.39 (0.89: 1.91)	58.9 (56.8: 61.1)	48.2 (46.9: 49.5)	67.9 (64.6: 71.2)
Follow-up 3	3935 (3458: 4443)	412 (386: 437)	2.29 (1.70: 2.86)	2.48 (1.81: 3.20)	1.60 (1.14: 2.05)	8.53 (7.58: 9.44)	2.44 (1.76: 3.20)	1.61 (1.10: 2.12)	55.1 (53.0: 57.1)	46.7 (45.4: 48.0)	67.4 (64.0: 70.6)
Follow-up 4	4038 (3558: 4532)	419 (394: 445)	2.23 (1.65: 2.82)	2.31 (1.64: 3.00)	1.50 (1.03: 1.95)	8.63 (7.69: 9.56)	2.79 (2.10: 3.51)	1.41 (0.91: 1.94)	54.3 (52.3: 56.4)	45.8 (44.5: 47.1)	67.1 (63.7: 70.3)
Follow-up 5	4180 (3681: 4672)	406 (379: 430)	2.22 (1.64: 2.81)	2.10 (1.39: 2.78)	1.36 (0.92: 1.82)	9.00 (8.03: 9.95)	2.91 (2.19: 3.64)	1.31 (0.80: 1.82)	62.7 (60.3: 64.9)	49.6 (48.3: 50.9)	66.7 (63.5: 70.1)
Male											
Pre-COVID-19	4102 (3624: 4572)	406 (381: 430)	1.53 (0.89: 2.23)	1.39 (0.62: 2.09)	1.93 (1.38: 2.47)	9.21 (8.17: 10.22)	3.4 (2.65: 4.17)	1.51 (0.97: 2.06)	77.2 (73.7: 80.8)	54.3 (52.8: 55.6)	73.3 (69.8: 76.8)
Follow-up 1	4309 (3788: 4822)	423 (396: 451)	1.5 (0.86: 2.19)	1.36 (0.6: 2.08)	1.62 (1.14: 2.13)	8.53 (7.52: 9.56)	3.55 (2.8: 4.33)	1.41 (0.85: 1.95)	57.8 (55.3: 60.0)	44.8 (43.4: 46.3)	71.8 (68.4: 75.4)
Follow up 2	4310 (3816: 4840)	406 (378: 433)	1.48 (0.84: 2.15)	1.47 (0.71: 2.2)	1.69 (1.21: 2.19)	9.02 (8.00: 10.07)	3.31 (2.56: 4.06)	1.38 (0.85: 1.96)	61.4 (59.2: 63.7)	48.4 (47.0: 49.8)	70.3 (67.0: 73.9)
Follow-up 3	3910 (3394: 4421)	410 (382: 438)	1.51 (0.85: 2.18)	1.62 (0.86: 2.36)	1.83 (1.33: 2.33)	8.45 (7.44: 9.46)	3.51 (2.71: 4.27)	1.58 (1.04: 2.14)	57.8 (55.6: 59.9)	45.6 (44.2: 47.1)	70.2(66.8: 73.8)
Follow-up 4	4021 (3488: 4524)	419 (389: 445)	1.42 (0.79: 2.10)	1.63 (0.87: 2.39)	1.54 (1.04: 2.04)	8.56 (7.58: 9.58)	3.66 (2.91: 4.44)	1.08 (0.53: 1.62)	57.2 (55.1: 59.5)	45.6 (44.2: 47.1)	70.2 (66.6: 73.6)
Follow-up 5	4225 (3717: 4761)	407 (380: 436)	1.41 (0.76: 2.06)	1.34 (0.58: 2.05)	1.59 (1.10: 2.08)	8.59 (7.54: 9.61)	3.40 (2.65: 4.17)	1.26 (0.71: 1.82)	64.1 (61.6: 66.4)	48.6 (47.1: 50.0)	69.9(66.4: 73.4)

Note: IPAQ-E = International Physical Activity Questionnaire –Elderly; LLFDI = Late-Life Function and Disability Instrument; Dates = Follow-up 1 (13/6/2020), Follow-up 2 (5/9/2020) Follow-up 3 (12/12/2020), Follow-up 4 (6/3/2021), Follow-up 5 (5/6/2021).

3.11. LLFDI

3.11.1. LLFDI function

Perceived function declined across the follow-up period (Table 2; Table 3) with a high probability (91.78%) that the decline went beyond a negligible effect (> 1.21 AU). While perceived changes in LLFDI function followed a similar pattern for both sexes, perceived function decreased greater in males (Table 2). There is a high probability that males perceived they had better function than females at the pre-COVID-19 survey (Table 3) and a 90.52% chance this difference was greater than negligible (>1.21 AU) but there is more uncertainty in the differences between subsequent follow-ups (ps range = 68.62%-79.26%).

3.11.2. LLFDI frequency

Frequency of tasks completed, reduced from the pre-COVID-19 survey (ps = 100%; >0.70 AU) to follow up one, then undulated across the

Table 3
Key differences for each measure across the follow up period and associated probability of direction as a percentage.

Contrasts	IPAQ_E Diff	IPAQ_E pd	IPAQ-sitting Diff	IPAQ-sitting pd	Tension Diff	Tension pd	Depression Diff	Depression pd	Anger Diff	Anger Pd	Vigour Diff	Vigour pd	Fatigue Diff	Fatigue pd	Confusion Diff	Confusion pd	LLFDI frequency Diff	LLFDI frequency pd	LLFDI limitation Diff	LLFDI limitation pd	LLFDI function Diff	LLFDI function pd
Pre COVID-19 - Follow-up 1	−135.2	93.19%	−14.83	**98.87%**	0.05	77.99%	−0.02	77.99%	0.26	93.92%	0.65	**99.33%**	0.56	**99.80%**	0.00	50.23%	11.02	**100%**	19.75	**100%**	0.25	73.95%
Pre COVID-19 - Follow-up 2	−164.7	**96.52%**	−3.13	68.80%	0.01	56.09%	−0.10	56.09%	0.20	76.45%	0.92	**99.99%**	0.16	79.50%	−0.15	79.58%	8.04	**100%**	15.64	**100%**	0.94	**99.30%**
Pre COVID-19 - Follow-up 3	162.4	**96.94%**	−4.66	75.86%	−0.01	54.77%	−0.30	54.77%	0.10	**98.27%**	1.14	**100%**	0.52	**99.78%**	−0.10	70.79%	9.93	**100%**	19.35	**100%**	1.21	**99.97%**
Pre COVID-19 - Follow-up 4	58.0	73.99%	−11.93	**95.91%**	0.04	73.17%	−0.21	73.17%	0.28	**99.38%**	1.04	**99.99%**	0.25	90.54%	−0.31	**95.60%**	10.17	**100%**	20.06	**100%**	1.51	**100%**
Pre COVID-19 - Follow-up 5	−93.3	84.71%	0.59	53.63%	0.05	77.33%	0.00	77.33%	0.33	**97.40%**	0.82	**99.91%**	0.12	72.78%	0.03	56.75%	6.49	**100%**	12.35	**100%**	1.74	**100%**
Follow-up 1 - Follow-up 2	−31.5	59.48%	11.67	92.87%	−0.04	74.90%	−0.08	74.90%	−0.06	82.23%	0.26	84.17%	−0.40	**98.22%**	−0.15	80.19%	−2.97	**100%**	−4.11	**100%**	0.69	**98.36%**
Follow-up 1 - Follow-up 3	296.9	**99.22%**	10.24	89.92%	−0.06	83.34%	−0.28	83.34%	−0.17	75.03%	0.48	**97.22%**	−0.04	57.79%	−0.10	71.69%	−1.09	**99.49%**	−0.39	73.58%	0.96	**99.87%**
Follow-up 1 - Follow-up 4	191.9	**93.83%**	2.97	63.63%	−0.01	56.93%	−0.19	56.93%	0.02	86.84%	0.38	93.15%	−0.31	**95.22%**	−0.31	**95.97%**	−0.84	**97.61%**	0.33	69.44%	1.26	**100%**
Follow-up 1 - Follow-up 5	41.3	63.00%	15.51	**97.11%**	0.00	52.36%	0.01	52.36%	0.06	69.59%	0.17	73.13%	−0.44	**99.13%**	0.03	56.40%	−4.52	**100%**	−7.39	**100%**	1.49	**100%**
Follow-up 2 - Follow-up 3	327.4	**99.63%**	−1.52	58.04%	−0.02	61.62%	−0.20	61.62%	−0.11	94.03%	0.22	79.97%	0.36	**97.26%**	0.05	60.97%	1.89	**100%**	3.72	**100%**	0.27	80.30%
Follow-up 2 - Follow-up 4	220.7	**96.23%**	−8.78	86.00%	0.03	69.69%	−0.11	69.69%	0.08	**97.85%**	0.12	67.72%	0.09	68.44%	−0.16	81.21%	2.14	**100%**	4.44	**100%**	0.56	**96.02%**
Follow-up 2 - Follow-up 5	71.6	71.99%	3.65	68.14%	0.04	73.80%	0.10	73.80%	0.12	92.22%	−0.10	64.65%	−0.05	59.39%	0.18	84.00%	−1.55	**99.98%**	−3.28	**100%**	0.80	**99.26%**
Follow-up 3 - Follow-up 4	−104.9	80.76%	−7.32	81.25%	0.05	78.69%	0.08	78.69%	0.19	65.37%	−0.10	65.22%	−0.27	93.33%	−0.21	87.93%	0.25	72.45%	0.71	87.54%	0.29	82.56%
Follow-up 3 - Follow-up 5	−255.9	**97.97%**	5.24	74.21%	0.05	82.03%	0.29	82.03%	0.23	55.97%	−0.31	89.27%	−0.40	**98.82%**	0.13	76.41%	−3.44	**100%**	−7.00	**100%**	0.53	**95.02%**
Follow-up 4 - Follow-up 5	−149.9	89.01%	12.43	93.58%	0.01	54.81%	0.21	54.81%	0.04	71.14%	−0.22	80.27%	−0.13	76.84%	0.34	**97.22%**	−3.68	**100%**	−7.71	**100%**	0.24	76.62%
Female Pre COVID - Follow-up 5	−92.18	84.30%	1.59	59.52%	0.03	58.97%	−0.05	61.48%	0.34	**97.39%**	1.01	**99.64%**	0.07	60.72%	−0.31	89.51%	7.23	**100%**	11.77	**100%**	2.17	**99.88%**
Male Pre COVID - Follow-up 5	−122.35	83.11%	−1.60	57.32%	0.11	83.84%	0.04	60.55%	0.33	**95.62%**	0.62	94.81%	0.17	71.36%	0.43	94.60%	5.65	**100%**	13.09	**100%**	3.39	**100%**
Female - Male: Pre COVID	−12.17	55.30%	1.38	55.70%	0.73	94.05%	0.70	92.38%	−0.22	71.81%	0.80	87.74%	−0.84	94.19%	−0.41	85.82%	2.56	**99.57%**	−2.71	82.93%	−4.40	**96.58%**
Female - Male: Follow-up 5	79.53	62.44%	−0.19	50.67%	0.82	**96.28%**	0.75	93.51%	−0.23	75.11%	0.41	72.06%	−0.74	91.71%	0.32	79.81%	1.00	84.05%	−1.40	79.79%	−3.16	90.68%

Note: values in bold exceed a 95% probability; IPAQ-E = International Physical Activity Questionnaire –Elderly; LLFDI = Late-Life Function and Disability Instrument; Dates = Follow-up 1 (13/6/2020), Follow-up 2 (5/9/2020) Follow-up 3 (12/12/2020), Follow-up 4 (6/3/2021), Follow-up 5 (5/6/2021).

rest of the data collection period (Table 2). There is a high probability of a decrease in LLFDI frequency from follow-up one to two and four and five with strong evidence (ps = 100.00%) that these increases are greater than negligible (>0.70 AU). There is also strong evidence (ps = 99.83%) for the reduction between follow-up two and three being more than negligible (>0.70 AU). Both sexes followed the average trend (Table 2).

3.11.3. *LLFDI limitation*

There is strong evidence scores for limitation reduced (perceived greater limitation) initially (ps = 100.00%; >1.46 AU), and then undulated across the rest of the study (Table 2). Although lower in magnitude, the increase in limitation score from follow-up one to two was greater than negligible (ps = 100.00%; >1.46 AU). Both sexes follow the average trend (Table 2).

3.11.4. *Qualitative data*

Table 4 displays a summary of qualitative data.

4. Discussion

The present study sought to determine the impact of a year of fluctuating COVID-19 restrictions on older adults living in the UK. This data provides important insight into how older adults reacted at different stages of restrictions and can be used by policy makers and practitioners to better understand the impact on and the needs of older adults during COVID-19. Our data uniquely tracked older adults over the duration of a year follow-up during COVID-19 and suggests that our participant group managed to maintain or even increase their PA levels compared to pre-COVID-19. However, the data from the LLFDI shows a high probability of a reduction in the frequency of daily tasks completed and also an increase in perceived limitation in completing those tasks compared with pre-COVID-19, which is unsurprising as the opportunity to carry out many listed activities were hindered by imposed COVID-19 restrictions. The LLFDI also indicates that despite the maintenance of PA, perceived physical function decreased in both sexes. Furthermore, sedentary time increased with a high probability at follow-up one and four. Lastly, mood largely undulated in a pattern that appears to reflect the tightening and easing of restrictions and by June 2021, mood scores were similar to pre-COVID-19. Therefore, hypotheses one and four must be rejected while the present study demonstrates support for hypotheses two and three.

The LLFDI function component has strong evidence of its construct validity, reliability and responsiveness to change (Beauchamp et al., 2015; Beauchamp et al., 2014). A change of 2 points per year in the function component has been shown to be a small, but meaningful change while a change of 5 points has been shown to be a substantial change in a large group of older adults of similar age (Beauchamp et al., 2018). Despite the participants in the study by Beauchamp, et al. (Beauchamp et al., 2018) having multi-morbidity's and a lower perceived functional capacity than those in the present study, those participants reported either no change or a small decline (<2 point change in the LLFDI function component) in perceived function over a year period (not during COVID-19). In the present study, male's perceived function dropped on average by 3.4 points and females by 2.2 points which indicates a potentially meaningful drop in function over the year.

Changes to the distribution of PA activities and intensities (walking, moderate, PA and vigorous PA from the IPAQ-E) may have played a role in the observed changes to perceived physical function. Although it is difficult to know exactly what has contributed to changes in PA (including seasonal variation), when PA patterns from March 2020 are compared to March 2021 (Supplementary Table 1), more time was spent walking in March 2021 but there was also less vigorous PA being carried out by both sexes. This same pattern is present between June 2020 and June 2021. As intensity of effort has been shown to be an important

Table 4
Other question responses across all surveys.

Questions	Sex	Follow-Up 1 13/6/2020	Follow-Up 2 5/9/2020	Follow-Up 3 12/12/2020	Follow-Up 4 6/3/2021	Follow-Up 5 5/6/2021
Have you tested positive for COVID-19 in the past 3 months? (*n* =)	M	0	0	0	0	0
	F	0	0	1	1	0
	T	**0**	**0**	**1**	**1**	**0**
Hospitalised with COVID-19 in the past 3 months (*n* =)	M	0	0	0	0	0
	F	0	0	0	0	0
	T	**0**	**0**	**0**	**0**	**0**
Have you been vaccinated against COVID-19? (*n* =)	M	N/A	N/A	N/A	45	46
	F	N/A	N/A	N/A	53	54
	T	**N/A**	**N/A**	**N/A**	**98**	**100**
On a scale of 1-10 how concerned are you about contracting COVID-19 in the coming weeks/ months? (1 = Not at all concerned; 10 = Extremely concerned)	M	4.5 ± 3.6	4.8 ± 3.2	5.4 ± 3.1	3.2 ± 3.2	2.1 ± 2.7
	F	4.8 ± 3.3	4.9 ± 3.0	5.2 ± 2.9	3.4 ± 2.7	2.7 ± 2.6
	T	**4.7 ± 3.4**	**4.9 ± 3.1**	**5.3 ± 2.9**	**3.3 ± 2.9**	**2.4 ± 2.6**
On a scale of 1-10 how concerned are you that close friends or family may be negatively impacted by COVID-19? (1 = Not at all concerned; 10 = Extremely concerned)	M	2.9 ± 3.8	3.7 ± 3.9	3.9 ± 3.9	2.6 ± 3.8	1.0 ± 2.6
	F	2.9 ± 3.8	4.2 ± 4.0	3.9 ± 3.9	2.1 ± 3.5	1.2 ± 2.9
	T	**2.9 ± 3.8**	**4.0 ± 3.9**	**3.9 ± 3.9**	**2.3 ± 3.6**	**1.1 ± 2.7**
Do you try and use digital means of communication more frequently than before the COVID-19 outbreak (*n* =)	M	N/A	34	40	40	34
	F	N/A	49	51	53	47
	T	**N/A**	83	91	93	81
Are you leaving your residence when you need/ want to? E.g. to see family, attend social gatherings, for exercise etc. (*n* =)	M	N/A	Yes: 19 Frequently: 7 Occasionally: 14 Rarely: 5 Very Rarely: 1 Never: 0	Yes: 15 Frequently: 6 Occasionally: 16 Rarely: 6 Very Rarely: 2 Never: 1	Yes: 17 Frequently: 7 Occasionally: 9 Rarely: 6 Very Rarely: 7 Never: 0	Yes: 28 Frequently: 4 Occasionally: 12 Rarely: 2 Very Rarely: 0 Never: 0
	F	N/A	Yes: 21 Frequently: 9 Occasionally: 17 Rarely: 4 Very Rarely: 3 Never: 0	Yes: 14 Frequently: 7 Occasionally: 18 Rarely: 9 Very Rarely: 5 Never: 1	Yes: 20 Frequently: 3 Occasionally: 17 Rarely: 9 Very Rarely: 4 Never: 1	Yes: 37 Frequently: 5 Occasionally: 11 Rarely: 0 Very Rarely: 1 Never: 0
	T	**N/A**	**Yes: 40 Frequently: 16 Occasionally: 31 Rarely: 9 Very Rarely: 4 Never: 0**	**Yes: 29 Frequently: 13 Occasionally: 34 Rarely: 15 Very Rarely: 7 Never: 2**	**Yes: 37 Frequently: 10 Occasionally: 26 Rarely: 15 Very Rarely: 11 Never: 1**	**Yes: 65 Frequently: 9 Occasionally: 23 Rarely: 2 Very Rarely: 1 Never: 0**
Have you adapted your daily routine to try and remain physically active? (*n* =)	M	21	23	30	28	21
	F	30	38	42	45	29
	T	**51**	**61**	**72**	**73**	**50**
		Most commonly cited adaptions to daily routines				
		Male		**Female**		
		1. Walking 3. Gardening	2. More Exercise 4. Puzzles/ Board games	1. Walking 3. Puzzles/ Board games	2. More Exercise 4. Gardening	
Participants that reported COVID-19 had an impact on their mental health? (*n* =)	M	11	14	21	13	15
	F	21	26	31	24	25
	T	**32**	**40**	**52**	**37**	**40**
Has the impact been positive or negative? (*n* =)		**Positive: Negative**				
	M	0:11	0:14	1:20	0:13	0:15
	F	1:20	1:25	5:26	0:24	4:21
	T	**1:31**	**1:39**	**6:46**	**0:37**	**4:36**
On a scale of 1-10 how much of a positive/ negative effect have the changes to your life due to COVID-19 had on your mental health? (1 = No negative effect at all, 10 = Extremely negative effect)		**Positive: Negative**				
	M	N/A: 6.4 ± 2.2	N/A: 6.0 ± 2.1	8.0 ± 0: 5.0 ± 1.9	N/A: 5.2 ± 1.8	N/A: 4.8 ± 1.5
	F	8.0 ± 0: 5.9 ± 2.0	3.0 ± 0: 5.6 ± 2.1	6.6 ± 2.6: 5.6 ± 1.7	N/A: 5.8 ± 1.8	7.3 ± 1.3: 5.3 ± 1.7
	T	**8.0 ± 0: 6.1 ± 2.0**	**3.0 ± 0: 5.7 ± 2.1**	**6.8 ± 2.4: 5.3 ± 1.8**	**N/A: 5.6 ± 1.8**	**7.3 ± 1.3: 5.1 ± 1.7**

Note: M = Male; F = Female; T = Total; All responses are Mean ± SD or *n* = number of participants.

factor in improving and maintaining both strength and functional performance in older adults (Richardson et al., 2019), these reductions in vigorous PA may have had an impact on the observed reduction in perceived physical function.

Although participants in the present study maintained their overall MET-minutes of activity, sitting time increased which has been shown to have a variety of negative effects on older adults including increase falls risk (Copeland et al., 2017) and may have also contributed to reduced perceived physical function. Furthermore, external determinants such as: depressive symptoms, cognitive function and marital status can affect perceived physical function of older adults (Cress et al., 1995). There are also innumerable possible stressors documented during COVID-19 that may have synergistically contributed such as: fear of infection, fear of death, uncertainty, loss of social contacts, confinement, conflicting advice, loss of activities, disconnection from nature, loneliness, depression, helplessness, and low self-esteem (Morales-Vives et al., 2020).

Participants in the present study have not followed the general trends of large reductions in PA described by Public Health England (Faizan Mahmood et al., 2021) who reported that 32% of older adults were inactive (less than 30 min PA per week) between March and May 2020, which represents a 27% increase in physical inactivity from 2019. In the same period, strength and balance activity decreased from 126 to 77 min per week. Based on these figures, prediction modeling estimates there could be 110,000 more older adults that will have at least one fall per year (Faizan Mahmood et al., 2021). It appears that older adults in present study made conscious effort to adapt their daily routine to maintain their PA levels. Table 4 displays the most popular adaptations with more walking and exercise being the top two changes for both sexes.

Similarly, Portegijs, et al. (Portegijs et al., 2021) reported that older adults adapted their daily habits around restrictions, which resulted in an overall reduction in activities, but many of the activities that were reported, involved planned exercise. Furthermore, as participants in the present study were already highly active prior to COVID-19, Suzuki, et al. (Suzuki et al., 2020) suggests that those older adults that were less physically active pre-COVID-19 had a 38% decline in all types of PA, whereas those who reported themselves to be more physical active actually saw a 47% increase in all types of PA during COVID-19. This suggests that previous exercise behaviour influences future behaviour and may help to explain the observed trends in the present study.

The present study observed that frequency of daily activities decreased and limitation in being able to complete those tasks increased. The LLFDI limitation scale is harder to interpret during COVID-19 as the closure of much of society is unprecedented. This particular measure is designed to be sensitive to both personal factors (health, physical or mental) and environmental factors (transportation, accessibility or socio-economic conditions) (Beauchamp et al., 2015; Beauchamp et al., 2014). The pattern of perceived limitation and frequency of tasks completed appears to ungulate in line with the level of restrictions that were in place at the time, which suggests a strong possibility that changes in limitation and frequency of tasks are linked to fluctuating restrictions. Indeed, similar patterns have been observed elsewhere with activity destinations amongst a group of older adults dropping by half during restrictions (Portegijs et al., 2021) and movements around the community have also been shown to substantially decrease amongst older adults during COVID-19 (Saraiva et al., 2021). Despite this, it is important to consider that as data was collected in different seasons, some activity variation is likely to be due to weather/daylight hours as PA has been shown to vary by season (Mobily et al., 1995).

Participant's mood undulated during the course of the year, but by follow-up 5 many elements of mood were at pre-COVID-19 levels with the exception of vigour and anger which had both decreased. These fluctuations may reflect an ‘emotional rollercoaster’ triggered by measures put in place to control COVID-19, economic fallout and constant tightening and easing of restrictions (Terry et al., 2020). Furthermore, older adults have been shown to be more mentally resilient and show less reactivity to stressors in the face of COVID-19 when compared to younger and middle aged adults (Klaiber et al., 2020) which may explain why emotional reactions were less severe and in general, remained similar to pre-COVID-19 levels. Additionally, as decreases in PA have been shown to have a profound negative impact on mental well-being (Maugeri et al., 2020), the fact participants maintained PA may have also somewhat stabilised mood. Lastly, as can be observed in Table 1, participants in the present study are generally well educated. Higher education levels have been linked to less depression and fatigue during COVID-19 for various reasons that include greater financial security (Terry et al., 2020). However, Table 4 shows that a substantial number of older adults still reported a negative impact of COVID-19 on their mental health. At all follow-ups, 31%–46% of participants reported that circumstances surrounding COVID-19 had a negative impact on their mental health.

5. Limitations and future research

Despite advertising for participation nationwide, our sample has a number of biases that make generalising these findings to the wider population of the UK difficult. Firstly, on average, participants in the present study were much more physically active (Table 1) when compared to other older adults in the UK (Jefferis et al., 2014). Secondly, as shown in Table 1, our sample was homogenous, consisting of individuals from similar ethnic backgrounds with high socio-economic status, and who were well-educated. Indeed, higher socioeconomic status and social participation prior to COVID-19 may also have been a factor in assisting these older adults to remain active during COVID-19 (Sasaki et al., 2021). As the follow-up surveys were distributed at 3-monthly intervals, the participants roughly answered questions during each of the four seasons; spring, summer, autumn and winter. There has been shown to be seasonal variation in both physical activity levels (Mobily et al., 1995) and mood (O'Hare et al., 2016) of older adults which means it's not clear exactly whether all observed changes were a direct result of variables concerning COVID-19 or due to seasonality. However, our conclusions can be strengthened when cross referenced with qualitative data presented in Table 4. Lastly, the IPAQ-E gives information on MET-minutes of PA but does not tell us exactly what activities participants were doing pre-COVID-19. Despite this, Table 4 provides some insight into how older adults adapted their routines to remain active. Interviewing groups of older adults during COVID-19 would be important future work for researchers to truly understand the experiences of older adult's during COVID-19.

6. Conclusion

Although PA levels were adapted to be maintained or even increased during the course of the year follow-up during COVID-19, sedentary time increased, daily activities decreased, accompanied by an increase in perceived limitation in completing those activities and a small but clinically meaningful decline in perceived physical function. Older adults adapted their routines in order to maintain their activity levels but there was a reduction in the intensity of exercise tasks. This reduction may have contributed to lower perceived physical function and may suggest that merely maintaining a total amount of PA, without sufficient intensity of effort is not enough to maintain perceived physical function. Additionally, the lack of daily activities and possible subsequent loss of familiarity with those tasks, coupled with greater sedentary time may have also contributed to decreased perceived physical function. As we have demonstrated, a perceived drop in physical function, an increase in sedentary time and other studies (Oliveira et al., 2021) have established a drop in PA, strategies to maintain physical function and prevent increases in sedentary behaviours and reductions in PA levels should be a priority for public health officials to address in the coming years to help protect health care systems from overwhelm.

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CRediT authorship contribution statement

D.R, J.T, M.D. and N.C were involved in study inception. D.R collected all data. D.R drafted the manuscript with input from J.T, M.D., T.M and N.C. All data was analysed and reported in the results section by T.M. All authors reviewed the study findings and approved the final manuscript before submission.

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Ethic board/committee

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P105110.

Declaration of competing interest

We declare no conflict of interests.

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